EFFECT OF DIFFERENT DIETARY SELENIUM SOURCES SUPPLEMENTATION ON NUTRIENT DIGESTIBILITY, PRODUCTIVE PERFORMANCE AND SOME SERUM BIOCHEMICAL INDICES IN SHEEP

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SUMMARY

A total number of 32 of Ossimi lambs averaged 29.25 ± 2.02 kg and 4 months old were used in this experiment to compare the effects of dietary supplementation of inorganic selenium (sodium selenite), organic selenium (Se-yeast) and Nano-Se particles on nutrients digestibility, nutritive value, productive performance and serum biochemical indices of lambs. The animals were allocated into four equal groups (8 lambs each). The lambs of control group were fed on basal diet containing 0.17 mg Se/kg dry matter (DM). The treated lamb groups fed on the same basal diet, in which Se at 0.30 mg/kg DM was provided as sodium selenite (SS), selenium yeast (SY) and Nano-Se particles (NS). The results showed that digestibility of DM was higher (P<0.05) for lambs fed SS, SY and NS than those fed control. Digestibility of OM, CP, CF, EE, NFE and the values of digestible crude protein (DCP) and total digestible nutrients (TDN) were increased (P<0.05) for lambs fed SY and NS compared with those fed SS or control. Averages of final body weight (FBW) were increased (P<0.05) for lambs fed SY and NS compared with those fed SS and control. Average of FBW was greater (P<0.05) for lambs fed NS than those fed SY. The averages of daily gain (ADG) were increased (P<0.05) for lambs fed SS, SY and NS vs. those fed control with significant (P<0.05) differences among treatments. No significant differences were detected in averages of feed intakes of Alfalfa, DM and total DM (TDM) for lambs fed SS, SY and NS vs. control. While, the intakes of DCP and TDN were greater (P<0.05) for lambs fed SS, SY and NS vs. those fed control with significant (P<0.05) differences among treatments. The averages of feed conversion (FC) of DM (FC-DM), DCP (FC-DCP) and TDN (FC-TDN) were improved (P<0.05) for lambs fed SS, SY and NS vs. those fed control. The highest values of productive performance parameters (FBW, ADG, DCPI, TDNI, FC-DCP and FC-TDN) were noticed for lambs fed NS followed by those fed SY and then SS and control. Lambs fed SY and NS had higher (P<0.05) values of serum total protein and globulin than those fed SS or control. Also, there was an increase (P<0.05) in serum glucose concentrations for lambs fed diets SS, SY and NS vs. control, with higher levels (P<0.05) in NS than in SS and SY. No significant differences were noticed in serum concentrations of albumin, cholesterol, alanine transaminase (ALT) and aspartate transaminase (AST) enzyme activities. Serum total antioxidant capacity (TAC) concentrations, glutathione peroxidase (GSH-Px) activity and testosterone levels were increased (P<0.05) for lambs fed SS, SY and NS vs. control. Higher (P<0.05) levels of TAC, GSH-Px and testosterone levels were observed for lambs fed NS than those fed SS and SY. It could be concluded that dietary supplementation of Nano-Se was more effective than sodium selenite and Se-yeast to improve nutrients digestibility, feeding values, growth performance, some serum metabolic indices, antioxidant status and reproductive efficiency of male lambs.

Keywords: Selenium sources, nutrients digestibility, productive performance, serum biochemical indices, sheep.

INTRODUCTION

Selenium (Se), as a trace mineral, has several biological functions in animals. As antioxidant, Se plays essential roles in animal nutrition, immunity, reproduction, protection of DNA, proteins from oxidation and thyroid hormone synthesis and metabolism (Lu and Holmgren, 2009; Yatoo et al., 2013). The enzyme I iodothyronine-5'-deiodinase is a selenoenzyme that required to convert thyroxin into the active T\(_1\) hormone. Furthermore, Se is an integral part of the enzyme glutathione peroxidase (GSH-Px) which is important for neutralizing free radicals or oxidants (Huang et al., 2012). In sheep, deficiency of Se has
been linked with a number of diseases mainly include white muscle disease and suppression of immune status (Rock et al., 2001). So, adequate supplementation of Se is of great important to avoid the risk of immune-suppression, liver necrosis, cardiovascular disease and myopathy (Hartikainen, 2005). Thus, animal health and performance negatively influenced by Se deficiency.

Dietary supplementation of Se can be provided using inorganic or organic sources. The supplemental inorganic forms of Se are commonly sodium selenite or selenate, while the organic are Se-enriched yeasts. Because of different metabolism, it has been noticed that inorganic forms of Se have lower bioavailability than the organic one (Weiss, 2005). In other words, organic Se has been shown to be more absorbed and utilized in ruminants when compared to inorganic sources (Gunter et al. 2003; Guyot et al., 2007). In beef heifers, switching from inorganic to organic Se improved meat quality and muscle Se content, confirming the greater bioavailability of the organic compared with the inorganic form (Sgoifo Rossi et al., 2015). The low inorganic Se absorption in ruminants could be resulted from reduction of dietary selenium (selenite and selenate) to insoluble forms such as elemental Se or selenides in the rumen environment (Mehdi et al. 2013).

