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Effects of Zn-L-selenomethionine on carcass composition, meat characteristics, fatty acid composition, glutathione peroxidase activity, and ribonucleotide content in broiler chickens

Abstract

The effects of organic Zn-L-selenomethionine (Zn-L-SeMet) at 0.3 ppm on carcass composition, meat characteristics, fatty acid composition, glutathione peroxidase activity, and ribonucleotide content were compared against the commercial inorganic sodium selenite (Na-Se) and the combination of the two, in commercial broilers. A total of 540 one day old chicks were assigned at random to 3 dietary treatments : i) commercial inorganic selenium as control or T1, ii) a 1:1 ratio of inorganic and organic selenium as T2, and iii) organic selenium as T3. Carcass composition, meat characteristics, cholesterol content, fatty acid composition, and ribonucleotide content were generally unaffected by treatments. However, discrepancy were significantly observed in glutathione peroxidase activity (GSH-Px) and water holding capacity, with organic selenium showing higher glutathione peroxidase activity ($p<0.01$) and lower shrinkage loss ($p<0.05$), respectively. These findings could be explained by the contribution of organic selenium in bioavailability of GSH-Px. However, having conducted in a commercial close house system with sufficient amount of nutritional supplementation, the present study demonstrated little or no effects of organic Zn-L-SeMet on meat characteristics, fatty acid composition, and ribonucleotide content (flavor characteristic) in broiler chickens.

Keywords : selenium source, body composition, meat quality traits, cholesterol content, flavor

Introduction

A good nutritionally balanced diet that will provide appropriate bioavailable quantities of nutrients required by the birds is the main goal of modern feed formulation. Energy and protein are principle nutrient component in the formulation. In addition, supplements provide minerals, vitamins and specific amino acids must be added to the diets as they are essential for growth performance and health (Ravindran, 2013). Selenium is a vital element for maintaining balance and healthy diet for chickens. They can either be found naturally or been added in both inorganic and organic forms. The bioavailability of selenium in chicken is complexed, whereby, the metabolism is affected by numerous factors and these include types of selenium, heavy metals, vitamins, methionine, and thiols (Fairweather-Tait and Hurrell, 2007). The physiological and biochemical factors of the birds itself may also contribute to the requirement of the bioavailability such as in heat and stress conditions.

An adequate intake of selenium helps maintaining healthy broiler, immunocompetent, better meat quality, and longer shelf life as it is involved in the antioxidative system which is a part of selenium-dependent Glutathione peroxidase (Colnago et al., 1984; Combs Jr, 1981; Kuricova et al., 2003; Ryu et al., 2005; Yang et al., 2012; Yoon et al., 2007; Zelenka and Fajmonova, 2005). Selenium is involved in lipid metabolism of which, several studies reported that selenium, when supplemented in animal diets, remodeled the composition of fatty acid in meat (Netto et al., 2014; Zanini et al., 2004). The ribonucleotide monophosphates like inosine monophosphate (IMP) and guanosine monophosphate (GMP) enhance the intensity of meat flavor, as they elicit an umami taste (Durnford and Shahidi, 1998; Spurvey et al., 1998). Selenium has also been associated with meat flavor as Zhou and Wang (2011) documented higher IMP content in chickens treated with Nano-Se when compared to control group.

Inorganic sodium selenite (Na-Se) has been traditionally supplemented in commercial

