Animal Science Papers and Reports vol. 32 (2014) no. 4, 283-299
Institute of Genetics and Animal Breeding, Jastrzębiec, Poland

The effect of selenium supplementation to the diet of dairy cows and goats on production traits and animal health* – a review

Józef Krzyżewski, Emilia Bagnicka, Jarosław Olav Horbańczuk**

Institute of Genetics and Animal Breeding, Polish Academy of Sciences,
Jastrzębiec, 05-552 Magdalenka, Poland

(Accepted October 17, 2014)

The results of studies conducted so far in the field of supplementing Se deficiency in cow and goat diets demonstrate unequivocally the positive influence of supplements used on the improvement of the health status of animals and an important increase in the concentration of this microelement in the obtained milk. The positive influence on health is reflected in the increased antioxidative status and immunological potential of these animals, in the reduced risk of mastitis, in the improvement of reproductive rate and increased Se transfer to cow foetus. The best results are obtained when the diet is supplemented with selenium yeast. The improvement in animal Se supply also has a positive influence on the increase of antioxidative properties of milk and meat. Further research in the field is necessary, connected among others with determining the relationship between the concentration of Se and antagonistic elements as well as vitamin E.

KEY WORDS: dairy cows / dairy goats / selenium yeast / selenium selenite / milk and blood / selenium / health status

The understanding of selenium (Se) role in animals and humans has changed in the last few decades. Se is characterized by low therapeutic index, as the range between its deficiency and excess in animals and humans is very narrow. For this reason, selenium had initially been treated as a toxic element, causing different types

*Conducted as part of the project "BIOFOOD – innovative, functional products of animal origin" No. POIG.01.01 02-014-090/09 co-financed by the European Union from the European Regional Development Fund under the Innovative Economy Operational Programme 2007 – 2013 and IGAB project S.IV.2.
**Corresponding author: j.krzyzewski@ighz.pl

of diseases, both in animals and humans. The excess of Se in ruminants causes a disease, called selenosis, manifested by, among other symptoms, muscle stiffness, fur loss and horn tissue necrosis. LD50 dose for adult cattle amounts to 0.501 mg kg^{-1} body weight, while for lambs it is 0.455 mg kg^{-1} body weight [Tinggi 2005]. However, an excess of Se occurs very rarely. Nevertheless, the administration per os of 1 ml 0.1% Na_2SeO_4, 3 ml 10% $ZnSO_4$ and 60 mg vitamin E resulted in weight loss and growth decrease in lambs of mothers ewes which were supplemented with non-organic selenium during pregnancy [Gabryszuk *et al*. 2009]. On the other hand, Kurth *et al*. [1958] proved that Se deficiency is responsible for so-called 'white muscle' disease in animals. In the 1980s and 1990s, it was proven that Se is characterized by anticarcinogenic properties [Combs and Combs 1986], as well as that it prevents heart and muscle diseases [Neve 1996] and has a positive influence on rat fertility [Oldereid *et al*. 1998]. It was demonstrated in subsequent years that Se plays an important role in the functioning of the immune system of different organisms, as it prevents, among other things, viral infections, increases immunity in AIDS patients [Baum *et al*. 2001], slows the ageing process and inhibits the development of cancer [Ip and Donk 2001]. Ramisz *et al*. [2012] summarized the results of studies by different authors and draw attention to the effects of Se deficiency in animals. It is manifested by the occurrence of the already mentioned white muscles in growing animals and in adult, by disorders of reproductive functions, reflected in ovary dysfunctions, fetal mortality, inflammation of endometrium together with placental retention and spermatogenesis disorders in males. In addition, in dairy cows Se deficiency results in a decrease in milk production and in the functioning of the immune system, resulting in an increase of vulnerability to illnesses, including the illnesses of the mammary gland [Smith *et al.* 1997]. Se deficiency also contributes to a decrease in bactericidal properties of neutrophils and to the inhibition of lymphocyte proliferation [Cao *et al*. 1992]. Deficiency of Se in cows also influences the decrease of the level and activity of the most important antioxidants, such as GPX-1, of mRNA and gene expression at the protein level, responsible for antioxidative defense mechanisms, which results in the increased vulnerability of cows to immunosuppression [Colitti and Stefanon 2006].