The nanotechnology development holds unique properties for Se Nano-particles (Nano-Se), because of its novel characteristics such as high surface activity, great specific surface area, a lot of surface active centers, strong adsorbing ability and high catalytic efficiency (Skalickova et al., 2016). Nano-Se has been efficiently function on animal growth, reproduction and immunity systems (Shi et al., 2009). In sheep, Nano-Se had improved ruminal fermentation, nutrient digestibility (Shi et al., 2011a) and feed intake (Wang, 2011). In addition, some reports on rats and mice demonstrated that Nano-Se had higher efficiency than sodium selenite and other Se sources in up-regulating selenoenzymes, exhibiting lower toxicity (Zhang et al., 2001; Wang et al., 2007; Zhang et al., 2008). Subsequent studies also pointed out that Nano-Se has more beneficial effects to improve activity of glutathione peroxidase, blood biochemical indices with lower toxicity comparing with organic or inorganic Se sources (Yaghmaie et al., 2017).

The novel effects of supplemental Nano-Se on animal metabolism and related physiological responses, especially when comparing with selenium inorganic and organic sources, have not been fully clarified. Therefore, the presented study aimed to compare the effects of dietary supplementation of inorganic Se (sodium selenite), organic Se (Se-yeast) and Nano-Se on nutrients digestibility, nutritive value, productive performance and some serum biochemical indices of Ossimi lambs.

MATERIALS AND METHODS

Experimental design:

This study used 32 of Ossimi lambs (averaged 29.25 ± 2.02 kg and 4 months old). The experiment was carried out at the Farm of Animal Production Department, Faculty of Agriculture, Minia University during the months from January to April, 2016.

Animals were fed on concentrate feed mixture (CFM) to cover their nutrients requirements according to their live body weight (NRC, 2007). The animals were randomly divided into four equal groups (8 lambs each) of similar initial body weights. The lambs of control group were fed on basal diet containing 0.17 mg Se/kg DM. The treated lambs fed on the same basal diet, in which selenium at 0.3 mg/kg DM was provided as sodium selenite (SS), selenium yeast (SY) and Nano-Se particles (NS).

The animals were housed inside window stables for feeding lot groups. The experimental animals were fed on concentrate feed mixture, contained 48 % wheat bran, 17 % yellow corn, 13 % soybean meal,10.8 % sunflower meal, 4.2 % molasses, 4 % rice hulls, 2 % calcium carbonate and 1 % sodium chloride to cover their requirements according to their live body weight (NRC, 2007). In this study, alfalfa as roughage source was offered ad libitum. The calculated concentration of Se in the CFM was 0.17 mg/kg DM. The requirements of sheep for Se are between 0.1-0.3 ppm (NRC, 2007). Feed were offered twice a day at 8 am and 2 pm and drinking water were available along the experiment. The measurements of lambs’ body weights were recorded at starting of the experiment and biweekly thereafter, while feed intakes recorded daily. Averages of daily gain and feed conversion rates of lambs were calculated. All the parameters were recorded at the morning before animals access to feed or water.

Dietary Sampling and laboratory analysis:

Dietary samples were collected daily in the last week of each month along the experiment period and a composite sample was performed. A portion of the composite sample was dried at 105 °C in a forced air
oven till constant weight for DM determination. The rest of composite sample was dried at 70 °C for a constant weight, ground and kept in closely tied jars for laboratory analysis. Diets were analyzed for dry matter (DM), organic matter (OM), crude protein (CP), crude fiber (CF), ether extract (EE) and ash according to AOAC (2003). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined according to Goring and Van Soest (1970). Grasp fecal samples were collected before feeding at 7 am and 1 pm for each lamb at last week of each month and mixed together, dried on 70 °C till constant weight and analyzed for DM, OM, CP, CF, NDF, ADF, EE and ash. Total tract digestibility of DM, OM, CP, CF, NDF, ADF, EE and NFE were determined using acid insoluble ash as an internal marker according to Van Keulen and Young (1977). Approximate analysis of concentrate feed mixture (CFM), Alfalfa and total mixed ration (TMR) are presented in Table (1).

Table (1): Approximate analysis of concentrate feed mixture (CFM), Alfalfa and total mixed ration (TMR) fed to lambs (% on DM basis).

