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Selenium retention in lambs fed diets supplemented with selenium from inorganic or organic sources

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ABSTRACT

The objective of this study was to compare the effects of feed supplementation with equivalent selenium doses from sodium selenite (SS) and selenised yeast (Se-yeast) on Se absorption, retention, balance, and tissue deposition in young rams. Fifteen male lambs of the Slovak valashka breed (4 months old) were randomly allocated to three dietary treatments consisting of unsupplemented basal diet (BD) containing only background Se (0.07 mg/kg dry matter; DM) and two treatments based on identical BD supplemented with 0.3 mg Se/kg DM either from SS or from Se-yeast. After 14 weeks, no differences in blood Se levels were observed between rams fed the diet supplemented with SS or Se-yeast (0.30 *vs.* 0.31 mg/L, respectively), while lambs given BD showed significantly lower Se level (0.07 mg/L, $P < 0.001$). A similar response was found in the activity of blood glutathione peroxidase (GPx), with mean values for BD, SS and Se-yeast groups of 132.8, 931.7 and 954.4 U/g Hb, respectively ($P < 0.001$). The balance measurements carried out in week 12 showed significantly higher relative Se retention (% of Se ingested) in the rams given Se-yeast (58.3%) than in those fed the diet supplemented with SS (45.4%, $P < 0.05$), both differing from the control group (51.6%). The apparent Se absorption rate was significantly higher in the Se-yeast group (62.0%) than in the lambs treated with SS (49.6%) or in those fed the unsupplemented BD (52.9%, $P < 0.001$). Due to lower absorption rate the rams given SS had significantly higher faecal Se excretion than the Se-yeast fed animals, whereas no differences between the supplemented groups appeared in urinary Se excretion. The 14-week intake of Se-yeast resulted in significantly higher Se deposition in liver, muscles, heart, pancreas and spleen than that from SS. The highest tissue Se concentrations in each group were found in the kidney cortex (BD, SS and Se-yeast were 6.0, 12.9 and 11.9 mg/kg DM, respectively), whereas the respective levels in the kidney medulla were about four times lower (1.4, 2.7 and 3.1 mg/kg DM). The results demonstrate that in sheep the feed supplementation with Se from Se-yeast results in higher absorption of Se from the digestive tract and greater body Se retention than from SS. However, the inorganic source of Se was as effective as the organic one in supplying this essential trace element for the activity of specific selenoprotein GPx in blood.

1. Introduction

Selenium is an essential trace element which plays an important role in the antioxidant, reproductive, endocrine and immune systems of animals. The majority of body Se is in the form of selenocysteine (SeCys) in the active centre of specific selenoproteins/selenoenzymes, in selenomethionine (SeMet) incorporated unspecifically into general proteins, and as methylated Se-compounds. To date more than 30 specific selenoproteins with various functions have been described (Hefnawy and Tórtóra-Perez, 2010).

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Table 1
Ingredients (g/kg as fed basis) and chemical composition of the basal diet (BD).

Ingredients	g/kg	Composition[a]	
Grass hay (62 μg Se/kg DM)[a]	595	Dry matter (g/kg)	886
Ground barley (67 μg Se/kg DM)[a]	357	Crude protein (g/kg DM)	134
Rapeseed oil meal (167 μg Se/kg DM)[a]	48	Acid detergent fibre (g/kg DM)	240
Trace mineral lick[b]		Neutral detergent fibre (g/kg DM)	338
		Ash (g/kg DM)	60.6
		Selenium (μg/kg DM)	68.8
		ME (MJ/kg DM)[c]	10.4

[a] Analysed values.
[b] Composition of mineral lick (g/kg), without Se: Ca 16.2, Na 316, Mg 32, Cu 0.7, Mn 2.5, Zn 3.1, Co 0.06, I 0.02 g/kg.
[c] Metabolisable energy (ME); calculated value (NRC, 1985).

It is generally known that in EU countries the unsupplemented feeding stuffs provide an inadequate and/or rather deficient supply of selenium for animals (Pappas et al., 2008). For this reason commercial animal feeds are routinely supplemented with various Se sources up to maximum EU authorised total Se content 0.5 mg/kg feed. Currently, sodium selenite and selenate as inorganic selenium sources and selenium enriched yeast (Se-yeast) as organic Se are routinely used for supplementation of animal feeds.

