Effect of dietary selenium on lipid oxidation, selenium and vitamin E content in the meat of broiler chickens

M. Skřivan, G. Dlouhá, O. Mašata, S. Ševčíková

Institute of Animal Science, Prague-Uhříněves, Czech Republic

ABSTRACT: An experiment was conducted to compare the effect of dietary sodium selenite and selenomethionine on selenium and α-tocopherol concentration in breast meat, oxidative stability of meat in broilers, and on growth performance, but only as an unimportant criterion in this case. Sexed broiler cockerels Ross 308 were allocated to 3 dietary treatments, each comprising 100 chickens. The basal diet was supplemented with 0 (control) or 0.3 mg/kg Se from sodium selenite (SS) or selenomethionine (SM). Dietary supplementation with SM increased ($P < 0.05$) body weight, but only by about 3%. Breast muscle Se concentration was increased ($P < 0.05$) by both Se sources, but more by SM (1.32 mg/kg dry matter; 0.47 mg/kg DM in control). The concentration of Se in excreta was 3 times higher with SS supplement than with SM supplement. Dietary Se supplementation increased ($P < 0.05$) the α-tocopherol content of breast meat from 25.9 mg/kg DM in the control to 33.2 mg/kg DM when SM supplementation was used. Furthermore, lipid peroxidation decreased compared to the control. The inclusion of SM in the diet reduced ($P < 0.05$) malondialdehyde (MDA) values in breast samples after 0, 3, and 5 days of cooler storage, whereas SS decreased ($P < 0.05$) the MDA of breast meat after 0 and 3 days of storage. The results of this experiment indicate that selenomethionine in the diet of broilers is capable of simultaneously increasing the content of selenium and vitamin E in broiler meat plus its stability in storage.

Keywords: broilers; sodium selenite; selenomethionine; vitamin E

Selenium plays an important role in the regulation of various metabolic processes in the body, being an integral part of selenoproteins. Organic Se in the form of selenomethionine is a predominant form of this element in feed ingredients. In forages, grains, and oilseed meals Se is bound to different amino acids, including methionine and cysteine. Selenomethionine represents about 50% of the Se in cereal grains (Olson and Palmer, 1976). Therefore, the digestive system of animals including chickens has adapted itself during evolution to this form of the element. Selenite, a common form of Se used in diets, is not found naturally and as a result is less effective in terms of assimila-

tion from feed and its incorporation into the body (Surai, 2002a).

Miller et al. (1972) reported no difference in the gain or feed intake of broilers fed various concentrations (0 to 0.5 ppm) of Se from sodium selenite or selenomethionine. Recently, there has been an interest in the use of Se-enriched yeast and Se-enriched alga *Chlorella* with a superiority of selenomethionine as a supplemental source of Se for broilers (Choct et al., 2004; Payne and Southern, 2005; Ševčíková et al., 2006; Dlouhá et al., 2008), layers (Ryu et al., 2005; Skřivan et al., 2006b), calves (Skřivanová et al., 2007), and for rabbits (Dokoupilová et al., 2007). Dietary Se levels

Czech J. Anim. Sci., 53, 2008 (7): 306–311

Original Paper

can influence the oxidative stability of the skeletal muscle. Unfortunately, there is little information available on the effects of Se supplementation on lipid oxidation in broiler chicks (Ryu et al., 2005). For comparison it is therefore necessary to pay attention also to data from other animal species.

Together with Se, vitamin E is an important component of the antioxidant defence system which helps to protect the polyunsaturated fatty acids in cell membranes from peroxidative damage (Hoekstra, 1975). Dietary Se significantly increased the vitamin E content of egg yolk (Surai, 2000) and vitamin E concentration in the plasma of chickens (Thompson and Scott, 1970), rats (Scott et al., 1977) and ducklings (Dean and Combs, 1981). However, these studies evaluated primarily the influence of Se supplementation on the antioxidant system of the animal and its offspring.

In experiments with layers and broilers (Skřivan et al., 2006a) selenium supplementation was found to increase the content of vitamin E in eggs and meat. A higher oxidative stability of lipids is connected with this effect (Dlouhá et al., 2008). Se-yeast and Se-*Chlorella* were developed for commercial purposes and contain many selenoproteins. Therefore, it is possible to experimentally verify the effect of selenomethionine itself on the concentration of vitamin E. The objectives of the present experiment were to compare dietary sodium selenite (SS) and selenomethionine (SM) supplementation with regard to selenium and α-tocopherol concentration in breast meat and the oxidative stability of meat in broilers. The performance of chicks was monitored only for guidance.