<table>
<thead>
<tr>
<th>Item</th>
<th>CFM 1</th>
<th>Alfalfa</th>
<th>TMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM</td>
<td>86.08</td>
<td>94.20</td>
<td>87.30</td>
</tr>
<tr>
<td>OM</td>
<td>95.98</td>
<td>89.58</td>
<td>95.02</td>
</tr>
<tr>
<td>CP</td>
<td>18.93</td>
<td>15.48</td>
<td>18.42</td>
</tr>
<tr>
<td>EE</td>
<td>3.15</td>
<td>0.76</td>
<td>2.79</td>
</tr>
<tr>
<td>CF</td>
<td>10.34</td>
<td>32.95</td>
<td>13.73</td>
</tr>
<tr>
<td>NDF</td>
<td>31.97</td>
<td>53.81</td>
<td>35.24</td>
</tr>
<tr>
<td>ADF</td>
<td>14.70</td>
<td>43.21</td>
<td>18.98</td>
</tr>
<tr>
<td>NFE</td>
<td>63.56</td>
<td>40.39</td>
<td>60.08</td>
</tr>
<tr>
<td>Ash</td>
<td>4.02</td>
<td>10.42</td>
<td>4.98</td>
</tr>
</tbody>
</table>

1 CFM = Concentrate feed mixture contained 48 % wheat bran, 17 % yellow corn, 13 % soybean meal, 10.8 % sunflower meal, 4.2 % molasses, 4 % rice hulls, 2 % calcium carbonate and 1 % sodium chloride.

Serum bio-indices analysis:

Non-heparinized blood samples were collected from the jugular vein of each animal. The samples were left to clot at room temperature for at least 4 h, then the clots were removed and sera were cleared and stored at -20 °C for later assay. Serum glucose, total protein, albumin, cholesterol, alanine transaminase (ALT) and aspartate transaminase (AST) were determined colorimetrically using commercial kits. Serum globulin concentrations were calculated by difference between total protein and albumin concentrations. Serum total antioxidant capacity (TAC) and glutathione peroxidase (GSH-Px) activities were analyzed colorimetrically by STAT-LAB SZSL60-SPECTRUM, using commercial kits. Serum testosterone concentrations were measured by the radioimmunoassay technique using Coat-a-Count 125I commercial kits (DCP, CA 90045-5597, USA). The analyses were performed at Cairo University Research Park (CURP), Faculty of Agriculture, Cairo University.

Statistical analysis:

Data were analyzed by least square means analysis of variance using General Linear Models (GLM) procedure of the statistical analysis system (SAS, 2000). The model used to analyze the different treatments studied for lambs was as follows:

\[ Y_{ij} = \mu + T_i + e_{ij} \]

Where: \( Y_{ij} = \) Observation, \( \mu = \) Overall mean; \( T_i = \) Effect of \( i^{th} \) treatments and \( e_{ij} = \) Experimental error. Duncan’s Multiple Range test was used to detect differences between means of the experimental groups (Duncan, 1955).

RESULTS AND DISCUSSION

Nutrients digestibility:

The data presented in Table (2) showed that digestibility coefficients of DM were higher (P<0.05) for lambs fed SS, SY and NS-supplemented diets than those fed control. Digestibility of DM, OM, CP, EE, CF, NDF and NFE was increased (P<0.05) for lambs fed SY and NS compared with those fed SS or control. There was no significant different in digestibility of ADF due to the experimental dietary
treatments of selenium compared with control. The results of nutritive values indicated that the DCP and TDN values were greater (P<0.05) with feeding SY and NS compared with those fed SS and control.

Table (2): Effects of supplemental Se sources on nutrient digestibility coefficients and nutritive values of experimental treatments (Mean ± SE).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control</th>
<th>SS</th>
<th>SY</th>
<th>NS</th>
<th>± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM (Nutrients digestibility (%))</td>
<td>68.29&lt;sup&gt;d&lt;/sup&gt;</td>
<td>70.12&lt;sup&gt;c&lt;/sup&gt;</td>
<td>72.40&lt;sup&gt;b&lt;/sup&gt;</td>
<td>74.81&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.122</td>
</tr>
<tr>
<td>OM</td>
<td>70.28&lt;sup&gt;c&lt;/sup&gt;</td>
<td>71.10&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>72.82&lt;sup&gt;b&lt;/sup&gt;</td>
<td>74.80&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.538</td>
</tr>
<tr>
<td>CP</td>
<td>62.13&lt;sup&gt;b&lt;/sup&gt;</td>
<td>63.97&lt;sup&gt;b&lt;/sup&gt;</td>
<td>66.36&lt;sup&gt;a&lt;/sup&gt;</td>
<td>68.30&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.686</td>
</tr>
<tr>
<td>EE</td>
<td>55.74&lt;sup&gt;c&lt;/sup&gt;</td>
<td>60.76&lt;sup&gt;b&lt;/sup&gt;</td>
<td>62.31&lt;sup&gt;b&lt;/sup&gt;</td>
<td>65.65&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.775</td>
</tr>
<tr>
<td>CF</td>
<td>59.65&lt;sup&gt;b&lt;/sup&gt;</td>
<td>60.27&lt;sup&gt;b&lt;/sup&gt;</td>
<td>64.44&lt;sup&gt;a&lt;/sup&gt;</td>
<td>66.29&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.778</td>
</tr>
<tr>
<td>ADF</td>
<td>55.67</td>
<td>56.25</td>
<td>57.29</td>
<td>60.61</td>
<td>1.700</td>
</tr>
<tr>
<td>NDF</td>
<td>60.26&lt;sup&gt;b&lt;/sup&gt;</td>
<td>61.82&lt;sup&gt;b&lt;/sup&gt;</td>
<td>63.89&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>65.98&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.190</td>
</tr>
<tr>
<td>NFE</td>
<td>70.80&lt;sup&gt;b&lt;/sup&gt;</td>
<td>71.97&lt;sup&gt;b&lt;/sup&gt;</td>
<td>74.07&lt;sup&gt;a&lt;/sup&gt;</td>
<td>76.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.641</td>
</tr>
<tr>
<td>DCP (Nutritive value (%))</td>
<td>11.44&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.78&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.22&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12.58&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.126</td>
</tr>
<tr>
<td>TDN</td>
<td>65.67&lt;sup&gt;b&lt;/sup&gt;</td>
<td>67.11&lt;sup&gt;b&lt;/sup&gt;</td>
<td>69.48&lt;sup&gt;a&lt;/sup&gt;</td>
<td>71.48&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.731</td>
</tr>
</tbody>
</table>