After ingestion, selenite is passively absorbed by simple diffusion along the concentration gradient, whereas selenate is actively absorbed *via* the co-transport pathway with sodium ions (Wolffram, 1999). In contrast, the absorption of SeCys and SeMet takes place from the small intestine by the Na-dependent system, an identical transport mechanism such as amino acids. While seleno-amino acids are absorbed preferably in the duodenum, selenite and selenate absorption takes place mainly in the ileum (Whanger et al., 1976). However, due to various anatomical and physiological functions of the digestive tract in different animal species, considerable differences in selenium absorption between simple stomach animals and ruminants have been identified (Mahan and Parrett, 1996; Koenig et al., 1997; Wolffram, 1999; Sager, 2006).

Currently it is well established that selenocompounds from dietary inorganic and organic Se-sources follow different metabolic pathways. All absorbed selenite is almost immediately reduced to dihydrogen selenide (H_2Se), while selenate requires several passes of blood *via* the liver to be metabolised into H_2Se. Consequently a considerable portion of absorbed selenate is excreted directly and unchanged in urine before being reduced. After absorption the portion of SeMet is transelenated to SeCys with subsequent metabolising into selenide, and the surplus of SeMet which escapes the transformation into selenide is unspecifically incorporated into general body proteins (Wolffram, 1999; Suzuki, 2005).

The aim of this study was to compare the effects of Se feed supplementation from sodium selenite and Se-yeast on the Se body retention, absorption, and tissue deposition in young rams.

2. Materials and methods

All procedures used in this study were in accordance with European Community guidelines. The experimental protocol was approved by the Ethical Committee of the Institute of Animal Physiology SASci and by the State Veterinary and Food Office (Ro-987/08-221).

2.1. Animals, diets and experimental design

Fifteen male lambs of the Slovak valashka breed (wool type), mean age 4 months and initial body weight 14.8 ± 0.7 kg (SEM), were randomly divided into three dietary treatment groups with five animals in each. Lambs were brought from a location where the Se status of sheep given feed without Se supplementation is known to be marginally deficient. After the allotting into groups, the treatment period followed for 14 weeks using a completely randomised design. According to the specific treatment, the control animals were fed unsupplemented basal diet (BD, analysed Se 0.07 mg/kg DM), whereas the two other groups were given identical BD supplemented with additional 0.3 mg Se/kg DM either from sodium selenite (SS) or selenised yeast (Se-yeast).

The lambs were housed in individual pens with bedding (1.65 m × 1.25 m). They were fed a restricted diet (840 g/day) divided into two portions offered at *ca.* 7.00 AM and 3.00 PM. The daily ration consisted of hay, ground barley and rapeseed meal (Table 1). The diets for all treatments were prepared fresh daily and differed only in the total dietary Se content or the form of selenium supplemented. There were no dietary refusals and feed was completely consumed by the animals. Throughout the whole experiment the animals had free access to fresh potable water and specially-prepared trace mineral lick without Se (for composition see Table 1). The background Se in BD provided each animal with a daily Se intake of only 51 μg, which is considered as deficient (NRC, 2007). In order to supplement the SS group diet with 0.3 mg Se from sodium selenite per kg DM, sodium selenite with 99% purity (Sigma–Aldrich, USA) was dissolved in water and top-dressed on ground barley during each feeding (twice daily 245 μg Na_2SeO_3 in 0.5 ml water), thus providing a total daily Se intake of 275 μg/head. Consumption of the added droplet containing supplemented sodium selenite was visually controlled in each animal. For the Se-yeast group, selenised yeast (Sel-Plex, Alltech, Nicholasville, KY, USA) was directly mixed with the ground barley in order to provide the additional 0.3 mg Se/kg DM of complete diet. Supplementation of barley with Se-yeast was analytically confirmed in triplicates and consequently the calculated total daily Se intake in this group of animals was 288 μg/head.

2.2. Measurement and sample collections

After a 12-week pre-treatment period feeding on the experimental diets, all rams (aged 7 months, mean body weight 21.8 ± 0.57 kg) were placed in metabolic cages for the measurements of Se balance. The same type and amount of the daily ration (840 g) depending on the treatment designation was individually offered to each animal twice daily and fresh potable water (4 L/head/day) was available *ad libitum*. Five-day adaptation of the animals to the metabolic cages was followed by a collection period of five days with quantitative and separated collection of urine and faeces for Se balance measurements.

During balance measurements the amounts of excreted faeces, urine and feed refusal were measured daily for each ram at 7:00 AM. However, all animals completely consumed their daily ration when placed in the metabolic cages. The daily total faecal output from each animal was weighed, and a 10% representative sub-sample was obtained. The daily faecal sub-samples were dried at 55 °C in a forced-air oven to reach a