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Selenium in poultry nutrition

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Abstract: Selenium (Se) has a special place among the feed-derived natural antioxidants, being an integral part of selenoproteins participating in the regulation of various physiological processes in the body. As a part of glutathione peroxidase (GSH-Px) Se belongs to the first and second major levels of antioxidant defense in the cell. There are two major sources of Se for poultry organic selenium, mainly in the form of selenomethionine (SeMet), which can be found in any feed ingredient in varying concentrations and inorganic selenium, mainly selenite or selenate, which are widely used for dietary supplementation. There is a principal difference in metabolism and efficiency of these two forms of selenium, with SeMet being more effective. In fact SeMet possesses antioxidant properties, however, in some conditions selenite can be a pro-oxidant. Selenium deficiency and excess in modern poultry production are very rare. In general, adequate Se supplementation is considered to be a crucial factor in maintaining the high productive and reproductive characteristics of commercial poultry The present research focuses on the effects of Se on meat and egg quality, antioxidant activity of Se, effects on fatty acid levels, activity of glutathione-peroxidase, or the effect of Se on the immune system. Ensuring natural Se supply in human nutrition by food of animal origin, mainly poultry meat and eggs.
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Introduction

Selenium sources and their efficiency

Sources of Se can be divided into several groups according to their efficiency:

Elementary selenium.

Elementary Se is stable and exists in modifications. It is virtually biologically inactive, especially for its poor resorption.

Inorganic selenium compounds.

Inorganic Se (sodium selenite) is not too biologically active. It accelerates oxidization processes in organism and may cause health problems. Most inorganic selenium is excreted from the body. Higher doses are toxic.

Organic selenium compounds.

Organic selenium compounds perform a key role in biological processes. They are more active than inorganic salts. They are part of proteins and include Se- Met and selenocysteine (Se-Cys). Se-Met exists in two isomer forms, d and l, and was identified in plant proteins **(Schrauzer 2000)**. Only the l-form occurs naturally, d-form may only be prepared synthetically. This form makes up to 50% of the total Se content in vegetarian food and higher organisms are unable to synthesizeit **(Schrauzer 2000)**. Se-Cys is the only Se compound forming part of effective selenium enzymes. It is mainly found in food of animal origin and in plants able to accumulate high levels of Se **(Hartikainen 2005).** Se-Met is quickly absorbed with the consequence of higher blood levels in comparison to inorganic Se. Bioavailability of Se depends on the chemical compound it is part of. Organically bound Se is mostly used in the form of Se-enriched yeast or other preparations. Se-enriched yeast contains Se in the form of Se-Met. This form is also contained in most plants and cereals. Most of Se in the inorganic form is excreted via urine while its organic form is excreted via faeces **(Groce et al. 1971; Hitchcock et al. 1978).** Se in its organic form shows higher bioavailability (75.7%) than Se bound in the inorganic form (49.9%) **(Mahan et al. 1999).** This is manifested by higher levels of organic Se in all tissues and anatomies It should be noted that activity of glutathione peroxidase (GSH-Px) in the serum remains the same both in the organic and the inorganic form. Maximum activity of GSH-Px is already achieved at the Se level of 0.1 mg/kg of fodder in the case of both organic and inorganic form. This activity is independent on the chemical form **(Xia et al. 1992)**.

Other selenium-enriched feedstuffs.

In addition to organic Se compounds, other sources have been tested and utilized, such as selenium-enriched algae *Scenedesmus quadricauda* (selenium-enriched *Scenedesmus* biomass) **(Umysova et al. 2009; Skrivan et al. 2010a),** Se-enriched unicellular alga *Chlorella* **(Travnicek et al. 2007)**, Se-enriched yeast **(Briens et al. 2013; Nyquist et al. 2013; Yuan et al. 2013)** or selenium chelate **(De Almeida et al. 2012).**

Selenium and poultry yield

Effects of various sources and levels of Se in the diet on poultry yield have been subject of a number of studies **(Dlouha et al. 2008; Attia et al. 2010; Heindl et al. 2010; De Medeiros et al. 2012; Yang et al. 2012; Chen et al. 2013; Habibian et al. 2013)** The achieved results are not uniform, both negative and positive responses being reported.

