The effect of dietary selenium sources and levels on performance, selenium content in muscle and glutathione peroxidase activity in broiler chickens

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ABSTRACT: The study examined the effect of dietary supplements of sodium selenite (SS), selenium-enriched yeast (Sel-Plex®, SP) and selenium-enriched alga Chlorella (SCH) on growth traits, carcass analysis, selenium content in breast meat, glutathione peroxidase (GSH-Px) activity in breast and thigh meat and liver of chickens. The experiment was realized with seven hundred thirty-five cockerels Ross 308 randomly divided into 7 dietary treatments with 3 replications in each treatment. Chickens were fed a diet supplemented with 0 (control), 0.15 or 0.30 mg of selenium/kg in the form of sodium selenite (SS), Sel-Plex® (SP) and selenium-enriched alga Chlorella (SCH). Selenium addition influenced body weight at 21 (P ≤ 0.001) and 35 (P ≤ 0.05) days of age. Significantly higher body weight at 35 days of age was determined in chickens receiving 0.15 mg of selenium from SP (2 122 g) and 0.3 mg of selenium from SCH (2 116 g) contrary to dietary treatment with a lower level of selenium from SCH (2 010 g) per kg of feed. The selenium content in breast muscle was increased (P ≤ 0.001) by both the lower and higher selenium concentration in the form of SP (0.6 and 0.85 mg/kg dry matter) and SCH (0.6 and 0.82 mg/kg dry matter) in comparison with the control (0.31 mg/kg dry matter). A significant increase (P ≤ 0.001) was ascertained even in SS treatments, but no significant differences were found between both levels. The selenium source and level, including SS, significantly (P ≤ 0.001) influenced the GSH-Px activity in breast and thigh meat.

Keywords: selenium source; performance; GSH-Px activity; broiler cockerels

Selenium (together with vitamin E) is one of the basic essential nutritional elements whose function consists in the protection of cells and tissues from oxidation damage (Schwarz and Foltz, 1957). Selenium has a specific anticarcinogenic effect (Schrauzer, 2003) and influences the parameters of immunity as a component of numerous selenoproteins and enzymes. It is important for the brain and thyroid function. Its main physiological role is mediated by the glutathione peroxidase group (GSH-Px), which has selenium as an integral part (Mills, 1957; Flohe et al., 1973; Rotruck et al., 1973). The basic function of GSH-Px is the removal of hydrogen peroxide (H₂O₂) excess from the cell cytoplasm (Burk, 1997). Schwarz and Foltz (1957) reported that selenium contained in yeast could protect geese against he-
patic necrosis and broiler chickens against exuda
diathesis.

The acceptable amount of selenium in diet for 
poultry in the European Union, including the Czech 
Republic, is 0.5 mg/kg (EU Directive, 2004).

The addition of selenium from selenomethionine 
to feed mixture increased body weight in chickens 
(Skřivan et al., 2008a). Dlouhá et al. (2008) also 
recorded higher body weight after selenium sup-
plementation in organic form. Conversely, Niu 
et al. (2009) found an insignificant effect of sele-
nium on body weight, while feed conversion was 
improved at a concentration of selenium supple-
ment 0.2 mg/kg. Peric et al. (2007) or Yoon et al. 
(2007) obtained similar results of an insignificant 
increase in growth.

The study of dietary sodium selenite or selenium-
enriched yeast supplement showed that the organic 
form of selenium was more efficiently stored in 
chicken breast meat compared to the inorganic 
form (Kuricova et al., 2003; Choc et al., 2004; 
Payne and Southern, 2005). Accordingly, Dlouhá 
et al. (2008) or Skřivan et al. (2008a) confirmed that 
organic sources of selenium increased its content 
in breast meat. The organic form of selenium is de-
posited to a greater extent than the inorganic form. 
Previous studies (Skřivan et al., 2006; Ševčíková et 
al., 2006; Dlouhá et al., 2008) showed the higher 
utilization of selenium-enriched alga *Chlorella* in 
laying hens or broiler chickens compared with so-
dium selenite.

It is clear from the literature that each source 
of selenium is utilizable in a different way. The 
question is whether different levels of different 
resources will function similarly.

The aim of the experiment was to compare the 
effect of selenium-enriched alga *Chlorella* and so-
dium selenite supplement at various concentrations 
on growth, carcass analysis, selenium content in 
breast meat and GSH-Px activity in breast meat, 
thigh meat and liver of chickens.