<sup>abc</sup> and d: Means within the same row having different superscripts significantly different (P<0.05).

SS = Sodium selenite, SY = Selenium yeast, NS = Nano-Selenium.

The present study clearly demonstrated that supplemental SY or NS at 0.3 mg/kg DM were more efficient than SS to improve (P<0.05) nutrients digestibility and the nutritive values (DCP and TDN). In case of supplemental SS at 0.3 mg/kg DM, there was a significant (P<0.05) increase in digestibility of DM and EE with tendency to improve other nutrients digestibility and their nutritive values compared with control. This result could be discussed in the light of the finding that organic or Nano-elemental forms of selenium are absorbed more readily by ruminants than inorganic forms (Xu et al., 2003). These results are mostly consistent with the previous studies dealt with the effects of dietary supplementation of selenium sources on nutrients digestibility. As regard to SS, supplemental selenium at 0.2 mg/kg DM to suckling ewes significantly (P<0.05) improved their nutrient digestibility of DM, OM, EE, CF and NDF and the nutritive values of DCP and TDN, reflecting on increased birth weight and daily gain of their lambs (Ibrahim, 2016). Such improvement in nutrients digestibility was also noticed for OM and NDF in male lambs when high selenium at 0.9 mg/kg DM, as sodium selenite, was supplemented, suggesting that absorption and availability of selenium in the rumen facilitates its use by the ruminal microorganisms (Del Razo-Rodríguez et al., 2013).

In the current study, the finding that supplemental SY was more efficient than SS in enhancing nutrients digestibility and nutritive value could be explained in the light of the view that absorption and bioavailability of selenium is considered one of the most important factors in its utilization because selenium must be absorbed before utilization (Mahima, 2012). At this point, several studies have been compared the bioavailability of dietary supplementation of inorganic vs. organic selenium. They have proved that organic selenium has 120-200 % more bioavailability than sodium selenite in sheep (Hall et al., 2011). In ruminants, the low absorption of inorganic selenium, comparing to organic one, could be attributed to the reductive rumen environment where the microorganisms convert selenium compound to insoluble form impairing its absorption in the intestine (Serra et al., 1994). So, the inorganic selenium becomes less available for absorption than organic selenium. Thus the beneficial effects of organic selenium predominate over the inorganic one in ruminants (Gammelgaard et al., 2012; Mehti et al. 2013). To this point, when Se was supplemented at 0.4 ppm, Se yeast was more effective than sodium selenite to increase (P<0.05) digestibility of DM, OM, CP, NDF and ADF in sheep (Alimohamady et al., 2013). In addition, dietary supplementation of SY at high levels (150 and 300 ppm) was also efficient to enhance digestibility of DM and CP in lactating dairy cows (Wang et al., 2009). In goats, although supplementation with either organic or inorganic Se had no significant effect on nutrients digestibility, however, the dry matter, organic matter and crude protein intake significantly increased with organic Se than inorganic one as reported by Zohreh et al. (2016). They concluded that organic Se seems to be a better choice, considering the nitrogen and energy available for metabolism.

The present study illustrated that dietary supplementation of NS at 0.3 mg/kg DM to lambs significantly improved all their nutrients digestibility and nutritive values of DCP and TDN. This effect of
NS predominates over SS in enhancing all nutrients digestibility and nutritive values. This difference could be ascribed to the different metabolic way between NS and inorganic selenium in the rumen. Supplemental NS was also more potent than SY to improve digestibility of DM, OM and EE. The beneficial effects of NS on animal metabolism and nutrients digestibility could be related to its role in improving rumen fermentation and feed utilization, stimulating rumen microbial activity, digestive microorganisms or enzyme activity (Shi et al., 2011a). Similar results were obtained by Xun et al. (2012) who found that dietary supplementation of NS at high dose (4 g/kg DM) improve (P<0.01) ruminal fermentation and digestibility of OM, CP, EE, NDF and ADF in the total tract in sheep. They also added that feeding supplemental NS could significantly increase growth and activity of celluloytic bacteria compared to SY, and thus improved rumen fermentation. So, these studies, together with the present results, may be signifying different metabolic mechanisms exist between the different Se forms in the rumen.