Negative response to the application of inorganic and organic sources of Se.

Rama Rao et al. (2013) studied various levels (0, 100, 200, 300, or 400 μg/kg diet) of organic Se in broiler chickens in tropical conditions. The results of the study indicate that the supplementation of Se did not influence body weight and feed efficiency. Similar findings have been reported by **Chen et al. (2013),** who fed the chickens with different levels of selenium yeast. The results showed that effects of different levels of Se on growth performance, slaughter performance, the immune status, drip loss, and flesh did not significantly differ. Organic Se was also fed to broiler chicks by **De Medeiros et al. (2012).** The results revealed that the supplementation with organic Se did not affect productive characteristics of the broilers. The effects of dietary vitamin E (0, 125, and 250 mg/kg), Se (0, 0.5, and 1 mg/kg), or their different combinations under either thermoneutral or heat stress conditions were studied by **Habibian et al. (2013)**. Body weight and feed intake were not influenced significantly by dietary vitamin E and Se, whereas feed conversion was improved significantly by 125 mg/kg vitamin E. The different levels of selenium and vitamin E applied in the feed mixtures were found not to affect the final body weight of the chickens **(Zdunczyk et al. 2011).**

Positive response to the application of inorganic and organic sources of Se.

In contrast to the above-mentioned reports, **Attia et al. (2010)** stated that addition of organic and inorganic Se improved the productive and reproductive performance of Gimmizah breeding hens. Effect of slaughter performance, the immune status, drip loss, and flesh did not significantly differ. Organic Se was also fed to broiler chicks by **De Medeiros et al. (2012).** The results revealed that the supplementation with organic Se did not affect productive characteristics of the broilers.

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Positive response to the application of inorganic and organic sources of Se.

In contrast to the above-mentioned reports, **Attia et al. (2010)** stated that addition of organic and inorganic Se improved the productive and reproductive performance of Gimmizah breeding hens. Effect of organic and inorganic Se supplementation on growth performance, meat quality, and antioxidant status of broilers was also studied by **Yang et al. (2012).** In the control group, 0.3 mg/kg inorganic Se (Na_2SeO_3) was added to the diets while in the experimental group, 0.3 mg/kg organic Se (Se-enriched yeast) was added to the same basal diets. The results show that organic Se could increase daily weight gain and feed intake by 8.92 and 3.99%, and decrease survival rate and feed conversion by 0.93 and 4.84%, respectively, indicating that the effects of organic Se on broiler growth performance were better than those of inorganic Se. **Dlouha et al. (2008)** studied the effects of supplementation of dietary sodium selenite and sodium-enriched alga *Chlorella* on the growth performance of sexed broiler cockerels Ross 308. The basal diet was supplemented with 0 (control) or 0.3 mg/kg Se from sodium selenite or Se-Chlorella (Se-CH). Dietary supplementation with Se-CH increased body weight. Also **Heindl et al. (2010)** confirmed that Se addition influenced body weight in 21- and 35-day-old broiler chickens. Significantly higher body weight at 35 days of age was determined in chickens receiving 0.15 mg of Se from selenium-enriched yeast (Sel-Plex® SP) and 0.3 mg of Se from selenium-enriched yeast contrary to dietary treatment with a lower level of Se from selenium-enriched alga *Chlorella* per kg of feed. Feeding of selenized yeast increased the live body weight of chickens compared with the controls **(Rozbicka- Wieczorek et al. 2012).**