Despite of experimental evidence confirming the indispensability of Se for the proper course of physiological and biochemical processes in animals, the US forage law allowed Se supplementation in the amount of 0.1 ppm in the dry weight of animal diet in the form of sodium selenite or seleniate as late as 1979. In 1987, an amendment was introduced to the law in force, allowing an increase of Se added to animal diets to 0.3 ppm in dry matter. Current EU regulations accept significantly a higher amount – 0.568 mg kg^{-1} dry matter, *i.e*. 0.568 ppm [Official Journal of the European Communities 2006].

Kurek *et al*. [2011] state in dairy cows, Se plays an important role in maintaining proper reproductive functions, as its deficiency is the cause of miscarriages, early embryonic mortality and spermatogenesis disorders in bulls. Publications include information also indicating the occurrence of other diseases caused by a deficiency of this microelement in cows, including diarrhea, liver necrosis, subclinical and clinical forms of mastitis, inflammation of endometrium, and placental retention [Mueller *et al*. 1989, Gerloff 1992, Jugola *et al*. 1996, Villar *et al*. 2002]. There are several publications confirming that an appropriate supply of Se and vitamin E has a positive influence not only on fertility, but also on cattle productivity, it supports immunomodulation properties and successful response in the course of numerous infectious diseases, in particular of the respiratory system. It also has a positive effect on the development of local udder and uterus immunity [Mueller *et al*. 1989, Gerloff 1992, Brzezińska-Ślebodzińska *et al*. 1994, Jugola *et al*. 1996, Villar *et al*. 2002].

Metabolism of selenium

Selenium shares the characteristics of both metallic and non-metallic elements. It exists in four oxidation states (Se^{-2}, Se^{0}, Se^{+4} i Se^{+6}) and as a result it plays various important roles in biochemical transformations [Mahima *et al*. 2012]. In animals, the highest concentration of Se is observed in muscles, liver, blood plasma, erythrocytes and kidneys. According to the current state of knowledge, Se is contained in ca. 100 proteins, so called selenoproteins; biochemical functions have been ascribed to 30 of them, while the role of the other 15 selenoproteins is connected to DNA [Arthur *et al.* 1997]. Selenoproteins act in particular as biocatalysts. [Schrauzer 2009]. Deagen *et al*. 1991 state that the functions of enzymatic selenoproteins, glutathione peroxidase (GPXs), thioredoxin reductase (TRs), iodothyronine deiodinase (TRs) as well as two selenoproteins, i.e. selenoprotein P (SeP) and selenoprotein W (SeW), have already been thoroughly examined. The first two enzymatic proteins mentioned, together with GSH and vit. E, protect phospholipid double bonds in cell membranes, together with lipoproteins and DNA against damage by reactive oxygen species produced during metabolism which have a destructive effect on the body, including cell destruction [Korniluk *et al*. 2007]. Enzymes from the glutathione peroxidase group catalyze the reaction of removing hydrogen peroxide from erythrocytes by means of reduced GSH. Other proteins participate in the control of the level of thyroid hormones, Se transport in redox processes in muscles, in the metabolism of calcium in the body and in reproduction processes [Mistry *et al*. 2012]. Selenium is also contained in proteins participating in antioxidative, endocrinological, immunological and anti-inflammatory processes. Se occurs in combination with amino acids contained in proteins, in particular with methionine and cysteine and is the basic source of this microelement in biochemical transformations in animals and humans. These combinations constitute 50-80% of the total Se contained in plants. However, the total quantity of Se incorporated into these amino acids in the body of animals and people is very small due to a low concentration of this microelement in plants [Calamari *et al*. 2010]. One of the causes of low concentrations of Se in plants is its low content of soil. Se is included in the food chain via plants, which then absorb it from soil in the form of a mineral and it is incorporated into amino acids only in plant tissues. A high deficiency of Se in soil is observed in numerous regions of the world, such as in China, Europe (including Poland), America and New Zealand [FAO/WHO 2004].

