Invited paper

EFFECTS OF INORGANIC AND ORGANIC SELENIUM SUPPLEMENTATION ON BLOOD AND MILK SELENIUM CONCENTRATION IN DAIRY COWS

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Abstract

Selenium is an important trace element in the nutrition of dairy cows because it prevents oxidative damages of tissue and in that way protects the animals from the incidence of various disorders. Addition of various levels of selenium in food leads to its increase in the milk what is important for postnatal calves development in which in the first weeks of life the milk is the only source of selenium. Into the food for dairy cows the inorganic selenium is added in the forms of – sodium selenite or sodium selenate (SS) or organic selenium – seleniium-enriched yeast (SY). Numerous studies have shown that organic selenium (SY) added into food for dairy cows provides better bioavailability than inorganic selenium (SS), hence the content of selenium in blood and milk of cows fed organic form of selenium is higher than in the inorganic selenium. The opinions about the effect of organic selenium on the activity of seleno-enzyme glutathione peroxidase (GPx) have not been reconciled yet. Adding selenium into food for dairy cows has no effect on the quantity of produced milk nor on the milk composition (proteins, fats and lactose). Selenium reduces the number of somatic cells in milk and in that way prevents the occurrence of the disease of mammary gland.

Key words: *blood, dairy cows, milk, selenium*

Introduction

Selenium is an essential element in the nutrition of diary cows. It reduces oxidative and metabolic stress, has immunostimulative effect, affects the muscular and neuromuscular functions and it is also important for physiological reproductive processes most notably it significantly reduces the incidence of retained placenta in dairy cows after the parturition (Jovanović et al., 2013). Colostrum and milk are good sources of selenium for calves in the first weeks of life.

Numerous regions in Europe, including Serbia, are poor or very poor in selenium (Thorn et al., 1978; Froslie et al., 1980; Maksimović et al., 1991; Mihailović et al. 1996; Jovanović et al., 1998). Concentration of selenium in cereals and forage feeds from these regions is low or very low. In order to ensure adequate levels of selenium for dairy cows the National Research Council (NRC, 2001) has recommended that the food for dairy cows should contain from 0.1-0.3 mg Se/kg DM, depending on the physiological state and the age of animal. However, the form of selenium supplement is not determined – whether it shoul be the organic or inorganic. Many authors (Weiss and Hogan, 2005; Slavik et al., 2008; Ran et al., 2010) established that adding the organic selenium into food for dairy cows leads to higher increase of selenium in blood and milk in relation to the same levels of inorganic selenium. However, the same levels of different forms of selenium lead to no significant differences in the activity of serum selenoenzyme glutathione peroxidase (GPx3) (Enjalbert et al., 1999; Ran et al., 2010).

Concentration of selenium in serum and whole blood can be used as an indicator of the selenium status so that the increase of its concentration in these body fluids leads to the enhanced function of neutrophiles, decrease in the number of somatic cells and the occurrence of mastitis (Weiss et al., 1990; Cebra et al., 2003; Ibeagha et al., 2009).

The content of selenium in colostrum on the first day postpartum is considerably higher in cows which received selenium supplemented food in relation to the individuals that received no such food. However, the content of selenium in colostrum on the third day is considerably lower both in treated and untreated animals taking into account that in cows that received SY the concentration of selenium was 37% lower, in animals treated with SS by 67%, and in cows that received no selenium by 32%. The fall in the concentration of selenium in all trial animals in colostrum on the third day is associated with the transition of colostrum into milk and greater binding of selenium into compounds with the milk proteins (Debski et al., 1987). Adding the selenium into food for dairy cows (SS or SY) leads to no significant increase of the quantity of milk, content of proteins and lactose, but the percent of milk fat was higher in the individuals that received SY than SS (Carlos et al., 2014).

Biological availability of selenium

Selenium is used for different physiological and metabolical processes in the organism in which the part of selenium is being transformed in various metabolic forms necessary for developing many physiological processes. One part of dietary selenium is being lost by respiratory, urinary and faecal path. A remaining part of selenium can be incorporated specific proteins and numerous other proteins of small molecular mass. The mostly of selenium in Se-yeast products is in the form of selenomethionine. No evidence exists that mammalian cells can differentiate selenomethionine from methionine during protein synthesis. However, absorption of selenomethionine from the intestine can result in incorporation of Se during protein synthesis into any protein that contains methionine. When inorganic selenium is fed, the Se is more likely to be associated with seleno-specific proteins (Weiss and Hogan, 2005). Resorption of selenium from food, organic or inorganic is about 70%, but it can vary considerably depending on the source of selenium. However, total quantity of resorbed selenium is not physiologicaly available because one part is being lost through lungs whilst the remaining part is transformed into selenium compounds – polypeptide and proteins of which only selenoenzyme GPx has certain physiological function.

Biological availability of selenium depends on numerous physiological and metabolic processes.There are many different procedures for determination of biological availability of selenium, however different values have been obtained for the same selenium source, using different methods. It is assumed that the established differences are consequences of different efficacy and utilisation of selenium for certain physiological processes in different kinds of animals and animal species. However, it was determined in many studies that seleno-aminoacids and selenium in plants have good bioavailability while inorganic forms of selenium have lower bioavailability (Mihailović, 1996).

