Selenium in poultry nutrition: a review

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ABSTRACT: Selenium has been known for two centuries and its biological activities have been studied for nearly a hundred years, however the problem of Se deficit has still been persisting both in humans and animals. The cause of Se deficit in animals may be low Se level in soil. This mainly applies to cattle and sheep with their direct link to soil via roughage. The risk of Se deficit in pigs and poultry is lower due to lower dependence on soil Se level in the region and Se fortification in feed mixes. 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 (the "functional foods"), is another area to which extensive attention has recently been paid.

Keywords: fatty acid; antioxidant; immunity; meat; egg; functional food

INTRODUCTION

Selenium was discovered in 1817 by J.J. Berzelius and primary interest in the element was shown by various branches of industry (glassmaking, pottery, rubber, steel, and electronic industries). Only around 1930 studies of selenosis evoked interest in biological activity of Se, culminating in 1950s by studies of the origin of liver necrosis in rats, preventive action against exudative haemorrhagic diathesis and muscle dystrophy (Muth et al. 1958), and studies of the relationships between vitamin E and Se.

Selenium may be present in inorganic or organic form in the diet. The main dietary factors affecting availability of Se include methionine, thiols, heavy metals, and vitamin C (Fairweather-Tait and Hurrell 1996). Se resorption from the gastrointestinal tract, its retention and metabolism in the body all depend on the quantity of Se intake and its chemical form. The highest resorption rate has been reported in the duodenum (Wright and Bell 1966). Effectiveness of Se absorption is relatively high, depending on its dietary form, higher absorption being documented for the organic forms (Robinson and Thomson 1983). For example, Se-methionine (Se-Met) in comparison to the inorganic form, is absorbed more quickly in the small intestine. It is resorbed independently of its levels in the organism and excreted mainly through the kidneys. The substance is not stored in the liver; in the case of insufficient intake its serum level decreases very quickly. The resorbed Se is transported by the bloodstream bound to plasmatic proteins and incorporated to all tissues (Cousins and Cairney 1961). Most of Se deposited in the tissues is quite labile.

Intestinal resorption of Se is higher in monogastric animals than in ruminants. The excreted quantities depend on the amount of Se intake, type of the Se compound, ration composition, and animal type. Se is excreted through urine, droppings, and expired air. Se expiration is an important detoxication route in the case of its high intake in the diet. Excretion of Se administered *per os* is higher in

Supported by the Ministry of Education, Youth and Sports of the Czech Republic (Project No. MSM 6215712402).

the faeces than in the urine in ruminants and the ration is opposite in monogastric animals.

Se is a trace element performing important biological functions in many organisms including humans. It usually affects organisms in a strictly dosage dependent manner being essential at low and toxic at higher concentrations (Umysova et al. 2009). An extensive study on Se in poultry breeder nutrition published Surai and Fisinin (2014).

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 synthesize it (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).

Effect of chelated Se dietary supplementation on broiler chicken meat quality was studied by De Almeida et al. (2012). Chelated Se in the feed improved the meat quality by reducing the lipid oxidation and cooking loss, however it did not increase the GSH-Px activity.

Nano-selenium. Products of nanotechnology have begun to be applied in the area of nutritional supplements and have become largely available and usable now. A good example may be nano-elements, including nano-selenium (nano-Se), with noted significant increase of chemical reactivity. The consequences include changed efficiency as well as potential toxicity of the elements. Effects of nano-Se on yield, meat quality, immune functions, oxidization resistance, and Se levels in tissues of broilers were studied by Cai et al. (2012), who reported significant effects on GSH-Px activity, free radical inhibition, and serum levels of IgM. Yield indicators were unaffected.

Biological effects of nano red elemental selenium (nano-Se) were studied by Zhang et al. (2001). Nano-Se has a 7-fold lower acute toxicity than sodium selenite in mice. In Se-deficient rat, both nano-Se and selenite can increase tissue Se and GSH-Px activity. Nano-Se and selenite are similarly cell growth inhibited and stimulate synthesis of GSH-Px, phospholipid hydroperoxide glutathione peroxidase, and thioredoxin reductase. Nano-Se shows less pro-oxidative effects than selenite, as measured by cell growth. These results demonstrate that nano-Se has a similar bioavailability in the rat and antioxidant effects on cells.

Se fulfils a number of significant functions by means of specific selenium enzymes, including antioxidant protection of the organism against free radicals, maintenance and strengthening of natural immunity of the organism, support for correct function of the thyroid gland and reproductive organs, and in the case of humans also significant prevention of cardiovascular diseases, breast, lung, prostate, colon, and rectum carcinomas and maintenance of mental health.