Shrift [1973] proved that selenomethionine (SeMet) may also be produced by yeast, bacteria and fungi. So, now it is possible to use Se as a supplement to cow and goat diets in mineral (sodium selenite or selenate) as well as organic forms as selenium yeast (Se-yeast), in which 54-90% of Se occurs in combinations with methionine [Rayman 2004]. In mineral and organic combinations is metabolized in a different way [Surai 2006]. Se in mineral combinations (sodium selenite or selenate) is absorbed in the small intestine by the process of simple diffusion, while in organic combinations, e.g. in selenium yeast, is absorbed together with amino acids with which it is combined by a chemical bond. An important amount of Se, in the form of mineral combinations in the rumen, is subject to a reduction by microorganisms in a form which has not been assimilated by ruminants. That is why its accessibility for these animals, e.g. from sodium selenite, reaches only 25-30% [Wright and Bell 1966]; only 15% of Se provided in the form of "unprotected" selenium salts is included in the cycle of metabolic transformations. In the body, Se provided in a mineral form is subject to complicated transformations and its incorporation into proteins synthetized in animals is only the last stage of these transformations. Nevertheless, only a relatively small part of Se provided in a mineral form is incorporated into proteins, the remaining amount, which was released from the salt, combines with other ingredients of the digested diet. Part of the obtained complex compounds cannot be absorbed in the intestine and is excreted with faeces. Moreover, selenium supplied in mineral form can act as a prooxidant and, in the situation of its higher concentration in diet, it shows toxic properties, in contrast to Se combined with methionine [Seko *et al*. 1989]. Se in organic combinations, as selenomethionine, selenocysteine and selenocystine contained in proteins together with other amino acids not combined with Se is absorbed together with these amino acids in the small intestine after the digestion of proteins; 34-49% of Se supplied as Se-Met contained in selenium yeast is included in the cycle of metabolic transformations. However, it is necessary to take into account the fact that the assimilability of Se by animals depends not only on the form in which it is administered, but also on the content and type of other nutrients in the feed ration, as well as the concentration of calcium, sulfur and iodine. The assimilability of Se decreases both at high levels of Ca, *i.e*. over 12 g kg^{-1} of feed ration dry matter, as well as at its low level, below 4 g kg^{-1} of feed dry matter [Harrison and Conrad 1984]. The assimilability of Se decreases linearly with an increase of the content of sulfur in diet, at a concentration of Se between 2.1 to 7.0 kg^{-1} feed ration dry matter. The increase in the concentration of Se in diet to the level of 0.41 mg kg^{-1} dry matter of ration results in the increased assimilability of copper and iron, while the assimilability of zinc is reduced. A high share of *Faboideae* plants containing cyanogenic glicosides in the diet contributes to the decrease in assimilability of Se, while the assimilability of Se increases with an increase in the level of concentrates in the feed ration [Gierus *et al*. 2002].

Experiments conducted on cattle showed that Se in organic combinations is characterized by 120-200% higher bioaccessibility in comparison to Se supplied in mineral form as sodium selenite [Juniper 2008, Liao *et al*. 2011]. In the research conducted on goats, no differences between the assimilability of Se supplied in mineral and organic form were observed [Pavlata *et al*. 2011]. In research conducted by Stockdale *et al.* [2011], Se doses used were ten times higher (3 ppm in the diet dry weight) than those accepted by applicable standards. This was done in order to determine the influence of very high doses of Se administered in an organic form on the health of cows, and on obtaining milk rich in Se, characterized by pro-health properties for the consumers of milk. Based on the results obtained, the authors suggest that doses of Se administered in an organic form could be even up to 50 times higher than those that prevent deficiencies of this microelement in animals. Results of the research summarized by Weiss and Hogan [2005] and Juniper *et al*. [2006] demonstrate that both in blood plasma, as well as in cow milk, the content of Se was higher when selenium yeast was used in comparison to the supplementation of a cow's diet with sodium selenite. The activity of glutathione peroxidase (GPX-1) in cow blood was also significantly higher, which indicates positive redox status in these animals.