Absorption of different sources of selenium

Mechanisms of digestive absorption of inorganic and organic selenium are completely separate, therefore the factors which reduce the absorption of inorganic selenium little affect the organic form (Weiss, 2005). Intestinal resorption of selenium is considerably higher in monogastric animals than in ruminants (Cousins and Cairney, 1961). Selenite (SeO_3) and selenomethionine cannot be resorbed from the sheep rumen and pig stomach (Wright and Bell, 1966).

Ruminal metabolism and intestinal absorption of inorganic and organic selenium is different. In ruminants the selenates (SeO_4) are being reduced to selenites (SeO_3) in rumen, although certain quantity of selenates passes through rumen and is being resorbed in small intestines. A part of intaken selenites in rumen is transformed into small insoluble molecules of selenium which cannot be used by the animal. A part of selenites in rumen is used for the synthesis of seleno-aminoacids, mostly selenocysteines, which are being incorporated into microbial proteins. Because it is very difficult to determine the quantity of various selenium components, their distribution from ruminal contents is limited (Weiss, 2005).

Of total quantity of selenites added into food, 30 to 40% is being transformed into insoluble forms, 10 to 15% is incorporated into microbial proteins and 40 to 60% remains in the form of selenites (Serra et al., 1994). When the animals are fed diets containing the organic selenium a considerably higher percent of selenium in the form of seleno-aminoacids (mostly seleno-methionine) reaches the intestinal tract in comparison to the animals fed inorganic selenium.

Concentration of selenium in blood and serum

Concentration of selenium in blood depends on the level, form (organic or inorganic selenium) and on the time of consuming the food supplemented by selenium. Ran et al. (2010) determined a considerably higher levels of selenium in blood of cows fed organic or inorganic selenium, than in the individuals that received no selenium in their food (control group). The authors also report that in cows fed organic selenium (SY), on 60th, 75th and 90th day after calving the concentration of selenium in blood was higher 10, 11 and 14% in comparison to the individuals fed inorganic selenium (SS). Similarly to previous reports, Slavik et al. (2008) determined the highest concentration of selenium in the blood of cows fed diets supplemented by organic selenium (SY group 93.0 μg/L; SS group 68.0 μg/L; group that received no selenium in food 35,1 μg/L). Ortman and Pehrson (1999) report that dairy cows fed diets containing 0.1-0.12 mg Se/kg food (organic or inorganic) had 65%, that is, 35% higher levels of selenium in blood than individuals that received no selenium. Research conducted by Weiss and Hogan (2005) also suggest that in dairy cows fed the same levels of organic and inorganic selenium (0.3 mg/kg food) on the 28th day after calving the concentration of selenium in blood serum differed significantly. In the individuals fed organic selenium the concentration of selenium in blood serum was 0.074 mg/L, and in the individuals fed inorganic selenium 0.054 mg/L. In addition, higher levels of selenium in blood serum were determined on the third day after birth in calves whose dams were fed organic selenium in relation to calves whose dams received inorganic selenium. The values of selenium concentration in calves serum were 0.062, that is, 0.042 mg/L. Gunter et al. (2003) also determined 1.85 times higher concentration of selenium in blood of calves whose dams were fed organic selenium in relation to calves whose dams were fed with inorganic selenium. The limit of selenium deficiency in cows is 0.056 mg/L selenium concentration in whole blood and 0.02 mg/L selenium concentration in blood plasma (Mihailović, 1996).

The activity of glutathione peroxidase (GPx) in blood and plasma

Its biological role selenium performs through enzyme of glutathione peroxidase (GPx), which in its active place contains selenium in the form of selenocysteine. The activity of this enzyme increases in plasma with the increase of its level in food what indicates its biological availability (Mihailović et al., 1991), although only at low levels of selenium. Becuase of that the determination of GPx3 in plasma is used as an appropriate method to determine the nutritive status of selenium. The activity of GPx3 in blood plasma is numerically higher during feeding the dairy cows with organic selenium what has been confirmed in many studies, although only in two studies the statistically significant differences were established (Weiss, 2005). The research by Knowles et al. (1999) suggests that there are no differences in the activity of GPx in cows whose ration was supplemented by 4 mg daily organic or inorganic selenium. However, the author reports that by administering 2 mg selenium daily the activity of selenoenzyme was 50% higher when the organic selenium was added into food. The research regarding the activity of GPx in calves plasma whose dams were fed organic or inorganic selenium are also not reconciled. Gunter et al. (2003) state that the activity of GPx in the plasma of calves whose dams were fed organic selenium was 75% higher than the activity of enzyme of calves delivered by the dams treated by inorganic selenium. However, Awadeh et al. (1998) found out that administration of organic selenium to dairy cows did not have any additional effect on increased activity of GPx in their calves, compared to those fed inorganic selenium. Ran et al. (2010) found out that both inorganic and organic selenium can lead to significant increase of erythrocyte GPx1 in dairy cows in relation to the individuals receiving no selenium (control group). However, the same authors did not determine significant differences in the activity of erythrocyte GPx between treated groups what is in harmony with the research of Weiss (2003). Moreover, Ortman and Pehrson (1999) report the increase of the activity of GPx1 erythrocytes in all treated groups and that the activity of this enzyme reached plateau on 75th day after the beginning of administration. Awadeh et al. (1998) report that only small quantities of administered selenium are associated with the activity of GPx serum. The lack of the effect of administering the selenium on GPx3 serum suggests that maximal activity of enzyme is obtained at adequate status of selenium (Todorović et al., 1999).