**MATERIAL AND METHODS**

Seven hundred thirty-five 0-day-old cockerels 
Ross 308 were randomly assigned to 7 dietary 
treatments containing 105 chicks. Each dietary 
treatment was replicated three times (35 chickens 
per pen). The basal diet composition fed as con-
control treatment is shown in Table 1. Other dietary 
treatments were supplemented with 0.15 mg and 
0.30 mg of selenium, respectively, in the form of 
sodium selenite (SS; Na₂SeO₃), Sel-Plex™ (SP) and 
selenium-enriched alga *Chlorella* (SCH) per kg of 
feed. Maize-wheat-soybean granulated basal diet 
contained 22.67% of crude protein, 12.87 MJ/kg of 
MEₙ and 50 mg/kg of vitamin E. Feed and water 
were provided *ad libitum*. Broiler chickens were 
oused in pens (1.98 m × 0.9 m) on wooden shav-
ings with 24-h lighting schedule. Body weight at 0, 
21st and 35th day by individual weighing, feed con-

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>(g/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>309</td>
</tr>
<tr>
<td>Wheat</td>
<td>284.5</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>300</td>
</tr>
<tr>
<td>Fish meal</td>
<td>28.5</td>
</tr>
<tr>
<td>Rapeseed oil</td>
<td>41.2</td>
</tr>
<tr>
<td>Limestone</td>
<td>12</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>12</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>2.8</td>
</tr>
<tr>
<td>Vitamin/mineral premix</td>
<td>10</td>
</tr>
</tbody>
</table>

**Analysed chemical composition**

| Dry matter | 890.1 |
| Crude protein | 226.7 |
| Fat         | 59.9  |
| Crude fibre | 24.1  |
| Calcium     | 10.2  |
| Total phosphorus | 6.9 |
| Selenium    | 79.10⁶ |
| MEₙ by calculation (MJ/kg) | 12.87 |

*a*experimental diets were supplemented with 0.15 or 0.3 mg 
of selenium per kg

*b*the vitamin/mineral premix provided per kg of diet: retin-
ynl acetate 4.5 mg; cholecalciferol 0.15 mg; α-tocopheryl 
acetate 50 mg; menadione 4 mg; thiamine 6 mg; riboflavin 
8 mg; pyridoxine 5 mg; cyanocobalamin 0.02 mg; niacina-
mide 60 mg; calcium pantothenate 18 mg; biotin 0.2 mg; 
folic acid 2 mg; choline chloride 300 mg; betaine 100 mg; 
L-lysine 1.6 g; DL-methionine 1.8 g; cobalt 0.4 mg; copper 
20 mg; iron 60 mg; iodine 1 mg; manganese 120 mg; zinc 
100 mg; molybdenum 1 mg
Carcass analysis of broiler chickens was performed on eight chickens from each dietary treatment representing the average live weight. The body weight of chickens was determined at 21 and 35 days of age. The dietary selenium supplement significantly influenced body weight at 21 (P ≤ 0.001) and 35 (P ≤ 0.05) days of age (Table 2). The highest values of body weight were reached at 21 days of age in chickens fed 0.3 mg/kg of SS (1 050 g) and at 35 days in dietary treatments with 0.15 mg/kg of SP (2 122 g) and 0.3 mg/kg of SCH (2 116 g). The lowest body weight at 21 days of age was determined in chicks receiving 0.15 mg/kg of SP (943 g) and at 35 days in broiler chickens with 0.15 mg/kg of SCH in feed mixture. No significant differences among dietary treatments were determined in feed conversion and mortality. Mortality was under 5% in all dietary treatments.

The selenium supplement significantly influenced the selenium content in the breast meat of broiler chickens (Table 4). These forms of selenium achieve higher values at a concentration of 0.3 mg/kg in mixture (0.85, 0.82 and 0.42 mg Se/kg dry matter, respectively), but lower values were recorded in the control treatment (0.31 mg Se/kg dry matter). No differences in selenium content in breast meat were found when using both levels of SS. Breast and thigh meat GSH-Px activity in experimental dietary treatments was significantly (P ≤ 0.001) different from the control. Higher GSH-Px activity was registered in the case of 0.3 mg/kg of SCH (0.31 U/g for breast and 0.42 U/g for thigh meat). The GSH-Px activity in liver was not significantly influenced either by selenium source or by selenium level. However, a higher value was determined in broilers receiving 0.15 mg of SP (2.39 U/g).

**Characterization of Sel-Plex® 2000**

<table>
<thead>
<tr>
<th>Product description</th>
<th>Selenium content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selenium-enriched yeast species <em>Saccharomyces cerevisiae</em> CNCM I-3060 (No. 3b8.10)</td>
<td>At least 2 000 mg Se/kg</td>
</tr>
</tbody>
</table>

**RESULTS**

The selenium supplement significantly influenced body weight at 21 (P ≤ 0.001) and 35 (P ≤ 0.05) days of age (Table 2). The highest values of body weight were reached at 21 days of age in chickens fed 0.3 mg/kg of SS (1 050 g) and at 35 days in dietary treatments with 0.15 mg/kg of SP (2 122 g) and 0.3 mg/kg of SCH (2 116 g). The lowest body weight at 21 days of age was determined in chicks receiving 0.15 mg/kg of SP (943 g) and at 35 days in broiler chickens with 0.15 mg/kg of SCH in feed mixture. No significant differences among dietary treatments were determined in feed conversion and mortality. Mortality was under 5% in all dietary treatments.