During pregnancy, Se passes through placenta to the foetus. In this way, a calf is supplied with a sufficient amount of Se even in the situation of moderate deficiency of this microelement in the mother's body [Gunter *et al*. 2003]. The concentration of Se in colostrum and milk depends on its amount supplied with feedstuff.

Supplementation of diets with Se

Se deficiency in cow diet is observed in all EU member states [Papas *et al*. 2008]. Polish soils are particularly poor in selenium and thus, more or less important deficiencies of this element may occur not only in animals, but also in humans [Wąsowicz *et al*. 2003]. On territories where the glacier reached, Se was leached out of the soil. Low concentration of Se is characteristic for acid soils which prevail in Poland. Irrespective of low concentration in general, in acid soils this microelement takes the form in which it is difficult to be absorbed by plants. Seleniates, easily assimilable by plants, are present in the soils with pH ≥7.0. In general, significant Se deficiency is observed in vegetable products. That is why industrial feeds are supplemented with different forms of Se in order to increase the concentration of this microelement in the diet to 0.5 mg kg^{-1} in diet dry matter. Sodium selenite or seleniate as well as Se-yeast are commonly used for this purpose. Se deficiency in diets is the cause of diseases in animals, in both clinical and subclinical form, and it is connected with no visible external signs of deficiency of this microelement.

Se concentration in animal tissues and body fluids may constitute an objective criterion for the assessment of deficiency. Under practical conditions, while assessing Se deficiency in animals, we usually refer to the concentration of this microelement in blood serum. Optimally, the concentration of Se in blood serum amounts to 0.07-

0.10 μg ml^{-1}. The concentration of 0.025 μg ml^{-1} is considered to be the border line of acceptable deficiency [Grace 1997], while the concentration of Se in the blood serum of newborn calves below 0.04 μg ml^{-1} indicates high deficiency of this microelement in mothers of calves.

In Poland, according to Andrzejewski [2012], the concentration of Se in the blood serum of cattle fed without supplementation is lower than 0.037 μg ml^{-1}, thus being two times lower than the lower limit of optimum reference range. As a result, very significant Se deficiency is observed in Poland. This fact is also confirmed by the results of author's own research on cows [Bagnicka, data unpublished]. Despite the fact that the diet was supplemented with mineral and vitamin mixture containing Se in the form of sodium seleniate, Se concentration of milk amounted to less than 10 ppb and was comparable with the concentration of this microelement in the milk of cows which were not supplemented with Se [Wang *et al*. 2009]. The results of research conducted by Brzóska *et al*. [2003] and Andrzejewski [2012] concerning Se content in plants grown in Poland showed that they are characterized by very low concentration of Se, not exceeding 60% of the content of this element specified in American tables of chemical standards for feedstuffs [NRC 2001]. That is why in Poland, there is a necessity to supplement cattle diets with preparations containing Se.

In the feed industry, inorganic Se compounds are used, in particular sodium seleniate (IV) (Na_2SeO_3), called sodium selenite, as well as sodium seleniate (VI) (Na_2SeO_4), commonly known as sodium seleniate. Due to the fact that salts are dissolved in the rumen, the formation of other compounds with the components of digested diet is possible. Some of the obtained complex compounds are not assimilated by ruminants. In order to prevent it, the encapsulation of salt molecules containing Se is practised, thanks to which they pass through the rumen and are dissolved in the small intestine. The attempts to use inorganic Se combinations in the form of nanoparticles, which are easily assimilated by the rumen microflora are also undertaken [Xun *et al*. 2012].