As there is a relation between Se and vitamin E in the sense that vitamin E "spares" the need of Se, it may be deduced that a positive effect on chicken yield indicators may be manifested even in the case of an insufficient supply of both these substances. The need for Se decreases inversely to vitamin E levels, which documents the sparing effect of vitamin E on the need for Se **(Toulova et al. 1977),** or Se deficiency increases the need for vitamin E **(De Almeida et al. 2012).**

Selenium and meat and egg quality

Antioxidant effects of selenium are manifested in meat quality by reduced oxidization of lipids **(Skrivan et al. 2008, 2012; De Almeida et al. 2012),** as well as by better color stability of heme pigments (**Yang et al. 2012**). Se also positively affects reduction of weight loss of meat, expressed by loss of water by dripping (**Wang et al. 2011b**; **Yang et al. 2012; De Medeiros et al. 2012)** and improvement of certain organoleptic properties of broiler chicken meat. Se-rich meat is more juicy, crispy, and better looking. For animal fodder enrichment, Se is used in combination with other antioxidants, such as tocopherol (vitamin E).

Positive effects of Se on quality and stability of broiler chicken meat have been confirmed by a number of authors **(Heindl et al. 2010; Wang et al. 2011b, c; De Almeida et al. 2012; De Medeiros et al. 2012; Yang et al. 2012).** Further studies focus on the effects of Se on egg quality **(Attia et al. 2010; Skrivan et al. 2013).**

Quality and stability of chickemeat. Values of Se levels in meat and other animal products show seasonal fluctuations and significant changes related to ration composition. Se shows a clearly positive effect on the quality or stability of poultry meat. Oxidative stability in broilers under heat stress is improved by supplemental vitamin E and Se **(Harsini et al. 2012).** Compared with the control (Na2SeO3), organic Se (Se-enriched yeast) increased meat red color degree of chest and thigh muscles by 13.98 and 20.83%, respectively; the drip losses of chest and thigh muscles were decreased by 13.57 and 24.92%, respectively **(Yang et al. 2012)**. Se in the feed improved meat quality by reducing the lipid oxidation and cooking loss **(De Almeida et al. 2012).** The supplementation with Se produced a linear reduction on the abdominal fat of the carcasses assessed. Regarding meat quality, the supplementation with organic Se linearly increased pH levels at the breast. Besides, it linearly reduced the loss of water by pressure and the shear force, which in turn improved the final quality of meat **(De Medeiros et al. 2012).**

Skrivan et al. (2012) studied oxidative stability of meat of broilers fed diets enriched with vitamin C (280 and 560 mg/kg) and Se (sodium selenite or selenized yeast, 0.3 mg/kg). Both Se sources increased the activity of GSH-Px and the oxidative stability of meat. Diets supplemented with vitamin C and Se increased protein concentrations in meat. Vitamin C reduced lipid oxidation in meat stored for 5 days.

Egg quality.

Levels of Se and α-tocopherol in eggs of egg-laying hens fed diets enriched with Se-Met, sodium selenite, and vitamin E were studied by **Skrivan et al. (2010b).** Supplementation of either form of Se significantly increased the Se concentration in egg yolks and whites, with a more pronounced effect caused by Se-Met. Supplementation of Se- Met significantly increased α-tocopherol content in eggs. A moderate decrease in yolk cholesterol was observed in hens fed Se-Met and α-tocopherol. In the case of egg-laying hens fed diets supplemented with vitamin C, sodium selenite or selenized yeast, **Skrivan et al. (2013)** noted significantly increased laying performance; however, vitamin C significantly decreased feed intake and egg production. Both selenite and Se-enriched yeast increased vitamin E concentration in yolk and Se concentration in yolk and albumen. The oxidative stability of yolk lipids was improved in hens fed diets supplemented with sodium selenite, but not in those fed diets supplemented with Se-yeast. The combined supplementation of vitamin C and Se did not prove to be successful.