As shown in Table 3, the dietary selenium supplement did not influence the characteristics of carcass analysis such as carcass weight, breast meat, thigh meat, heart, gizzard and abdominal fat share and dressing percentage. However, significantly (P ≤ 0.05) higher liver weight was determined in chickens from dietary treatment with 0.3 mg/kg of SS (3.8%) in comparison with SCH at both selenium levels (3.1 and 3.0%).

Selenium supplements in the form of Sel-Plex®, selenium-enriched alga *Chlorella* and sodium selenite significantly (P ≤ 0.001) influenced selenium content in the breast meat of broiler chickens (Table 4). These forms of selenium achieve higher values at a concentration of 0.3 mg/kg in mixture (0.85, 0.82 and 0.42 mg Se/kg dry matter, respectively), but lower values were recorded in the control treatment (0.31 mg Se/kg dry matter). No differences in selenium content in breast meat were found when using both levels of SS. Breast and thigh meat GSH-Px activity in experimental dietary treatments was significantly (P ≤ 0.001) different from the control. Higher GSH-Px activity was registered in the case of 0.3 mg/kg of SCH (0.31 U/g for breast and 0.42 U/g for thigh meat). The GSH-Px activity in liver was not significantly influenced either by selenium source or by selenium level. However, a higher value was determined in broilers receiving 0.15 mg of SP (2.39 U/g).
Table 2. Effect of selenium source on the growth performance in broiler chickens

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Dietary selenium supplementation and the source</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.0 mg control</td>
<td>0.15 mg SP</td>
</tr>
<tr>
<td>BW (0 day; g)</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>BW (21\textsuperscript{st} day; g)</td>
<td>1 013\textsuperscript{ab}</td>
<td>946\textsuperscript{b}</td>
</tr>
<tr>
<td>BW (35\textsuperscript{th} day; g)</td>
<td>2 111\textsuperscript{ab}</td>
<td>2 122\textsuperscript{a}</td>
</tr>
<tr>
<td>F:G (35\textsuperscript{th} day; g:g)</td>
<td>1.85</td>
<td>1.88</td>
</tr>
<tr>
<td>Mortality (%)</td>
<td>4.76</td>
<td>2.86</td>
</tr>
</tbody>
</table>

\textsuperscript{a,b} means with different superscripts differ significantly, determined by Scheffe’s test.

\textsuperscript{**}P \leq 0.001; \textsuperscript{*}P \leq 0.05; NS = not significant

SP = Sel-Plex; SCH = selenium-enriched \textit{Chlorella}; SS = sodium selenite; BW = body weight; F:G = feedgain

Table 3. Effect of dietary selenium source on some indicators of carcass composition and dressing percentage

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Dietary selenium supplementation and the source\textsuperscript{1}</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.0 mg control</td>
<td>0.15 mg SP</td>
</tr>
<tr>
<td>Carcass weight (g)</td>
<td>1 420</td>
<td>1 442</td>
</tr>
<tr>
<td>Breast (%)</td>
<td>24.8</td>
<td>25.7</td>
</tr>
<tr>
<td>Thigh (%)</td>
<td>23.6</td>
<td>22.7</td>
</tr>
<tr>
<td>Liver (%)</td>
<td>3.3\textsuperscript{ab}</td>
<td>3.2\textsuperscript{ab}</td>
</tr>
<tr>
<td>Heart (%)</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Gizzard (%)</td>
<td>1.7</td>
<td>1.8</td>
</tr>
<tr>
<td>Abdominal fat (%)</td>
<td>1.7</td>
<td>1.9</td>
</tr>
<tr>
<td>Dressing percentage (%)</td>
<td>73.7</td>
<td>72.8</td>
</tr>
</tbody>
</table>

\textsuperscript{a,b} means with different superscripts differ significantly, determined by Scheffe’s test.