Se in organic combinations is added to diets in the form of selenium yeast (Se-yeast). Yeast growth in the environment rich in Se results in its successful incorporation into methionine and cystine; 90% of Se occurs in the form of Se-Met [Schrauzer 2006]. In EU, Se supplementation of cow diets is allowed both in the form of selenium seleniate as well as selenite [Annex to the notice of the Ministry of Agriculture and Rural Development MRiRW 2004] as well as selenium yeast *Saccharomyces cerevisiae CNCM I-3060* [Official Journal of the European Communities. Commission Regulation No. 1750/2006].

Influence of the form of Se supplement used on milk yield, properties and their concentration in milk

In the available literature, prevailing research results show the lack of the influence of Se supplement in organic form on milk production. However, few studies demonstrate the influence of selenium on production characteristics. This discrepancy is probably caused by a short research period of some studies as well as by the lack of information on Se deficit in cows existing before the start of the research. Nevertheless, Wang *et al*. [2009] showed, that Se supplementation of a cow's diet in the form of selenium yeast positively influenced milk production. The effect was obtained thanks to the positive influence of selenium yeast on fermentation in the rumen, which in turn resulted in the enhanced digestibility of nutrients contained in feed ration. According to the authors, the optimum dose of selenium yeast should be 300 mg/kg of ration dry matter. The results of research by Harrison *et al*. [2005] are worth particular attention. They conducted experiment within the period of 3 years on 30 commercial herds across three US states, with 2376 dairy cows in total. The replacement of mineral Se supplement in dairy cow diets by Sel-Plex selenium yeast resulted in productivity increase on average of 1.4 kg/cow daily, with constant fat content and an insignificant decrease in the percentage of protein contained in the milk; despite this fact, protein efficiency was higher.

The author's own research on dairy goats conducted throughout the whole lactation period (ca. 270 days) showed an increase in daily milk yield, in fat, total protein (including caseins) as well as lactose and thus, in dry matter and solid not fat in goats supplemented with the organic form of selenium compared with goats supplemented with sodium selenate [Bagnicka *et al*. 2014]. The content of the above mentioned components, as well as the content of free fatty acids and citric acid were not subject to change, *i.e.* they did not fall due to increased milk yield. However, the results obtained in the majority of studies performed in the short time period show that neither the form nor the amount of Se supplement used had a significant influence on milk yield and the content of fat, protein and lactose [Gievens *et al*. 2004, Calamari *et al*. 2011]. Stockdalle *et al*. [2011a,b] while using significantly ranging doses, *i.e.* 20-60 mg Se/d/cow in the form of selenium yeast, did not show differences in the daily yield of milk and its components either, after 2 as well as 6 weeks of the research period. Zhao *et al.* [2008] proved that Se supplementation of cow diets in the form of selenium yeast did not have an impact on the amount of dry matter consumed, on milk yield and the content of basic nutrients, but vit. E supplementation used simultaneously in the cow diet resulted in an increase of fat percentage and its output in milk, and additionally increased the protection of milk fat against oxidation. Results obtained by different authors show clearly that selenium supplementation of cow diet in the form of selenium yeast resulted in an increased concentration of Se in milk. The research performed on cows demonstrated that Se concentration of cow milk was by 34-90% higher compared to inorganic Se supplementation [Ortman and Pehrson, 1997, Juniper *et al.* 2006,]. Slavik *et al*. [2008] showed, based on their research performed on beef cows, that the content of Se of milk was 2.5-3 times higher while using Sel-Plex as a diet supplement as compared to the milk of cows which were not supplemented or in which their diet contained an equivalent amount of Se in the form of NaSe. In the milk of dairy cows fed with a diet supplemented with Sel-Plex, the content of Se was 1.5-2 times higher in comparison to NaSe supplementation [Phipps *et al*. 2007, Calamari *et al*. 2010]. It is worth emphasizing that while increasing NaSe supplementation over a certain level, Se content in milk did not increase, while supplementing the diet with Sel-Plex showed a significant increase in the content of Se of milk (respectively 42.3 *vs.* 60.2 ng/g of milk). Also Knowles *et al*. [1999], while using a Sel-Plex diet supplement, obtained 2-3 times higher concentration of Se in cow milk in comparison to the milk of respective animals fed with a NaSe supplemented diet. The author's own research on milk cows also confirms ca. 300% higher concentration of selenium in the milk of cows supplemented with organic selenium in comparison with cows supplemented with sodium selenite (9.90 *vs*. 30.65 ppb after 90 days of supplementation with selenium yeast) [Bagnicka, data unpublished]. An increased concentration of Se in the milk of cows supplied with Se in the form of selenium yeast was observed in all studies concerning the comparison of both forms of Se [Weiss 2005 – review paper, Givens *et al*. 2004, Juniper *et al*. 2006]. According to Juniper *et al*. [2006] and Doyle *et al*. [2011] linear relationship exsists between the amount of Se added to a diet in the form of selenium yeast and the concentration of Se in milk, blood, urine and faeces of the animals. This relationship is also confirmed by the result of research by Stockdale *et al*. [2011a,b] who found increase in Se concentration of ca. 80-300 µg/L.