poultry diets to ensure an optimal supply for growth performance and productivity. Organic sources of selenium, for example Se-enriched yeast and synthesized L-selenomethionine (L-SeMet), are reported to be more suitable forms of selenium for dietary supplements according to their lower toxicity and higher bioavailability than inorganic form. (Delezie et al., 2014; Surai, 2007). L-SeMet is the major form of organic selenium presented in natural food and feed ingredients. Selenium enriched yeast has been commercially used as a practical affordable source of L-SeMet. However, the concentration of organically bound selenium in yeast can vary markedly among sources of Se-enriched yeast due to its ability to form L-SeMet from the selenite enriched media (Geraert et al., 2015; Whanger, 2002). Broilers supplemented with dietary L-SeMet had better efficiency of selenium deposition of in breast muscle than Se-enriched yeast but L-SeMet appeared to be unstable when mixed with a standard premix (Geraert et al., 2015). More recently, organic selenium is available as Zn-L-selenomethionine (Zn-L-SeMet), which is 1:1 complex of essential metals and amino acids. Zn-L-SeMet has been designed to be highly soluble and of increased bioavailability of selenium (Ward, 2003). It is hypothesized that a more stable source of organic selenium as described by the producer, Zn-L-SeMet, has possible benefits from Se-enriched diets for animal production. The information on the utilization of Zn-L-SeMet in broiler chickens is limited. Therefore, this study aimed to examine the impacts of this organic selenium form (Zn-L-SeMet) against inorganic Na-Se and also their combination on carcass composition, meat characteristics, fatty acid composition, flavor associated ribonucleotides, and glutathione peroxidase activities in commercial broilers raised in a commercial closed house system.

Materials and Methods

Animal ethics

The handling and care of experimental animals in the research were approved by the

institutional Animal Care and Use Committee at King Mongkut's Institute of Technology Ladkrabang.

Animals

Five hundred and forty one day old chicks (Arbor Acre) were assigned at random to 3 dietary groups of 6 replicates, with 30 chicks per pen. The stocking density per pen was of 15 mixed-sex broilers/m^2 (measuring 2 m^2/pen). The birds received feed ad libitum through 3 phase feeding programs with continuous 24 h lighting (see Table 1). The treatment groups comprised of: i) T1: inorganic sodium selenite (Na-Se) at 0.3 ppm; ii) T2: mixed organic and inorganic selenium, with combination of 0.15 ppm Na-Se + 0.15 ppm Zn-L-SeMet, and, iii) T3: organic selenium from Zn-L-SeMet at 0.3 ppm. The chicken were fasted for 12 h and weighed out before slaughter at 39 days old. Three birds per replicate in each group were sacrificed by cervical dislocation, scalded at 60℃ for approximately 3 min, following with defeathered for 2 minutes using a rotary drum picker, and eviscerated manually. Then the carcasses were chilled in ice water for 45 min and weighed after waiting for 1 h at 1℃ in a cold room aimed to strain water remains from the chilling process. The whole carcass was cut up into the form of breast, fillet, wing, and leg manually by knife. The weight of all dissected parts were documented in percentages to total carcass weight. The right side breast muscles from each carcass were used for quality traits analysis. Meanwhile, the breast muscle from left side carcass was taken from one chicken per each replicate for fatty acid composition, GSH-Px activity, and ribonucleotide content analysis.

Experimental Diets

The experimental diets were formulated to meet nutrient requirement for broiler chicken recommended by the National Research Council (Table 1). The organic and inorganic selenium used for this experiment were incorporated into the diet as presented in Table 1. Infectious Bronchitis and Newcastle Diseases vaccinations to broilers were performed as

stated in the manufacturer's instructions (Nobilis® MA5+Clone 30, Intervet International B.V. Boxmeer, Holland).

Meat Characteristics

pH measurement

Muscle pH of the right pectoralis major was inspected at 45 min, 24 h, and 4 d postmortem using a spear tip glass probe connected to a portable pH meter (SG2 - ELK Seven Go™, Mettler Toledo International Inc., China).

Drip loss measurement

Meat samples were suspended in tightly sealed plastic bag filled with air and kept at 4 to 6℃ for 48 h (Honikel, 1998). Drip loss was calculated as a percentage of the weight loss after suspension**.**

Color measurement

Following to 30 minutes of blooming period, meat color (CIE L*a*b*) of pectoralis major was determined at 3 h postmortem at 25±2℃ using a handheld colorimeter (CR-400 chromameter, Konica Minolta Sensing Co., Ltd., Japan).