Content of selenium in colostrum and milk

Dairy cows fed organic selenium have higher concentrations of selenium in all tissues in relation to the cows fed inorganic selenium, the greatest portion of it being incorporated into the proteins as selenomethionine. The increase of selenium body reserves is very important for calves as well. Calves generating from dams fed organic selenium have higher concentration of selenium in tissues and higher GPx activity than calves produced by cows which received inorganic selenium in their food. Moreover, the colostrum of cows fed SY contains higher levels of selenium than the colostrum of cows fed SS (Weiss, 2005). Weiss and Hogan (2005) determined that in both groups of cows fed 0.3 mg Se/kg feed SY or SS, the concentration of selenium in colostrum was 3.8 times higher than in milk. The authors also state that the concentration of selenium in colostrum is considerably higher in cows fed SY than in cows fed SS. Ran et al. (2010) established that the cows fed diets supplemented by organic selenium (5 mg daily) had on 60th, 70th and 90th day after calving 43, 39 and 53% higher concentration of selenium in milk than cows fed with SS. Organic selenium is much more efficient than inorganic one at increasing the selenium concentrations in milk what is the result of its better bioavailability (Ortman and Pehrson, 1999; Ceballos et al., 2009). In line with previous reports Phipps et al. (2008) established that when supplementing food for dairy cows with 0.16 mg/kg SS and 0.30 mg/kg SY and 0.45 mg/kg SY, the highest values of selenium in milk were found in the milk of cows which received the highest levels of organic selenium.

Better transfer of selenium of organic origin into milk can be explained by higher level of methionine in milk which is about two times higher than in blood plasma. Hence the selenomethionine from SY is being easily incorporated into the milk proteins (Weiss, 2005). Concentration of selenium in milk increases lineary at adding SY into cows ration. However, at adding SS its concentration does not change significantly. Nutrition of dairy cows fed rations supplemented by SY for the last 60 days of gestation has a positive effect on the calves health (Weiss, 2005). Addition of organic or inorganic selenium into the dairy cows ration leads to no increased production of milk, increased level of lactose and proteins but it leads to the increase in the percent of milk fat (Wang et al., 2009). The individuals into whose food was added organic or inorganic selenium had 4.15, that is, 3.96% milk fat. This increase can be associated with reduced number of somatic cells (SCC) and lower percent of the incidence of mastitis what can affect the milk quality as well (Carlos et al., 2014). The influence of selenium on the composition of fatty acids in milk was studied by Ran et al. (2010). These authors report that in cows treated with SY and SS there occurred the increase only in C16:1 fatty acid which is formed under the influence of enzyme delta-9 desaturase in mammary gland. C18:1 fatty acid is produced also under the influence of the same enzyme but its higher concentration has not been determined. The opinion that the activity of mentioned enzyme can be increased at adding selenium into cows rations is not fully justified. The same authors established a significant increase of polyunsaturated fatty acids (PUFA) and linoleic acid (cis-9, cis-12) in milk fats during the treatment of cows with organic selenium. However, saturated fatty acids (SFA) had a tendency to decrease. Cabré et al. (1992) reported that there existed a positive correlation between the selenium concentration in serum and the percent of essential fatty acids and PUFA what is combined with antioxidative action of selenium. However, the authors Ran et al. (2010) report that their result are not complete and that it is necessary to continue the research.

The concentration of selenium in milk depends also on a physiological state of the animal. In early lactation the concentration of selenium is lower than in later stages of lactation what can be explained by the effect of dilution (Wichtel et al., 2004). The studies on distribution of selenium into different milk fractions showed that the highest concentration of selenium is in whey and the lowest in milk fats (Muňiz-Naveiro et al., 2005a). However, in their subsequent researh these authors (Muňiz-Naveiro et al., 2005b) report that adding of organic or inorganic selenium into food for dairy cows results in its increase in milk but the quantity in separate milk fractions (whey, casein and fat) does not differ.

Conclusion

Decades long research on physiological role of selenium has not given any complete explanations yet. Besides the fact that it is difficult to define bioavailability of inorganic and organic selenium in dairy cows many authors state that it is more profitable to use organic selenium in cows nutrition than the inorganic selenium. There are several reasons for that: 20-30% higher bioavailability and reduced toxicity, higher body reserves of selenium, considerably increased concentration of selenium in milk what is good for human health, increased concentration of selenium in colostrum what is important for the calf health state, antagonists do not significantly decrease the absorption of organic selenium.

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