The results of all studies performed on goats and concerning the comparison of the influence of Se added to diets in the form of Se-yeast and sodium selenite or selenate show unequivocally that Se-yeast supplementation influences in a more effective way the increase of the content of this microelement in goat milk [Pechova *et al*. 2007]. Moreover, Gresakova *et al*. [2013] demonstrated in the research conducted on calves that the supplementation of diet with Se-yeast in comparison with the equivalent amount of Se supplied in the form sodium selenite also resulted in a significantly higher content of this microelement in all tissues. Kachue *et al*. [2013], while supplementing the diet of goats in the last stage of pregnancy with Se in the form of L-selenomethionine (Se-Met) or sodium seleniate, obtained a slightly higher content of this element in colostrum in the case of supplementing the diet with Se in the form of Se-Met. The results of research conducted by Petrera *et al*. [2009] show that in goats, with the appropriate level of selenium, only Se-yeast supplementation may result in a further increase of its level of milk.

Grilli *et al*. [2013] demonstrated that Se supplementation of cow diet, in the form of sodium selenite, with 0.3 mg/kg of the ration dry matter, administered as microcapsules, passes into the milk in similar quantity, as it is the case while the same amount of Se is added to diet in the form of selenium yeast. Se administered in amount of 0.5 mg/kg of diet dry matter in the form of sodium selenite administered as microcapsules resulted in higher concentration of Se in cow blood and milk as compared to selenium yeast supplementation. Ortman and Pehrson [1999] called into question in their earlier research the possibility of obtaining the optimum concentration of Se in milk for consumers by supplementing cow diets with sodium seleniate, taking at the same time into account the US and EU limits (respectively 0.3 and 0.5 mg Se kg^{-1} diet dry matter).

Differences in the concentration of Se in milk of cows supplemented with mineral Se, without any processing and in an organic form, are conditioned by a diverse degree of utilization of this microelement. Calamari *et al*. [2010] proved that as little as 3.2% of Se added to the diet in the form of sodium selenite passed to milk, while Givens *et al*. [2004] estimated that this ratio amounted to 9.9-12.5%. Calamari *et al*. [2010] stated that while supplementing cow diets with selenium yeast, Se transfer to milk reached 16.3%. Ceballos *et al.* [2009], based on the performed meta-analysis, demonstrated that the degree of Se transfer from different dietary supplements falls within a broad range, conditioned by such factors as milk yield, amount of dry matter of diet consumed as well as lactation stage of cows. Increased absorption of Se from selenium yeast is related to the difference in absorption in the intestine, the specificity of the metabolic process after absorption as well as to the preference for absorption of Se from different sources by the mammary gland Calamari et al. [2010]. In selenium yeast, the dominating form is selenium combined with methionine (SeMet), which constitutes 63% of the total Se contained in this product in organic form. Cows are not able to synthetize Se-Met from the available mineral Se. Selenium contained in Se-Met is more easily assimilable, as it is incorporated in a nonspecific way in milk or body protein together with methionine. In this way, factors influencing the synthesis of milk proteins also influence the concentration of Se in milk. Calamari *et al*. [2010] state that in cows supplemented with selenium yeast, the increase of Se concentration in milk is influenced in as many as 60.3% by SeMet, while the influence of selenocysteine (SeCys) amounts only to 5.2-6.3%. This thesis constitutes the confirmation of results obtained in the earlier studies by Ceballos *et al*. [2009], who proved that Se supplementation of cow diet in the form of selenium yeast contributed, to a greater extent, to the increase of its concentration in milk in comparison to selenium added to cow diets in the same quantity but in a mineral form. The research on pigs also confirmed that the bioaccessibility of Se incorporated in milk protein amino acids is much higher than the bioaccessibility of Se administered in the inorganic form [McIntosh *et al*.2008]. Selenium administered in the form of chelates with amino acids is characterized by an increased efficiency in preventing chemically induced cancer in mice [Hu *et al*. 2008].