In the present study, supplemental NS was more effective to increase CP digestibility by 3.5 and 6.9 % than SY and SS, respectively. These results agree with those reported by Xun et al. (2012) on sheep. They found that the digestibility of CP was higher with feeding NS than SY treatment, suggesting that NS supplementation could significantly increase activity of protein-decomposing bacteria and promote proteolytic digestive enzymes activity. The beneficial effect of supplemental NS to increase CP digestibility, shown in the present study, agree also with similar results reported in sheep by Shi et al., (2011a) and in dairy cows by Wang et al. (2009).

On the other hand, some studies did not signify any difference in selenium absorption and metabolism with supplementation of inorganic and organic selenium sources in goats (Palvata et al., 2011). In addition, other study showed no significant effect of organic selenium on all nutrients digestibility’s of cross-bred calves; however the disease occurrence was low in Se supplemented-calves (Vinu et al., 2012).

**Productive performance:**

The data presented in Table (3) showed that the averages of final body weight (FBW) were increased (P<0.05) for lambs fed SY and NS compared with those fed SS or control. Average of FBW was also greater (P<0.05) for lambs fed NS than those fed SY. The averages of FBW were comparable for lambs fed SS and SY. The averages of daily gain (ADG) were increased (P<0.05) for lambs fed SS, SY and NS compared with those fed control. Also, the differences in ADG among selenium source treatments were significant (P<0.05). Data showed no significant differences in averages of feed intakes of alfalfa, DM and TDM for lambs fed SS, SY and NS compared with control. Meanwhile, the intakes of DCP and TDN were greater (P<0.05) for lambs fed SS, SY and NS compared with those fed control with significant (P<0.05) differences among selenium sources treatment. The results also indicated that the averages of feed conversion (FC) of DM (FC-DM), DCP (FC-DCP) and TDN (FC-TDN) were significantly (P<0.05) improved for lambs fed SS, SY and NS compared with those fed control. The highest values of the previous productive performance parameters were noticed for lambs fed NS followed by those fed SY and SS.

The present results indicated that dietary supplemental SS, SY and NS were significantly able to improve FBW and ADG in sheep. Supplemental NS was more potent (P<0.05) to enhance ADG of lambs than SS and SY by 35.6 and 17.5 %, respectively. Also, supplemental SY was effective by 15.4 % than SS treatment. The higher improvement noticed in growth performance for lambs fed SY and NS than those fed SS could be attributed to the significant increase (P<0.05) in their nutrients digestibility and nutritive value, feed intakes and feed conversion, which reflected on their growth performance. The results are consistent with similar findings reported by Shi et al. (2011b) working on growing male goats. They found that FBW was increased (P<0.05) in different selenium sources-supplemented bucks compared with control, and the ADG was greater (P<0.05) with feeding Nano-selenium and selenium yeast than sodium selenite. Kumar et al. (2009) concluded that supplemental organic selenium was more effective than inorganic in improving growth performance in male lambs. In addition, FBW and ADG were significantly (P<0.05) improved for growing rabbits fed organic Se at 0.3 ppm (Ebied et al., 2012). In the same way, ADG was enhanced with supplemental selenium sources in goats (Yue et al., 2009).

However, some studies, showed no effect of selenium sources on ADG in calves (Gunter et al., 2003) and in lambs (Vignola et al., 2009). Also, growth performance was not affected by supplemental organic selenium; but the disease occurrence was low in selenium supplemented-calves (Vinu et al., 2012). In beef heifers, also, supplemental selenium at 0.2 mg/kg DM as sodium selenite or selenium yeast did not affect their final body weight and average daily gain, however switching from inorganic to organic selenium in the last two months of fattening improved some traits of their meat quality (Sgoifo Rossi et
The observed differences in ADG response to selenium sources between studies possibly attributed to the variation in background selenium in feedstuffs, breeds or the environmental conditions.

**Table (3): Effects of supplemental Se sources on productive performance of growing lambs (Mean ± SE).**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Treatment</th>
<th>Control</th>
<th>SS</th>
<th>SY</th>
<th>NS</th>
<th>± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBW (kg)</td>
<td></td>
<td>29.37</td>
<td>29.50</td>
<td>28.75</td>
<td>29.37</td>
<td>2.016</td>
</tr>
<tr>
<td>FBW (kg)</td>
<td></td>
<td>41.57</td>
<td>43.0</td>
<td>44.33</td>
<td>47.67</td>
<td>2.173</td>
</tr>
<tr>
<td>ADG (g/day)</td>
<td></td>
<td>135.56</td>
<td>150.00</td>
<td>173.11</td>
<td>203.33</td>
<td>0.007</td>
</tr>
<tr>
<td>Feed intake (kg / day):</td>
<td></td>
<td>Alfalfa</td>
<td>0.22</td>
<td>0.23</td>
<td>0.23</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DMI</td>
<td>1.23</td>
<td>1.26</td>
<td>1.27</td>
<td>1.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TDNI</td>
<td>1.45</td>
<td>1.49</td>
<td>1.50</td>
<td>1.57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DCPI</td>
<td>0.166</td>
<td>0.176</td>
<td>0.183</td>
<td>0.198</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TDNI</td>
<td>0.953</td>
<td>1.000</td>
<td>1.042</td>
<td>1.122</td>
</tr>
<tr>
<td>Feed conversion (FC, kg feed / kg gain):</td>
<td></td>
<td>FC-DM</td>
<td>10.70</td>
<td>9.93</td>
<td>8.67</td>
<td>7.72</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FC-DCP</td>
<td>1.23</td>
<td>1.17</td>
<td>1.06</td>
<td>0.97</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FC-TDN</td>
<td>7.03</td>
<td>6.67</td>
<td>6.02</td>
<td>5.52</td>
</tr>
</tbody>
</table>

*a, b, c and d*: Means within the same row having different superscripts significantly different (P<0.05).