Water loss and shear force measurement

After taken from carcass, the breast muscles were weighed and kept for 4 d at 4℃ and then brought to 25℃ before weighing and calculating sample weight difference. The measurement were conducted before and after storage as a percentage of shrinkage loss. The 1 inch thick sample from each bird was cooked for approximately 20 min to 70℃ temperature internally in a water bath (One14, Memmert, Germany). Core temperature of the end point was monitored by a thermometer (TM-19475D, Lutron Electronics Inc, Taiwan). Cooked samples were left at room temperature to cool down before weighing. Weight loss after cooking was calculated and expressed as the percentage loss relative to the weight before cooking. Ten slices were cut parallel to the fiber orientation of the cooked sample. A Texture Analyser

Machine (Model EZ-SX, Shimadzu, Japan) attached to a 50 kg load cell using 50 mm/min crosshead speed was used to measure a Warner-Bratzler shear force. Signals were processed by Tapezium software (Shimadzu, Japan).

Fatty acid analysis

Fatty acid composition was determined according to the method of Raes et al. (2016). The lipid extraction with chloroform were performed as described by Folch (1957). The internal standard, methyl nonadecanoate (SFA-013N, Accu Standard, New Haven CT06513, USA) was added during extraction process. The gas chromatography (7890B Agilent, USA) with a fused silica capillary column (model SPTM-2560, Supelco, Bellfonte, PA) for FAME (100 m × 0.25 mm x 0.2 µm film thickness) was used to analyse fatty acid methyl esters (FAME). Following was the gas chromatography conditions: injected temperature, 240℃; detector temperature, 260℃; carrier gas, He; split ratio, 10:1; temperature program, initial temperature 60℃, followed by an increase of 20℃/min to 170℃, 5℃/min to 220℃ then 2℃/min to 240℃. The peaks of fatty acid methylester were identified by comparison of retention times with authentic standards (F.A.M.E. Mix, C4-C24, Supelco, Bellefonte, PA) and quantified by an internal standard of nonadecanoic acid (C19 : 0).

Cholesterol analysis

Cholesterol measurement was performed using the method outlined by Du and Ahn (2002). The frozen samples (after immersion in liquid nitrogen) were pulverized using grinder (WSG30E, Waring, USA). Ground breast meat of 0.4 g was extracted with 10 mL of saponification reagent (ethanol: 33% KOH (w/v): 20 % ascorbic acid (94: 6: 0.5). A 50 µL of 5 α-cholestane solution (1 µg/µL in hexane) was subsequently added as an internal standard. The mixture were homogenized using a homogenizer (T25 Ultra-Turrax®, Ika, Malaysia) before adding 10 mL of HPLC water and 10 mL of hexane, consecutively. The homogenate samples were then briefly vortexed (Vortex Genie 2 Mixer, Overstock Lab Equipment, USA),

left for 15 h to allow sample to separate into phase, then centrifuged at 1,000 x g at 4℃ for 15 min. The hexane layer containing unsaponifiables was carefully collected and evaporated by nitrogen blowdown. The dry sample was dissolved in 200 µl ethyl acetate and later analyzed using gas chromatography (7890B Agilent, USA).

Glutathione peroxidase activity assay

One gram of breast muscle samples, pulverized in liquid nitrogen, were homogenized in 2 mL of ice-cold glutathione peroxidase activity (GSH-Px) buffer using a homogenizer (T25 Ultra-Turrax® , Ika, Malaysia) at 23,319 x g then centrifuged at 10,000 x g for 15 min at 4℃. The supernatant was collected and kept at -20 ℃ for GSH-Px assays the next day. Glutathione peroxidase activity was measured according to the manufacturer protocols (Glutathione Peroxidase Colorimetric Assay Kit, Catalog Number #K762-100, Biovision, USA).

Ribonucleotide analysis

According to the method of Tikk et al (2006), one gram of pulverized breast muscle in 6 mL of cold 0.6 M perchloric acid was homogenized at 23,319 x g for 10 sec (T25 Ultra-Turrax® , Ika, Malaysia). The homogenate was left on ice for 15 min and then neutralized by adding 5.4 mL of 0.8 M KOH and 0.25 mL of KH_2PO_4 buffer. The pH of mixed sample was adjusted to 7 with 0.8 M KOH and the volume was finally made up to 15 mL with HPLC water. After centrifugation at 10,000 x g for 10 min at 4℃ (Scanspeed 1580R, Labogene, Denmark), 1 mL of supernatant was aspirated to a small tube and frozen at -80℃.