MATERIAL AND METHODS

Broiler cockerels Ross 308 were obtained from a commercial hatchery on day 0 post- hatching. They were randomly assigned to 3 dietary-treatment groups of 100 chickens per treatment. Treatments consisted of (1) maize-wheat-soybean meal basal diet with no supplemental Se, (2) basal diet supplemented with 0.3 mg/kg from SS (Na_2SeO_3), and (3) basal diet supplemented with SM (provided by Sigma) (Table 1). Dietary selenium concentrations were 0.11, 0.38 and 0.36 mg/kg. Feed and water were provided *ad libitum.* Broilers were kept in pens 2 m × 3.3 m on wood shavings, with gas heating, ventilation with a temperature-controlled fan, and a 24 h lighting program, at the Institute of Animal Science, Prague. Each pen was equipped

with 7 nipple drinkers, 3 pan feeders, and a feed hopper. At the chickens' age of five weeks samples of excreta were collected for the analysis of selenium content. With termination of the experiment at 42 days of age, 20 broiler chickens representing the average live weight of the group were selected and slaughtered conventionally at a slaughtering plant. Ten breast (*M. pectoralis maior* and *minor)* fillets were freeze-dried and ground (1-mm screen) for the analysis of dry matter, fat, selenium, and α-tocopherol. The remaining 10 breast fillets were ground and divided into three parts for the determination of dry matter and lipid oxidation during storage for 0, 3, or 5 days at 3 to 5°C before the determination of malondialdehyde.

Table 1. Composition of basal diet[a]

Ingredient	g/kg
Maize	299
Wheat	290
Soybean meal	320
Fish meal	20
Rapeseed oil	40
DL-methionine	2
Limestone	12
Dicalcium phosphate	10
Sodium chloride	2
Vitamin/mineral supplement[b]	5
Analysed chemical composition	
Dry matter	882
Crude protein	217
Crude fat	63
Crude fibre	34
Calcium	8.4
Phosphorus	5.6
Selenium	11×10^{-5}
α-tocopherol	35
AME by calculation (MJ/kg)	12.35

[a]experimental diets were supplemented with Se at 0.3 mg/kg

[b]vitamin/mineral supplement provided per kg of diet: vitamin A 9 000 IU; cholecalciferol 500 IU; vitamin E 20 mg; menadion 3 mg; thiamine 3 mg; riboflavin 5 mg; pyridoxine 4 mg; vitamin B_{12} 0.04 mg; niacin 40 mg; calcium pantothenate 12 mg; biotin 0.15 mg; folic acid 1.5 mg; choline chloride 250 mg; ethoxyquin 100 mg; copper 12 mg; iron 50 mg; iodine 1 mg; manganese 80 mg; zinc 60 mg

Analyses

Feed, meat, and excreta dry matter were determined by oven drying at 105°C, ashing at 550°C (AOAC, 1997), and fat by extraction with petroleum ether with a Soxtec 1045 apparatus (Tecator Comp., Sweden). The protein content of feed was determined using a Kjeltec Auto 1030 (Tecator Comp., Sweden). Ca in the feed was determined after ashing of samples by atomic absorption spectrometry (Solaar M-6, TJA Solutions, UK) whereas P analyses were done colorimetrically (Huxtable and Bressler, 1973). To determine Se in the diets, freeze-dried meat and excreta samples were mineralized using a microwave digestion technique in a closed system (Milestone Ethos TC, Italy) in the presence of HNO_3 and H_2O_2. Se in the processed samples was measured by atomic absorption spectrometry (Solaar M-6 instrument). The analytical procedures for Se were validated by the analysis of certified reference material RM 8414 Bovine Muscle (NIST). The α-tocopherol content of feeds and meat was determined according to the EN 12822 European Standard (2000) by HPLC (Shimatzu, VP series) equipped with a diode-array detector. Lipid peroxidation in breast fillets was measured by the thiobarbituric acid method of Piette and Raymond (1999) and the results were expressed as thiobarbituric acid-reactive substances (TBARS) in mg of malondialdehyde/kg.

Statistical analyses

The assumption of homogeneity of variances was checked using Levene's homogeneity test before ANOVA analysis and was performed using the GLM procedure. In the case of homogeneity of variance, the results of ANOVA and the differences of means with Scheffe's adjustment, to control the overall type 1 error rate, were accepted. In another case the MIXED procedure was used in order to take into account different variances in the variance-covariance structure of the model. A level of $P < 0.05$ was chosen as the limit for statistical significance. Statistics were obtained using the SAS programme for Windows (SAS, 2002–2003).