\textsuperscript{*}P \leq 0.05; NS = not significant

SP = Sel-Plex; SCH = selenium-enriched \textit{Chlorella}; SS = sodium selenite

\textsuperscript{1}n = 8 per treatment
Table 4. Effect of dietary selenium source on selenium content (mg/kg DM) in breast meat and activity of glutathione peroxidase (U/g)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Dietary selenium supplementation and the source</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.0 mg control</td>
<td></td>
</tr>
<tr>
<td>Me Se in breast meat</td>
<td>0.31d</td>
<td></td>
</tr>
<tr>
<td>GSH-Px in breast meat</td>
<td>0.16d</td>
<td>0.6b</td>
</tr>
<tr>
<td>GSH-Px in high meat</td>
<td>0.31e</td>
<td>0.34b</td>
</tr>
<tr>
<td>GSH-Px in liver</td>
<td>0.62</td>
<td>2.39</td>
</tr>
</tbody>
</table>

= means with different superscripts differ significantly, determined by Scheffe’s test
**= P < 0.001; NS = not significant

SP = Sel-Plex; SCH = selenium-enriched Chlorella; SS = sodium selenite

DISCUSSION

Similarly to this experiment, many authors described the influence of selenium supplement on body weight. Škrivan et al. (2008a) found out the positive effect of organic and inorganic selenium form on an increase in body weight and Ševčíková et al. (2006) or Dlouhá et al. (2008) also reported the positive effect of organic selenium source. But other authors (Choct et al., 2004; Yoon et al., 2007) did not observe any significant differences in the final body weight of chickens after addition of selenium in organic form. The same results were obtained in chickens receiving an inorganic selenium source. Miller et al. (1972) did not reveal any differences in the body weight of chickens fed various concentrations (0–0.5 mg/kg) of selenium from SS or selenomethionine. Similar findings were reported by Yoon et al. (2007) using different levels (0–0.3 mg/kg). The insignificant effect of selenium supplementation on carcass weight in this experiment is not in accordance with some studies (Choct et al., 2004; Payne and Southern, 2005) which found a higher carcass share in chickens receiving the organic form of selenium. The present study showed the insignificant effect of organic and inorganic selenium on an increase in the breast meat share. On the other hand, Choct et al. (2004), Payne and Southern (2005) or Ševčíková et al. (2006) determined higher breast meat weight in broiler chickens fed the organic form of selenium. Similarly, Ševčíková et al. (2006) did not ascertain any significant effect of organic source of selenium on an increase in thigh meat weight.

The increase in selenium concentration in breast meat due to dietary selenium supplementation is in agreement with findings presented by Ševčíková et al. (2006), Dlouhá et al. (2008) and Škrivan et al. (2008a). Little information about the effect of SCH and SP on selenium content in breast meat and GSH-Px activity was published. Inconsistent results were also obtained for selenium deposition in poultry meat after SS addition. Our results correspond with the findings of some authors (Cantor et al., 1982; Payne and Southern, 2005; Ševčíková et al., 2006; Dlouhá et al., 2008; Škrivan et al., 2008a,b), who showed an increase in selenium in the breast meat of poultry fed selenomethionine, SCH and selenium-enriched yeast. The published results are ambiguous in the case of SS. Shan and Davis (1994) reported an increase in selenium concentration in the breast meat of chickens that
received SS. Whereas, Cantor et al. (1982), Payne and Southern (2005) or Dlouhá et al. (2008) ascertained no significant differences in breast muscle selenium content after SS addition. In our study, selenium content in breast meat increased after SS addition, but no significant differences were found between the levels.

Recent research has shown that less selenium is maintained in chicken tissue when the inorganic form of selenium is used compared to the organic selenium source. Mahan and Parrett (1996) and Dlouhá et al. (2008) found that SS was retained at a lower concentration in muscle tissue, was absorbed less efficiently and was excreted at a higher rate than the organic selenium source.

The GSH-Px activity was balanced in all experimental dietary treatments without depending on the concentration and form of selenium, but an insignificantly higher enzyme activity in breast and thigh muscle was after addition of 0.3 mg of selenium from SCH. It was probably caused by differences in metabolic pathways (Forstrom et al., 1978). The observed differences in GSH-Px activity in our study are in agreement with results published by other authors (Cantor et al., 1982; Hassan et al., 1988; Spears et al., 2003; Dlouhá et al., 2008), who found that selenium supplementation increased GSH-Px activity. In addition, GSH-Px activity was significantly higher in the case of using SS in comparison with SCH. In this study, the effect of dietary selenium supplement was not recorded in GSH-Px activity in liver. Whereas, Pappas et al. (2005) indicated that selenium addition contributed to an increase of GSH-Px activity in liver, blood and breast muscle. Selenium, regardless of its form, must be converted to selenocysteine before its incorporation into the enzyme pGPX3. Sunde and Hoekstra (1980) found that inorganic SS was efficiently metabolizable into selenocysteine, while Henry and Ammerman (1995) determined that selenomethionine has slower transfer efficiency into selenocysteine.

This study adds published data on selenium enrichment of animal products. The results confirmed the identical effect of SP and SCH in broiler chickens. The new benefit is the finding that addition of sodium selenite at both levels of 0.15 and 0.30 mg Se/kg in diets may have the same effect. Furthermore, the organic selenium supplement (SP, SCH) was effectively absorbed into muscles of chickens contrary to SS. Selenium-enriched alga Chlorella could be applied in commercially produced premixes as a potential source of organic selenium form.

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