**SS = Sodium selenite, SY = Selenium yeast, NS = Nano-Selenium.**

**Serum biochemical metabolites:**

As shown in Table (4), there were significant (P<0.05) increase in serum concentrations of total protein (TP) and globulin, but not albumin, for lambs fed SY and NS compared with those fed SS and control. This means that either supplementation with SY or NS was more effective than SS to improve protein synthesis and metabolism. The increase in serum TP could be related with the significant (P<0.05) improvement observed in digestibility of CP, DCPI and nutritive value of DCP for lambs fed SY or NS supplemented diets, reflecting the significant improvement gained in their FBW and ADG. According to Pechova *et al.* (2012), working on goats, supplementation of mothers with selenium both in organic (SY) and inorganic (SS) forms was sufficient to prevent selenium deficiency in kids at the time of weaning. They found similar response of increased (P<0.05) serum TP concentrations for bucks whose mothers supplemented with SY, however, their serum TP levels remains unchanged with supplemental SS.

**Table (4): Effects of supplemental Se sources on biochemical parameters of growing lambs (Mean ± SE).**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Treatment</th>
<th>Control</th>
<th>SS</th>
<th>SY</th>
<th>NS</th>
<th>± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total protein (g/dl)</td>
<td></td>
<td>5.40</td>
<td>5.40</td>
<td>5.83</td>
<td>5.75</td>
<td>0.105</td>
</tr>
<tr>
<td>Albumin (g/dl)</td>
<td></td>
<td>3.70</td>
<td>3.63</td>
<td>3.82</td>
<td>3.63</td>
<td>0.043</td>
</tr>
<tr>
<td>Globulin (g/dl)</td>
<td></td>
<td>1.70</td>
<td>1.77</td>
<td>2.01</td>
<td>2.12</td>
<td>0.085</td>
</tr>
<tr>
<td>Glucose (mg/dl)</td>
<td></td>
<td>59.92</td>
<td>65.34</td>
<td>67.66</td>
<td>72.75</td>
<td>1.454</td>
</tr>
<tr>
<td>Cholesterol (mg/dl)</td>
<td></td>
<td>95.05</td>
<td>96.42</td>
<td>95.79</td>
<td>92.59</td>
<td>1.905</td>
</tr>
<tr>
<td>ALT (U/L)</td>
<td></td>
<td>14.82</td>
<td>14.38</td>
<td>14.03</td>
<td>14.30</td>
<td>0.337</td>
</tr>
<tr>
<td>AST (U/L)</td>
<td></td>
<td>109.74</td>
<td>108.57</td>
<td>109.41</td>
<td>109.89</td>
<td>2.220</td>
</tr>
<tr>
<td>TAC (mM/L)</td>
<td></td>
<td>1.57</td>
<td>2.0</td>
<td>2.20</td>
<td>2.96</td>
<td>0.127</td>
</tr>
<tr>
<td>GSH-Px (mU/ml)</td>
<td></td>
<td>93.41</td>
<td>115.92</td>
<td>130.49</td>
<td>143.76</td>
<td>6.378</td>
</tr>
<tr>
<td>Testosterone (ng/ml)</td>
<td></td>
<td>245.21</td>
<td>288.88</td>
<td>297.01</td>
<td>383.65</td>
<td>20.007</td>
</tr>
</tbody>
</table>

*a, b, c*: Means within the same row having different superscripts significantly different (P<0.05).

**SS = Sodium selenite, SY = Selenium yeast, NS = Nano-Selenium.**
The data indicated that serum globulin concentrations were higher (P<0.05) by 13.6 and 20.0 % with feeding SY and NS, respectively than SS. Although the levels of serum globulin were comparable with SY and NS, supplemental NS increased serum globulin by 5.5 % compared with SS. These findings may be indicated that either supplementation with Nano-Se or organic Se (SY) was more effective than inorganic Se (sodium selenite) to increase serum globulin concentrations. These results agree with similar response of Wistar male rats fed sodium selenite and Se nanoparticles at 150 ppb Se, where Nano-selenium was potent (P<0.05) to increase serum globulin concentrations by 8.5 % than sodium selenite (Bunglavan et al., 2014). The presented results are also consistent with similar increased serum globulin levels in layer chicks fed Nano-Se at 0.3 ppm (Mohapatra et al., 2014), male buffalo calves supplemented with 0.3 ppm Se (Mudgal et al., 2008), and buffalo heifers supplemented with Se at 0.2 ppm (Ganie et al., 2012). In addition, serum globulin levels were increased (P<0.05) concomitant with improving immune response and antioxidant function for growing rabbits fed organic Se at 0.3 ppm (Ebied et al., 2012).