RESULTS

Table 2 shows the effect of dietary Se supplementation on performance traits and mortality. The SM supplement increased ($P < 0.05$) the live weight of chickens at day 42, but only by about 3%. The inclusion of SS in the diet increased ($P < 0.05$) intramuscular fat concentration (37 g/kg DM) compared with the control diet (28 g/kg DM). Breast muscle Se concentration was increased ($P < 0.05$) by both Se sources, and this effect was more pronounced in the SM treatment (Table 3). The concentration of Se in excreta was 3 times higher with SS supplementation than in the case of SM treatment. Supplementation with SM, compared to the control, increased ($P < 0.05$) the concentration of α-tocopherol in breasts. The extent of lipid oxidation, as measured by MDA formation, in breast meat was lower in broilers fed the supplemented Se diets than in the control group (Table 4). The inclusion of SM in the diet reduced ($P < 0.05$) MDA values in breast samples after 0, 3 and 5 days in cooler storage, whereas SS decreased ($P < 0.05$) the MDA of breast meat after 0 and 3 days of storage.

DISCUSSION

In the present study dietary Se supplementation with SS and SM increased breast Se concentrations

Table 2. Effect of Se source on growth performance (LSM ± SE)

Parameter	Basal	SS	SM	SE	*P*
d-0 BW (g)	46	46	46	0.37	0.87
d-21 BW (g)	828 ± 10	866 ± 13	853 ± 12		0.06
d-42 BW (g)	2 779 ± 21[a]	2 834 ± 30[a]	2 870 ± 30[b]		<0.05
F:G, g:g, 0 to 42 days	1.66	1.61	1.64		
Mortality (%)	5	4	6		

SS = sodium selenite; SM = selenomethionine; BW = body weight; F:G = feed:gain
[a,b]treatment means with different superscripts differ at $P < 0.05$

Table 3. Concentration of selenium and α-tocopherol in diets (mg/kg) and breast muscle, and selenium in excreta (LSM ± SE; *n* = 10 per treatment)

Treatment	Diet		Breast muscle[1]		Excreta[1]
	selenium	α-tocopherol	selenium	α-tocopherol	selenium
Basal	0.11	35	0.47 ± 0.01[a]	25.9[a]	0.25[a]
SS	0.38	37	0.59 ± 0.02[b]	27.6[a]	1.02[b]
SM	0.36	39	1.32 ± 0.04[c]	33.2[b]	0.37[a]
SE				1.2	0.03

SS = sodium selenite; SM = selenomethionine

[1]mg/kg DM

[a,b]treatment means with different superscripts differ at *P* < 0.05

compared to no supplementation. The results agree with those of Shan and Davis (1994), who found increased breast Se concentrations due to SS supplementation. Spears et al. (2003) reported that the feeding of 0.15 ppm SM to broilers resulted in higher Se concentrations in the breast meat of broilers compared to those fed SS.

Supplementation with SS increased the intramuscular fat of the breast muscle. Ševčíková et al. (2006) observed an increase in fat in poultry meat due to Se-*Chlorella* supplementation.

In agreement with previous findings (Skřivan et al., 2006a), this study presents evidence that dietary Se supplementation increased the α-tocopherol content of broiler meat. However, the mechanism of this synergism remains unclear. It can be speculated that Se is a component of glutathione peroxidase and actively participates in lipid peroxide removal from cells, sparing the use of vitamin E for this purpose (Surai, 2002a; Singh et al., 2006). Another possibility is that Se might have an effect on other aspects of vitamin E metabolism and transport to target tissues (Surai, 2002a). It has been demonstrated in chickens that Se preserves the integrity of the pancreas, which permits normal fat diges-

tion and vitamin E absorption. Furthermore, Se assists in a certain unknown way in the retention of vitamin E in blood plasma (Thompson and Scott, 1970).

In this study selenomethionine was found to be more effective in increasing the Se and α-tocopherol contents of broiler meat than inorganic Se. Ševčíková et al. (2006) and Dlouhá et al.(2008) reported a considerably lower Se breast concentration of broilers fed Se-yeast and Se-*Chlorella* supplemented diets. This illustrates a higher bioavailability purely of selenomethionine, although in Se-yeast and Se-*Chlorella* this is usually only 1–3% of selenite. Inorganic Se is passively absorbed, whereas selenomethionine is absorbed actively in the intestine by a process similar to that used for the absorption of methionine (Rayman, 2004; Surai, 2002b). Likewise, different results regarding Se content in meat and eggs were reported when comparing inorganic dietary Se with Se-yeast (Leng et al., 2003) and *Chlorella* Se (Skřivan et al., 2006b; Dlouhá et al., 2008).