Different Se levels of the organic and inorganic form and their interaction did not significantly affect egg production percentage, and most of egg quality traits. Egg weight and egg mass significantly increased and the feed conversion ratio was significantly improved due to Se supplementation compared with hens fed the control diet. In addition, the levels of organic and inorganic Se and their interaction significantly decreased plasma cholesterol concentration. Yolk selenium concentration significantly increased due to Se supplementation and the greatest increase was recorded by a group fed a high-level (0.40 mg) organic Se diet **(Attia et al. 2010).** Se concentration in diets affected significantly the content of Se in albumen and yolk **(Kralik et al. 2009).**

Selenium and immune system

Opponents of the human and animal immune system. Se deficit damages both cellular and humoral immunity **(Artur et al. 2003)**. Se stimulates the immune system, strengthening proliferation of activated T lymphocytes **(Rayman 2000)**. Daily intake of 200 μg of Se causes increased reaction of lymphocytes to antigenic stimulation and increase of their ability to mature to cytotoxic lymphocytes destroying tumor cells. The activity of natural killers increases, too. This mechanism is closely connected with increased numbers of receptors for interleukin-2 on the surface of the activated lymphocytes and natural killers. These interactions are critical for clonal expansion and differentiation to cytotoxic T cells (Rayman 2000; Arthur et al. 2003). Effects of supplemented organic Se on immune response in broiler chickens were studied by **Rama Rao et al. (2013).** The cell-mediated immunity (lymphocyte proliferation ratio) increased linearly with dietary Se concentration. Another study **(Funari et al. 2012)** was conducted to evaluate the effect of different levels and sources of Se on humoral immunity of broilers. The immunity was evaluated by means of the reaction against the vaccine of Newcastle disease, and a reaction against sheep red blood cells (SRBC). The source and the level of Se showed no effect on the response against Newcastle vaccine and SRBC. The effect of Se source and its quantity on immune functions of broilers under thermal stress was studied by **Liao et al. (2012).**

The results indicated that Se yeast was more effective than Na2SeO3 or Se protein (AMMS Se) in increasing tissue Se retention; however, AMMS Se was more effective than Na2SeO3 or Se yeast in improving immune functions of heat-stressed broilers. Low-Se diet caused a decrease in the activities of total antioxidant capacity, superoxide dismutase, GSH-Px, and an increase in xanthine oxidization activity and malondialdehyde content. The study demonstrated that chickens fed diets deficient in Se exhibited lesions in immune organs, decreased serum interleukin-1β, interleukin-2 content, and serum tumor necrosis factor content, indicating that oxidative stress inhibited the development of immune organs and finally impaired the immune function of chickens **(Zhang et al. 2012)**.

Intoxication with selenium

Generally speaking, inorganic compounds are more toxic than organic ones. In the order of decreasing toxicity the compounds may be sorted as follows: the most toxic selenite > selenate > selenocysteine > methylated selenium compounds. Selenium acid is the most toxic form of selenium **(Barceloux 1999)**. **Bartik and Piskac (1974)** defined three types of intoxication with selenium: acute, subacute, and chronic poisoning (alkali disease). Acute intoxication is manifested with respiratory disorders, ataxia, diarrhoea or death. The signs include garlic odour of the breath caused by the presence of methyl selenide. The chronic form of intoxication caused by long-term supply of high selenium levels in the diet causes reduced feed intake, slowed down growth, hair loss, liver cirrhosis or anaemia. Chronic poisoning, called selenosis, most often occurs in regions with high selenium levels in soil and drinking water.

The range of selenium intake sufficient and still non-toxic for the organism is very narrow, depending, however, on the chemical form of Se. Trials in rats showed that Se intake in the amount of 5 mg/kg of body weight caused growth retardation, while 6.4 mg/kg of body weight caused liver changes and 8 mg/kg of body weight caused anaemia and increased mortality. The reason for growth retardation is reduced secretion of the growth hormone **(WHO 1996)**. Complex poultry fodder mixes are recommended to include Se supplement of 0.5 mg/kg of the fodder mix. Higher Se levels in the rations can negatively affect animal health.

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