The increase in Se concentration of milk and dairy products is an interesting issue from the point of view of meeting the demand of consumers for this microelement. Se demand of an adult amounts to 55 μg/day, while from the point of view of Se health preventive properties, the quantity of Se should amount to 150-200 μg/day [McIntosh *et al*. 2008]. Stockdalle *et al*. [2011a,b] conducted research on the use of very high doses of Se in cow diet in order to determine animal tolerance and the possibility of maximum supplementation of milk with Se for consumer health prevention. It was demonstrated that the quantity of Se in organic combinations administered to cows might even be 50 times higher as compared to the quantity of this element, which is necessary to meet animal demand [Walker *et al*. 2010, Stockdale *et al*. 2011b].

Influence of Se supplementation of diet on ruminants health status

Harrison *et al*. [1984] demonstrated that the administration of Se in the amount of 0.1 mg kg^{-1} body weight to cows 3 weeks before the expected calving date contributed to the reduction by 70% of the incidence of inflammation of endometriosis and by ca. 40% of the incidence of polycystic ovaries. Duration of the inflammation of mammary gland was reduced by half and the incidence of placental retention was reduced to zero. Our own results of research on dairy goats conducted throughout the lactation period (ca. 270 days) showed decreased the number of somatic cells and increased the freezing point in milk goats fed diets supplemented with the organic form of selenium compared with milk goats fed diets supplemented with sodium selenate [Bagnicka *et al*. 2014]. The content of the abovementioned components demonstrate the improvement in health status of the udder and in physiological condition of dairy goats. The results of research conducted by Weiss *et al*. [1990] on commercial dairy cow herds demonstrated a negative relationship between the increase of Se concentration in animal blood and the number of somatic cells as well as the incidence of inflammations of the mammary gland. This thesis is confirmed by the results of research conducted over the period of 3 years on 30 commercial dairy cow herds [Harisson *et al*. 2005]. In 73% of herds, SCC in cow milk was reduced by 67%; the best results in the field of the increase of milk yield and the reduction of SCC were obtained in heifers. The results of research on supplementing cattle diets with different substances containing Se proved unequivocally that after obtaining optimum selenium status, increased efficiency of animal immunological system is observed, linked with the proper functioning of thyroid hormones and higher activity of proteins participating in neutralizing reactive oxygen species, generated during metabolism [Carlson *et al*. 2010].

Research on the level of cholesterol (LDL and HDL) of blood serum of lambs demonstrated that the administration per os of the supplement in the form of 1 ml 0.1% Na_2SeO_4, 3ml 10% $ZnSO_4$ and 60mg vitamin E daily/lamb during fattening resulted in the decrease of LDL level and an increase of HDL level in blood serum of the experimental group as compared with the concentration of these substances in blood serum of lambs from the control group [Gabryszuk *et al*. 2007].