Poultry meat is quite sensitive to oxidative deterioration due to its high content of polyunsaturated fatty acids. The TBARS formation in breast

Table 4. Effect of cooler storage (3 to 5°C) on the concentration of malondialdehyde (mg/kg) in breast muscle (LSM ± SE; *n* = 10 per treatment)

Time of storage	Basal	SS	SM	SE
d-0	0.59[a]	0.50[b]	0.45[b]	0.02
d-3	1.09 ± 0.06[a]	0.90 ± 0.04[b]	0.82 ± 0.03[b]	
d-5	1.39[a]	1.22[a,b]	1.06[b]	0.08

SS = sodium selenite; SM = selenomethionine

[a,b]treatment means with different superscripts differ at *P* < 0.05

meat decreased in SM treatment compared with the control, but not with SS. Selenomethionine was therefore less successful in the protection of lipids than in meat Se deposition. The malondialdehyde values for breast meat from chickens fed the basal diet are within the range of those reported by DeVore et al. (1983) for broiler meat that was stored for 4 days. There are several reports comparing the formation of TBARS in the meat of other animals. The increase in the dietary Se (according to the Se-yeast) level in rabbits from 0.12 to 0.50 mg/kg did not decrease the oxidation of lipids expressed as production of TBARS. Therefore, in rabbits the supranutritional Se supply has only a limited potential for increasing the oxidative stability of meat (Dokoupilová et al., 2007). Skřivanová et al. (2007) reported that the oxidative stability of refrigerator-stored veal meat was increased by dietary Se-yeast and vitamin E supplementation in calves. The recommended selenium intake for adult humans is 55 μg/day, with the tolerable upper intake level 300 μg/day (Rayman, 2004). The recommended vitamin E intake is 10–15 mg/day (Institute of Medicine, 2000).

It can be concluded from this study that dietary selenomethionine supplementation is capable of increasing the selenium as well as α-tocopherol content of broiler meat and can prevent the oxidation of products during storage. The content of selenium in chicken raw meat can be 33 mg/100 g and that of vitamin E 0.83 mg/100 g.

REFERENCES

AOAC (1997): Official Methods of Analysis 16th ed. AOAC. Virginia, USA.

Choct M., Naylor A.J., Reinke N. (2004): Selenium supplementation affects broiler growth performance, meat yield and feather coverage. Brit. Poult. Sci., 45, 677–683.

Dean W.F., Combs G.F. (1981): Influence of dietary selenium on performance, tissue selenium content and plasma concentrations of selenium-dependent glutathione peroxidase, vitamin E and ascorbic acid in ducklings. Poult. Sci., 60, 2555–2663.

DeVore V.R., Colnago G.L., Jensen L.S., Greene B.E. (1983): Thiobarbituric acid values and glutathione peroxidase activity in meat from chickens fed a selenium-supplemented diet. J. Food Sci., 48, 300–301.

Dlouhá G., Ševčíková S., Dokoupilová A., Zita L., Heindl J., Skřivan M. (2008): Effect of dietary selenium sources on growth performance, breast muscle selenium, glutathione peroxidase and oxidative stability in broilers. Czech J. Anim. Sci., 53, 265–269.

Dokoupilová A., Marounek M., Skřivanová V., Březina P. (2007): Selenium content in tissues and meat quality in rabbits fed selenium yeast. Czech J. Anim. Sci., 52, 165–169.

EN 12822 (2000): Foodstuffs – Determination of vitamin E by high performance liquid chromatography – measurement α-, β-, γ-, and δ-tocopherols. European Committee for Standardization, Brussels, Belgium.

Hoekstra W.G. (1975): Biochemical function of selenium and its relation to vitamin E. Feed. Proc., 34, 2083–2089.

Huxtable R., Bressler R. (1973): Determination of orthophosphate. Anal. Biochem., 54, 604–608.

Institute of Medicine (2000): Dietary Reference Intakes for Vitamins. The National Academies Press, Washington, USA.