After thawing the frozen sample and centrifuging at 10,000 x g for 5 min at 4℃ (Scanspeed 1580R, Labogene, Denmark), the supernatants were then analyzed for IMP, inosine, hypoxanthine, and GMP using the HPLC (Chromaster, Hitachi, Japan) fitted with a UV detector (210 nm). A stationary phase was the TSK Gel Amide-80 column (Tosoh, Japan) while the eluent phase consisted of a buffer containing acetonitrile : KH2PO4, 70: 30. The

content of ribonucleotide was quantified based on a standard curve using external standards (57510 Inosine-5-monophosphate disodium salt hydrate, 14125 Inosine, H9377 Hypoxanthine, and G8377 Guanosine-5-monophosphate disodium salt hydrate, Sigma-Aldrich, USA).

Statistical Analysis

Analyses of variance was analyzed using the GLM procedure (SAS Institute. Inc., Cary, NC) where selenium sources were defined as treatment. Least square means were separated using the PDIFF option and differences were considered as significant if $p \leq 0.05$.

Results and Discussion

The live, and carcass weight, and the body and carcass composition of chickens from different dietary treatments are as shown in Table 2. The aforementioned parameters between the treatments showed no significant differences. In agreement with our finding, the supplementation of neither organic nor inorganic selenium have significant effect on live weight, carcass weight, and carcass composition in broilers by other researchers (Downs et al., 2000 ; Payne and Southern, 2005 ; Mikulski et al., 2009). Furthermore, no significant differences were occurred in samples of birds subjected to the combination of organic and inorganic supplement at 0.3 ppm. In this study, sources of selenium did not affect ($p>0.05$) drip loss but significantly impacted on shrinkage loss between T1 and T3 ($p<0.05$), and cooking loss among T1, T2, and T3 ($p<0.0001$) at day 4 postmortem (Table 3). The lowest shrinkage was found in samples of organic selenium supplemented birds (T3). Meanwhile, the highest and lowest cooking loss after day 4 postmortem was observed in samples of T3 and T1, respectively (Table 3). The lower shrinkage loss noted in the T3 meat samples could be explained by a possible increase in antioxidant property as indicated by higher GSH-Px activity ($p = 0.009$; Table 5) recorded in samples of birds subjected to the organic selenium

supplementation (T3). This was explained by Zhan et al. (2007) who demonstrated higher meat water holding capacity in animals treated with SeMet than their counterparts which were assigned to inorganic Na-Se supplementation. Furthermore, Surai (2007) reported that selenium was crucial for both intra- and extra-cellular antioxidant system in the body. In present study, T3 showed higher cooking loss when compared to both T1 and T2. This could possibly be explained by higher water content in the samples upon cooking as resulted from lower shrinkage loss in the respective samples. Different mechanisms have been proposed by researchers on how antioxidant could influence drip loss and water holding capacity. These include the stabilization of membrane postmortem (Asghar et al., 1991), reducing proteolysis and protein oxidation which in turn influence moisture retention capacity in meat and meat products (Huff-Lonergan and Lonergan, 2005). Selenium sources did not affect meat color in this study. This conforms to the finding of Jiang et al. (2009) and Perić et al. (2009). Dietary selenium sources were also not significant effect on pH value at various storage times from 45 min to 4 days of postmortem in the current study ($p>0.05$) (Table 3). In contrast with our results, Li et al. (2018) presented that organic selenium-enriched yeast and selenomethionine supplementation resulted in increasing breast pH of broiler chickens at 45 min postmortem with no affect at 24 h postmortem. In the present study, shear force values were unaffected by the inorganic, organic, and the combination supplementation. However, Li et al. (2018) reported the lower shear force value of breast meat from chickens supplemented with organic selenium-enriched yeast and selenomethionine supplementation than those supplemented with inorganic sodium selenite. The improvement of the tenderness as the reduction in shear force value could be related to the higher intramuscular fat in chickens fed with organic selenium (Yoon et al., 2007).