Data in Table (4) indicated that, There were significant ((P<0.05) increase in serum glucose concentrations for lambs fed diets SS (65.34), SY (67.66) and NS (72.75) vs. control (59.92 mg/dl). The values of serum glucose concentrations were higher ((P<0.05) with feeding NS than those of SS and SY. This response of elevated serum glucose levels for lambs fed SS, SY and NS-supplemented diets could be explained by the significant (P<0.05) improvement occurred in their nutrients digestibility of CF and NFE. Otherwise, the increase in serum glucose concentrations may be an indication of shifting the site of carbohydrate digestion from the rumen to the intestinal section (McDonald et al., 1994). In this way, these increments in serum glucose concentrations for lambs fed different selenium sources, in the present study, may account for the significant (P<0.05) improvement that was noticed in their productive performance of FBW and ADG.

The data showed no significant differences in serum concentrations of ALT and AST enzymes activity in lambs fed supplemental selenium sources of SS, SY and NS compared with control. This finding agree with similar trend of unchanged serum ALT and AST enzyme activities in lambs supplemented with organic SY at 0.3 mg/kg DM (Faixova et al., 2007). In the same way, these enzymes activity did not change in Merino lambs fed either inorganic SS (sodium selenite) or organic selenium (Se-plex) at 0.3 mg/kg (Antunovic et al., 2014). Also in goats, similar unchanged trend of serum AST enzyme activity was detected for bucks whose mothers supplemented with either sodium selenite or selenium yeast at 0.3-0.9 mg/goat/day (Pechova et al., 2012). These studies, together with the present results, may be indicated a case of normal hepatic metabolism in sheep fed diets supplemented with either inorganic or organic selenium sources.

Data in Table (4) showed no significant differences in serum concentrations of albumin and cholesterol with feeding lambs different selenium sources. This results agree with similar trend of unchanged serum albumin and cholesterol levels in male goats fed either sodium selenite or selenium yeast at 0.3 mg selenium /kg DM (Kamdev et al., 2015); and in growing male rabbits fed organic Se at 0.3 ppm (Ebied et al., 2012). Also, similar results had been shown in Merino lambs fed either inorganic Se (sodium selenite) or organic selenium (Se-plex) at 0.3 mg/kg (Antunovic et al., 2014).

There were significant ((P<0.05) increase in serum total antioxidant capacity (TAC) concentrations for lambs fed SS, SY and NS vs. control. The values of serum TAC concentrations were higher (P<0.05) with feeding NS than those of SS and SY (Table, 4). In addition, data showed that serum glutathione peroxidase (GSH-Px) activity was increased (P<0.05) for lambs fed diets SS, SY and NS vs. control. Serum GSH-Px activity was higher (P<0.05) with feeding NS than those of SS and SY. Generally, the present results indicated that dietary supplementation at 0.3 mg/kg DM of different Se sources as SS, SY and NS to growing lambs were effective to significantly increase serum TAC and GSH-Px activity, improving their antioxidant status. To compare the potency of these Se sources in improving antioxidant function, supplemental NS was more effective than SS and SY by 48.0, 34.5 % with serum TAC and by 25.9, 11.4 % with serum GSH-Px activity, respectively. These findings on sheep strongly agree with similar observations of Shi et al. (2011b) on growing male goats fed Se at 0.3 mg/kg DM as sodium selenite, selenium yeast and Nano-Se. They found that serum GSH-Px activity was higher (P<0.05) with feeding Nano-Se than sodium selenite and selenium yeast concomitant with increased serum Se concentrations and improved growth performance, suggesting that elemental Nano-Se could be utilized more effectively comparing with inorganic or organic Se. The highest activity of serum GSH-Px detected with supplemental NS, in the present study on sheep and others on goats (Shi et al., 2011b), could be discussed in the light of the view that Nano-Se particles displayed a preeminent bioavailability because of its specific properties such as high catalytic efficiency, strong adsorbing ability and low toxicity, explaining the greater bioavailability of Nano-Se when compared with organic or inorganic Se forms (Zhang et al., 2008).
The presented data illustrated that, supplemental SS and SY led to increasing serum GSH-Px activity was comparable, are in agreement with similar results observed in Merino lambs fed inorganic or organic Se at 0.3 mg/kg (Antunovic et al., 2014). These findings are also standing with results reported on sheep supplemented with Se yeast alone (Faixova et al., 2007) or various forms of selenium (Palvlata et al., 2013). Although the levels of serum GSH-Px activity were statistically comparable with SS and SY, supplemental SY increased serum GSH-Px activity by 13.0 % compared with SS. To this point, supplemental Se was noticed to increase plasma GSH-Px activity, but this increase was less pronounced with inorganic compared with organic Se (Wang and Xu, 2008). In addition, dietary supplementation with organic Se at 0.3 ppm significantly improved serum TAC and reduced lipid peroxidation, enhancing humeral immune response and antioxidant status in growing rabbits (Ebied et al., 2012). However, in contrast to the above mentioned observations, some studies showed no effect of Se sources or concentration on blood GSH-Px activity in broilers (Payne and Southern, 2005) or GSH-Px activity increase much faster with selenium compared to organic Se in goats (Pavlata et al., 2011).