Leng L., Bobček R., Kuricová S., Boldizárová K., Grešáková L., Ševcíková Z., Révajová V., Levkutová M., Levkut M. (2003): Comparative metabolic and immune responses of chickens fed diets containing inorganic selenium and Sel-Plex[TM] organic selenium. In: Lyons T.P., Jacques K.A. (eds.): Proc. Altech's 19th International Symposium. Nutritional Biotechnology in the Feed and Food Industries. 131–145.

Miller D., Soares J.H. Jr., Bauersfeld P. Jr., Cuppett S.L. (1972): Comparative selenium retention by chicks fed sodium selenite, selenomethionine, fish meal, and fish solubles. Poult. Sci., 51, 1669–1673.

Olson O.A., Palmer L.S. (1976): Seleno amino acids in tissues of rats administered inorganic selenium. Metabolism, 25, 299–306.

Piette G., Raymond Y. (1999): Vergleichende Bewertung verschiedener Methoden. Bestimmung der Ranzigkeit in Fleischprodukten. Fleischwirtschaft, 7, 69–73.

Payne R.L., Southern L.L. (2005): Comparison of inorganic and organic selenium sources for broilers. Poult. Sci., 84, 898–902.

Rayman M.P. (2004): The use of high-selenium yeast to raise selenium status: how does it measure up? Brit. J. Nutr., 92, 557–573.

Ryu Y.-C., Rhee M.-S., Lee K.-M., Kim B.-C. (2005): Effects of different levels of dietary supplemental selenium on performance, lipid oxidation, and colour stability of broiler chicks. Poult. Sci., 84, 809–815.

SAS (2002–2003): SAS System for Windows, Release 9.1 (TS1M3), SAS Institute, Inc., Cary, NC, USA.

Scott D.L., Kelleher J., Losowsky M.S. (1977): The influence of dietary selenium and vitamin E on glutathione

peroxidase and glutathione in the rat. Biochem. Biophys. Acta, 497, 218–224.

Shan A.S., Davis R.H. (1994): Effect of dietary phytate on growth and selenium status of chicks fed selenite or selenomethionine. Brit. Poult. Sci., 35, 725–741.

Singh H., Sodhi S., Kaur R. (2006): Effects of dietary supplements of selenium, vitamin E or combinations of the two on antibody response of broilers. Brit. Poult. Sci., 47, 714–719.

Skřivan M., Ševčíková S., Dlouhá G., Tůmová E., Ledvinka Z. (2006a): Enhancement of vitamin E and A in animal products. Patent Application. Office of Industrial Proprietorship, Czech Republic.

Skřivan M., Šimáně J., Dlouhá G., Doucha J. (2006b): Effect of dietary sodium selenite, Se-enriched yeast and Se-enriched alga *Chlorella* on egg Se concentration, physical parameters of eggs and laying hens production. Czech J. Anim. Sci., 51, 163–167.

Skřivanová E., Marounek M., De Smet S., Raes K. (2007): Influence of dietary selenium and vitamin E on quality of veal. Meat Sci., 76, 495–500.

Spears J.W., Grimes J., Lloyd K., Ward T.L. (2003): Efficacy of a novel organic selenium compound (zinc-L-selenomethionine, Availa Se) in broiler chicks. In: Proc. 1st Latin American Congress of Animal Nutrition, Cancun, Mexico, 197–198.

Surai P.F. (2000): Effect of selenium and vitamin E content of the maternal diet on the antioxidant system of the yolk and the developing chick. Brit. Poult. Sci., 41, 235–243.

Surai P.F. (2002a): Selenium in poultry nutrition. 1. Antioxidant properties, deficiency and toxicity. Worlds Poult. Sci. J., 58, 333–347.

Surai P.F. (2002b): Selenium in poultry nutrition. 2. Reproduction, egg and meat quality and practical applications. Worlds Poult. Sci. J., 58, 431–450.

Ševčíková S., Skřivan M., Dlouhá G., Koucký M. (2006): The effect of selenium source on the performance and meat quality of broiler chickens. Czech J. Anim. Sci., 51, 449–457.

Thompson J.N., Scott M.L. (1970): Impaired lipid and vitamin E absorption related to atrophy of the pancreas in selenium –deficient chicks. J. Nutr., 100, 797–800.

Corresponding Author

Prof. Miloš Skřivan, DrSc., Institute of Animal Science, Přátelství 815, 104 01 Prague 10-Uhříněves, Czech Republic
Tel. +420 267 009 720, fax +420 267 711 448, e-mail: skrivan.milos@vuzv.cz