In this study, source of dietary selenium did not affect levels of cholesterol content and fatty acid composition in chicken breast. There were no previous studies that reported the

234 association between selenium sources and cholesterol content in broiler meat. According to
235 our findings, the amount of unsaturated fatty acid was not significantly different among
236 treatments, this may suggested that the internal oxidation against unsaturated fatty acid may
237 not occur or in control. Although the content and composition of individual saturated fatty
238 acid (SFA) and polyunsaturated fatty acid (PUFA) were similar, the total amount of SFA and
239 PUFA in T2 broiler meat were less than in T1 and T3 resulting in the lower PUFA: SFA ratio
240 (Table 4). Netto et al. (2014) and Zanini et al. (2004) stated that selenium involved in lipid
241 metabolism by remodeling the fatty acid composition. In agreement with Puerto et al. (2017),
242 the most finding saturated fatty acids (SFA) in this study was palmitic acid (C16:0) while it
243 was oleic acid (C18:1n9c) for monounsaturated fatty acids (MUFA).

244 In this study, sources of selenium supplemented in the diets affected GSH-Px activity
245 (Table 5) and this was exhibited by higher GSH-Px activity ($p<0.01$) in the breast meat
246 obtained from birds fed diets containing 0.3 ppm Zn-L-SeMet (T3-organic selenium) than
247 those of birds fed with 0.3 ppm Na-Se (T1-inorganic selenium). The finding of increasing
248 tissue antioxidant enzyme GSH-Px by organic selenium in this study were consistent with
249 Zhang et al (2014). This may be due to organic source of dietary selenium has a higher
250 bioavailability and thus enhances the selenium retention, leading to the increasing of GSH-Px
251 levels (Mahan et al., 1996 ; Surai, 2007 ; Zhang et al., 2014). In addition, Dalia et al (2017)
252 stated that bacterial organic selenium can be considered as an effective source of selenium in
253 broiler chickens as it improved selenium deposition in tissue, antioxidant status, and
254 glutathione peroxidase gene expression compared to those supplemented with inorganic
255 selenium. In accordance with Slavik et al. (2008) who found higher level of GSH-Px activity
256 in beef cows fed with organic selenium (Se-enriched yeast) than those fed with inorganic
257 selenium (sodium selenite). Whereas, Heindl et al. (2010) reported that the source of selenium
258 did not affect GSH-Px activity in broiler chickens. However, the combination of 0.15 ppm

Na-Se + 0.15 ppm Zn-L-SeMet (T2) did not result in any difference in GSH-Px activity when compared to T1 and T3. The ribonucleotides, mainly IMP and GMP contribute to meat flavor perception, as they hold umami taste characteristics (Dunford and Shahidi, 1998). Selenium might be involved in meat flavor as Zhou and Wang (2011) reported a higher IMP content in chickens fed with Nano-Se as compared with the control group. Nevertheless, in this study, there were no differences ($p>0.05$) in flavor related ribonucleotides (IMP, GMP, inosine, hypoxanthine) among the meat samples of birds supplemented with different sources of selenium (Table 5).

Conclusions

In general, the supplementation of selenium in any forms at 0.3 ppm (either as organic, combination of organic and inorganic, or inorganic) has no impact on carcass and fatty acid composition, other meat quality traits (drip loss, color, pH, and shear force), and ribonucleotide content of breast muscle in broiler chickens raised in a commercial closed house system. However, organic selenium improved GSH-Px activity and increase moisture retention capacity in meat as shown by lower shrinkage loss. Therefore, organic selenium could be considered as an effective source of selenium in broiler chicken diet especially in terms of biochemical benefits.