In the present study, it was interesting to note that the higher (P<0.05) serum TAC and activity of serum GSH-Px for Ossimi lambs fed supplemental NS was concomitant with greater (P<0.05) FBW and ADG compared to those fed SS or SY. These findings agree with recent results reported by Yaghmaie et al. (2017) on Makuei lambs received sodium selenite and Nano-Se treatments. They found out that supplemental Se increased (P<0.05) serum Se concentrations and GSH-Px activity in which it was predominant in Nano-Se than in sodium selenite group, detecting a positive relationship (r= 0.98, P<0.01) between weight gain and serum GSH-Px activity in lambs received Nano-Se treatment compared with sodium selenite. So, the present results, together with the reports of Shi et al. (2011b) on growing male goats and Yaghmaie et al. (2017) on Makuei lambs, may suggest that effect of supplemental Nano-Se in improving antioxidant status and increasing weight gain is acceptable and preferable than sodium selenite in sheep.

Data presented in Table (4) showed that serum testosterone concentrations were higher (P<0.05) for lambs fed diets SS, SY and NS than the control. Also, serum testosterone levels were higher (P<0.05) with feeding NS than SS and SY. These results indicated that serum testosterone levels were increased by 17.8, 21.2 and 56.45 % due to supplemental SS, SY and NS compared with control, respectively. The positive effect of supplemental SY on increasing serum testosterone levels of lambs agree with similar response of significant increase in serum testosterone observed in male Baladi goats fed a diet supplemented with selenium yeast at 0.15 ppm, improving their reproductive efficiency (El-Sisy et al., 2008). It has also been reported that supplementation of 0.6 mg / head / day Se as sodium selenite for 100 days increased the percentages of spermatids in male goats (Ganabadi et al., 2010). In this way, selenium is stated to be essential in maintaining male fertility (Brown and Arthur, 2001); and it is required for biosynthesis of testosterone and for formation and normal development of spermatozoa (Behne et al., 1996). Also, both the testis and epididymis require bioavailability of selenium to synthesize selenoproteins (Shalini and Bansal, 2007). That is why serum testosterone levels were significantly lowered in Se-deficient than Se-adequate rats (Behne et al., 1996).

The beneficial effects of different Se sources in increasing serum testosterone levels, shown in the present study with feeding SS, SY and NS could be associated with their significant effectiveness in enhancing serum GSH-Px activity. Selenium is an essential component of GSH-Px, an enzyme involved in detoxification of hydrogen peroxide and lipid hydroperoxides. The enzyme GSH-Px has been localized immunocytochemically in the cytoplasm of Leydig cells (Murakoshi et al., 1983). So, it is possible that the metabolic pathway of testosterone biosynthesis requires higher activity of GSH-Px to protect against peroxidation (Behne et al., 1996). Accordingly, the significant increases in serum testosterone concentrations for lambs fed different Se sources may be related to the significant concomitant increase in their serum GSH-Px activity, protecting the testes and Leydig cells against peroxidation and thus improving its steroidogenic function.

CONCLUSION

Based on the results of the present study, dietary supplementation of Nano-Se could be utilized more effectively than sodium selenite and Se-yeast to improve nutrients digestibility, feeding values, growth performance, some serum metabolic indices, antioxidant status and reproductive efficiency of male Ossimi lambs.
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تأثير الإعداد الغذائي بمصادر متنوعة من السيلينيوم على معاملات الهضم، الأداء الإنتاجي وبعض مؤشرات السيرم البيوكيميائية في الأغنام

عمدائيين: هشام بن أحمد و محمد سالم إبراهيم

أسم الإنتاج الحيوي: كلية الزراعة - جامعة المنهاج - المنهاج - مصر.

أُجريت هذه الدراسة على ثمانية أبقار وكلها من سلالة الحليب، و تم توزيعها على أربعة مجموعات متساوية (8 أبقار لكل مجموعة) مع جرد معاملات الهضم، الأداء الإنتاجي، و بعض مؤشرات السيرم البيوكيميائية. تم تزويد الجامعات بسمنتين سيلينيوم في مصادر مختلفة: السيلينيوم الصوديوم (NaSe)، السيلينيوم ثنائي مواد (NaSe2)، السيلينيوم النانو (NanoSe) و السيلينيوم في الجيوب (NanoSe) بالقدرة على تحسين معاملات الهضم، الأداء الإنتاجي وبعض مؤشرات السيرم البيوكيميائية، حيث أن معاملات الهضم، الأداء الإنتاجي، و بعض مؤشرات السيرم البيوكيميائية تحسن بشكل ملحوظ مع كل مصدر من السيلينيوم.