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; Rama Rao et al. 2013 a.o.). 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 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 colour 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 a.o.). Further studies focus on the effects of Se on egg quality (Attia et al. 2010; Skrivan et al. 2013).

Quality and stability of chicken meat. 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 (Na_2SeO_3), organic Se (Se-enriched yeast) increased meat red colour 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). Eggs laid by hens contained 11–19 μg of Se, with more Se in the yolk. If a high Se intake in fodder is achieved, Se levels in eggs increase and Se distribution between yolk and white changes in favour of the egg white. This finding has led to utilization of eggs as a source of Se. Selenium-enriched organic eggs represent a modern "functional organic food" containing Se in a biologically available form.

Functional foods. Sufficient and natural supply of essential nutrients in a suitable and available form can be achieved by consumption of "functional organic food". This mainly means food of animal origin (meat, eggs, milk) when the animals are kept on a specially adapted diet enriched with substances whose levels in standard food are insufficient. These modern "functional organic foods" also include selenium organic eggs. These eggs contain super-standard levels of Se in the form of the essential amino-acid Se-Met. The Se level in a standard egg is 11 µg, while the selenium-enriched organic egg contains 32.6 µg of Se. Consumption of two selenium-enriched organic eggs a day covers over 70% of the Se daily dose recommended to humans.

Fish and mushroom, although containing high levels of Se, are known for relatively low bioavailability of their Se, while high bioavailability of Se is reported for meat, wheat, and selenium yeast (Levander et al. 1983; Van der Torre et al. 1991).

Selenium and antioxidant stability of chicken meat

The antioxidant effect of Se on the stability of broiler chicken meat has been documented by a number of authors (Dlouha et al. 2008; Skrivan et al. 2008; Wang et al. 2011c; Liao et al. 2012; Yang et al. 2012; Rama Rao et al. 2013 a.o.).

The inclusion of Se-Chlorella in the diet enhanced the oxidative stability of meat in broilers expressed as reduced malondialdehyde values in breast meat after a 0-, 3-, and 5-day refrigeration at 3–5°C (Dlouha et al. 2008). Skrivan et al. (2008) confirmed these findings in a similar study.

Comparisons of effects of various forms of Se in the diet on growth, meat quality, Se storage, and antioxidant properties in broilers were performed by Wang et al. (2011b). The addition of L-Se-Met and D-Se-Met increased Se concentration in serum and different organs studied of broilers in comparison with broilers fed sodium selenite (SS) diet. Therefore, dietary L-Se-Met and D-Se-Met supplementation could improve antioxidant capability and Se deposition in serum and tissues and reduce drip loss of breast muscle in broilers compared with SS. Besides, L-Se-Met is more effective than D-Se-Met in improving antioxidant status in broilers. Yang et al. (2012) confirmed that the effects of organic Se on enhancing body oxidation resistance were superior to those of inorganic Se.

The antioxidant status of 1-day-old chicks was greatly improved by maternal Se-Met intake in comparison with maternal sodium selenite intake and was evidenced by the increased GSH-Px activity in breast muscle, superoxide dismutase activity in breast muscle and kidney, glutathione concentration in kidney, total antioxidant capability in breast muscle and liver, and decreased malondialdehyde concentration in liver and pancreas of 1-day-old chicks (Wang et al. 2011a).

Information on the combined effect of dietary vitamin C and Se on the composition and oxidative stability of meat of broilers is mentioned by Skrivan et al. (2012). Male broiler chickens were fed a maize-wheat-soya diet supplemented with vitamin C at 280 and 560 mg/kg of diet, and Se (sodium selenite or selenized yeast) at 0.3 mg/kg for 5 weeks. In the meat of broilers fed these diets, vitamin C decreased the lipid oxidation of meat that had been stored for 5 days. No sparing effect of vitamin C was apparent on the amount of vitamin E in the meat. Selenized yeast was more effective in the enrichment of meat with Se than Se alone. Both Se sources increased the activity of GSH-Px and the oxidative stability of the meat.