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Table 1. Formula of basal diets

Item	Starter (0-21 d)	Grower (22-30 d)	Finisher (31-37 d)
Ingredients			
Broken rice	28.60	34.96	38.85
Corn	30.00	30.00	30.00
Soybean meal	29.50	21.93	18.24
Fish meal	6.00	8.00	8.00
Vegetable oil	1.64	0.84	1.11
Monocalcium phosphate	1.35	1.24	1.00
Limestone	0.77	0.90	0.79
Premix[1, 2]	0.60	0.60	0.60
Salt	0.42	0.39	0.39
Lysine	0.39	0.41	0.40
DL methionine	0.29	0.26	0.25
L threonine	0.19	0.18	0.14
Choline chloride	0.14	0.14	0.14
Antifungal	-	0.10	0.10
Monensin sodium[3]	0.05	0.05	-
Nutrient and energy level (calculated)			
Xanthophyl (ppm)	11.70	11.70	11.70
ME (kcal/kg)	3100	3100	3150
Protein (%)	21.50	19.00	17.50
Ash (%)	4.38	4.06	3.58
Fat (%)	4.29	3.79	4.02
Fiber (%)	2.37	2.21	2.08
Calcium (%)	0.90	0.90	0.80
Total phosphorus (%)	0.72	0.67	0.60
Available phosphorus (%)	0.48	0.45	0.40
Salt (%)	0.44	0.42	0.42
Lysine (%)	1.28	1.15	1.06
Methionine (%)	0.52	0.47	0.45
Methionine + Cysteine (%)	0.91	0.83	0.79
Threonine (%)	0.96	0.86	0.79
Tryptophan (%)	0.22	0.19	0.25
Sodium (%)	0.20	0.19	0.19

[1] Vitamin-mineral mixture provides the following (per kg of diet): 25,000 IU of vitamin A; 5,000 IU of vitamin D_3; 100 mg of vitamin E; 6 mg of vitamin K_3; 4 mg of vitamin B_1; 10 mg of vitamin B_2; 30 mg of vitamin B_3; 6 mg of vitamin B_6; 60 mg of nicotinamide; 2 mg of folic acid; 0.06 mg of vitamin B12; 0.2 mg of biotin; 1,000 mg of choline chloride; 2 mg of Co, 4 mg of I, 120 mg of Mn, 40 mg of Fe, and 100 mg of Zn

[2] The T1, T2, and T3 treatment diet contained 0.3 ppm Na-Se, 0.15 ppm Na-Se + 0.15 ppm Zn-L-SeMet, or 0.3 ppm Zn-L-SeMet.

[3] Coccidiostat (Maxiban® for starter, Cygro® 1% for grower)

398 **Table 2**. Effects of dietary selenium sources[1] on body and carcass composition in commercial
399 broiler chickens

Traits	T1	T2	T3	RMSE	*P*-value
Live weight (kg)	2.58	2.61	2.66	0.09	0.092
Carcass weight (kg)	2.08	2.09	2.92	0.07	0.251
Body composition (% of live weight)					
Carcass dressing	80.53	80.13	79.92	1.85	0.603
Abdominal fat	1.01	0.97	0.95	0.34	0.868
Liver	2.16	2.29	2.31	0.34	0.378
Gizzard	1.01	1.04	0.99	0.16	0.659
Heart	0.34	0.33	0.35	0.09	0.826
Spleen	0.07	0.06	0.06	0.02	0.579
Head	1.86	1.84	1.91	0.68	0.925
Neck	3.36	3.44	3.36	0.68	0.925
Carcass composition (% of carcass weight)					
Breast	26.41	26.83	26.48	1.93	0.783
Fillet	4.97	4.87	4.64	0.72	0.375
Wing	10.85	10.18	10.13	1.63	0.343
Leg	27.57	27.88	28.43	1.23	0.120

400 [a-b] LSMeans in the same row with different letters are significantly different ($p<0.05$).
401 [1] The T1, T2, and T3 treatment groups were fed diets containing 0.3 ppm Na-Se, 0.15 ppm
402 Na-Se + 0.15 ppm Zn-L-SeMet, and 0.3 ppm Zn-L-SeMet, respectively.
403

404 **Table 3.** Effects of dietary selenium sources[1] on meat quality traits of *Pectoralis major* m.
405 broiler in commercial broiler chickens

Traits	T1	T2	T3	RMSE	*P*-value
Drip loss (%)	2.40	2.57	2.52	0.88	0.866
Shrinkage loss (%)	2.60[a]	2.15[ab]	1.80[b]	0.70	0.012
Cooking loss (%)	10.36[c]	12.23[b]	13.52[a]	1.66	<0.0001
L*	50.98	49.51	50.00	.349	.0444
a*	2.12	1.80	2.13	0.74	0.321
b*	6.42	6.19	6.26	1.25	0.852
pH 45 min (unit)	6.55	6.6	6.54	0.34	0.838
pH 24 h (unit)	6.04	6.05	5.97	0.23	0.546
pH 4 d (unit)	5.93	5.96	5.97	0.12	0.615
Shear force (kg)	2.26	2.34	2.32	0.33	0.764

406 [a-c] LSMeans in the same row with different letters are significantly different ($p<0.05$).
407 [1] The T1, T2, and T3 treatment groups were fed diets containing 0.3 ppm Na-Se, 0.15 ppm
408 Na-Se + 0.15 ppm Zn-L-SeMet, and 0.3 ppm Zn-L-SeMet, respectively.
409

410 **Table 4**. Effects of dietary selenium sources[1] on cholesterol content and fatty acid composition of

411 *Pectoralis major* m. in commercial broiler chickens

Traits[2]	T1	T2	T3	RMSE	*P*-value
Cholesterol	1.12	1.16	1.16	0.18	0.901
C14:0	0.10	0.09	0.11	0.05	0.881
C15:0	0.19	0.19	0.18	0.03	0.823
C16:0	5.01	4.27	5.18	1.76	0.642
C16:1	1.20	0.94	1.28	0.44	0.407
C18:0	1.21	1.19	1.29	0.40	0.905
C18:1n9c	6.28	5.88	7.59	2.70	0.534
C18:2n6c	4.89	3.77	4.79	1.61	0.433
C18:3n3	0.24	0.17	0.23	0.08	0.420
C23:0	0.54	0.47	0.48	0.11	0.507
SFA	7.05	6.21	7.23	2.26	0.712
MUFA	7.49	6.82	8.87	3.10	0.522
PUFA	5.12	3.94	5.02	1.69	0.433
n-6/n-3	21.02	21.52	20.82	0.93	0.421
PUFA: SFA	0.72[a]	0.64[b]	0.70[a]	0.04	0.014

412 [a-b] LSMeans in the same row with different letters are significantly different ($p<0.05$).

413 [1] The T1, T2, and T3 treatment groups were fed diets containing 0.3 ppm Na-Se, 0.15 ppm
414 Na-Se + 0.15 ppm Zn-L-SeMet, and 0.3 ppm Zn-L-SeMet, respectively. SFA- saturated
415 fatty acids; MUFA- monounsaturated fatty acids; PUFA- polyunsaturated fatty acids;
416 PUFA: SFA - ratio of PUFA to SFA

417 [2] mg/100 g

418

Table 5. Effects of dietary selenium sources[1] on glutathione peroxidase activity and ribonucleotides content of *Pectoralis major* m. in commercial broiler chickens

Traits	T1	T2	T3	RMSE	*P*-value
GSH-Px[2]	0.51[b]	0.62[ab]	0.77[a]	0.11	0.009
Hypoxanthine[3]	2.89	4.71	3.78	1.71	0.247
Inosine[3]	43.47	51.94	40.20	14.82	0.394
IMP[3]	229.85	190.40	175.66	42.62	0.136
GMP[3]	2.67	2.34	2.01	0.76	0.385

[a-b] LSMeans in the same row with different letters are significantly different ($p<0.05$)

GSH-Px - glutathione peroxidase; IMP - inosine monophosphate; GMP - guanosine monophosphate

[1] The T1, T2, and T3 treatment groups were fed diets containing 0.3 ppm Na-Se, 0.15 ppm Na-Se + 0.15 ppm Zn-L-SeMet, and 0.3 ppm Zn-L-SeMet, respectively.

[2] unit/mg protein

[3] mg/100 g