The effects of sodium selenite (SS) and selenium yeast (SY) alone and in combination (MS) on the Se content, antioxidant enzyme activities (AEA), total antioxidant capacity (TAC), and oxidative stability of chicken breast meat were investigated (Ahmad et al. 2012). The results showed that the highest GSH-Px activity was found in the SS-supplemented chicken breast meat; however, SY and MS treatments significantly increased the Se content and the activities of catalase (CAT), total superoxide dismutase (T-SOD), and TAC, but decreased the malondialdehyde content at 42 days of age. Twelve days of storage at 4°C decreased the activity of GSH-Px, but CAT, T-SOD, and TAC remained stable. SY decreased the lipid oxidation more effectively in chicken breast meat. It was concluded that SY and MS are more effective than SS in increasing the AEA, TAC, and oxidative stability of chicken breast meat.

Selenium and activity of glutathione-peroxidase

Glutathione peroxidase is an enzyme transforming the toxic and carcinogenic hydrogen peroxide to harmless water and oxygen. Its activation requires small amounts of Se (selenocysteine), probably substituting sulphur in the glutathione molecule and causing development of modified enzyme GPx4. The basic function of GSH-Px is elimination of excessive peroxide and hydrogen peroxides of fatty acids resulting from oxidative elimination of lipids (De Almeina et al. 2012). In this it acts in synergy with vitamin E.

Lipid peroxidation in plasma decreased, while activities of GPx and glutathione reductase in plasma increased linearly with Se concentration in a broiler chicken diet (Rama Rao et al. 2013). The selenium source (selenium-enriched yeast and selenium-enriched alga *Chlorella*) level, including sodium selenite, significantly influenced the GSH-Px activity in breast and thigh meat (Heindl et al. 2010).

The activity of GSH-Px in breast meat was significantly higher in all treatments (0.16 U/g in control, 0.30 U/g in sodium selenite, and 0.23 U/g in sodium selenite-enriched alga of the *Chlorella* group). The inclusion of selenite-enriched alga of *Chlorella* in the diet enhanced the oxidative stability of meat expressed as reduced malondialdehyde values in breast meat after 0-, 3-, and 5-day refrigeration at 3–5°C (Dlouha et al. 2008).

The effect of organic and inorganic selenium on growth, meat quality, and antioxidant properties of broiler meat was studied by Yang et al. (2012). Serum GSH-Px activity in the experimental group was by 155.83% higher than that in the control. These results indicate that the effects of organic selenium on enhancing body oxidation resistance were superior to those of inorganic selenium.

The enzyme as such cannot be supplied with food as it is decomposed in the digestive tract. Therefore its concentration in the body is increased by the supply of its coenzyme, tri-peptide of glutathione.

Selenium and immune system

Selenium is essential for the activity of multiple components 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 tumour 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). Se insufficiency also affects humoral immunity resulting in reduced levels of IgG and IgM antibodies.

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 Na_2SeO_3 or Se protein (AMMS Se) in increasing tissue Se retention; however, AMMS Se was more effective than Na_2SeO_3 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 tumour 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).

Selenium and fatty acids in muscle tissue

The effects of Se on fatty acid composition and oxidative stability of lipids in the breast muscle tissue were studied by Pappas et al. (2012). A yeast source was used for adding Se. Addition of supranutritional Se levels to chicken diets led to the production of Se-enriched meat. The levels of long-chain polyunsaturated fatty acids, namely C20:3n-6, C20:4n-6, C20:5n-3, C22:5n-3, and C22:6n-3, increased linearly as the Se inclusion levels in the diets increased. At slaughter, a linear decrease in lipid oxidation was observed with Se addition, possibly attributed to the antioxidant properties of Se. Addition of supranutritional Se to chicken diets, at levels well below those causing toxicity, leads to production of Se-enriched meat, protection of health-promoting long-chain fatty acids like C20:5n-3 and C22:6n-3, and protection of meat quality from oxidation at day 1 after slaughter.

Zdunczyk et al. (2011) studied effects of Se and vitamin E on the profile of fatty acids in breast musculature of broiler chickens. Fat of the breast muscle was demonstrated to contain a relatively high content of PUFA n-3 (4.84–5.25%), including C20:4n-3, C20:5n-3, C22:5n-3, and C22:6n-3 fatty acids originating from fish meal. In turn, no differences were reported in the fatty acid profile of fat of the broiler chickens breast muscle as affected by Se and vitamin E levels in the muscle. Higher proportions of n-3 poly-unsaturated fatty acids and reduction of mono-unsaturated fatty acids in the muscle tissue after supply of the organic form of Se were noted by Kralik et al. (2012, 2013).

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, sub-acute, 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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Received: 2014–09–02
Accepted after corrections: 2014–10–03

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