It is worth emphasizing that supplementation of cow diet with Se contributes to proper development of fetuses and to increased activity of the immunological system, which results in the increase in immunity of newborn calves to infectious diseases and thus in the increased effectiveness of their rearing [Enjalbert 2009]. There are only limited informations concerning the influence of the level of Se in diets on the activity of glutathione peroxidase (GPx) in cow blood which plays the key role in keeping the oxidizing status on the optimal level. [Zhao *et. al*. 2008] proved that the addition of 0.3 mg Se/kg to the dry weight of cow diet and 10 000 I.U./cow/d vitamin E resulted in an increase the activity of GSH-Px in cow blood. Wang and Xu [2008] state that diet supplementation with inorganic Se in comparison with the addition of Se-yeast results in a lower activity of this enzyme. No differences in the activity of GPx depending on the form of Se supplied were stated in the majority of studies conducted. Only in a few studies was an increased GPx activity observed in the conditions of supplementing the diet with sodium selenite as compared to inorganic Se [Pavlata *et al*. 2011].

In the recent years, successful attempts to use single "shock" doses of Se in dairy cows have been undertaken. The doses significantly exceed animal demand for this microelement. Such treatment contributes to the increased activity of mammary gland secretory tissue, which is reflected in the increased milk yield, characterized at the same time by the desired higher content of Se [Ceballos *et al*. 2009].

Nutritive value of milk and meat after Se supplementation of ruminant diet

Milk is an important source of nutritive compounds in the human diet [Jóźwik *et al*. 2010b, Strzałkowska *et al*. 2009ab, 2010]. Milk of dairy cows fed the diet supplemented with selenium yeast is a recognized, good natural source of Se for consumers. Based on the results of research conducted on dairy cows fed with a diet supplemented with Se-yeast up to the level of ca. 50 mg Se kg^{-1} dry matter of ration, it was demonstrated that Se content in the obtained milk may reach 60 µg kg^{-1}, while after diet supplementation with sodium selenite, a lower concentration of Se in milk is obtained, reaching 20 µg kg^{-1} [Calamari 2010]. In the first case, the transfer of Se from the feed ration to milk reached 16.3%, while in the case of the dose with sodium selenite – only 3.2%. Summary of the results of research by other authors is presented in Table 1.

Table 1. Se level of the milk of cows fed with diets supplemented with Sel-Plex or NaSe [Calamari *et al*. 2010, Ceballos *et al*. 2009]

Item	Control group	Sel-Plex supplementation		NaSe supplementation	
Se added to ration (ppm/kg of dry matter)	0	0.3	0.5	0.3	0.5
Se consumed (mg/cow/d)	2.36	6.82	11.05	7.14	11.15
Se content of milk (µg/L)	16.2	42.3	60.2	22.8	25.8
Milk consumed (ml/person/d)	Se consumed, µg/person/d	Se consumed, µg/person/d		Se consumed, µg/person/d	
250	4.05	10.6	15.1	5.7	6.5

After supplementing the ratio with Se-yeast for beef cattle, the obtained concentration of Se in meat amounts to 223-263 µg kg^{-1} [Chladek *et al*. 2002]. To meet the minimum demand for this microelement of an adult, it is enough to consume 100 g of beef of this kind and drink a glass of milk [Gertig and Przysławski 2007]. The results of scientific studies demonstrated that Se has a positive effect on human cardiovascular system as well as prevents cancerous processes [Lei *et al*. 2009, Wu *et al*. 2010]. These properties constituted the basis for including food products with the increased concentration of Se, also milk and meat, in the "functional food category" [Reily 1998]. According to Gertig and Przysławski [2007], problems related to critically low level of Se consumed include circulatory failure, arrhythmia and enlarged heart muscle. The syndrome was called juvenile cardiomyopathy or Keshan disease. The list of diseases connected with moderate Se deficiency is very long, as it includes abnormalities in the functioning of heart, pancreas, liver, lymphadenitis, decreased in immunity, changes in skin and hair pigmentation, diabetes, stroke and some forms of cancer. Se deficiency is also diagnosed in patients suffering from mucoviscidosis, phenylketonuria, rheumatoid arthritis, renal failure, retinopathy and accelerated ageing of the body. In men, Se deficiency is the cause of spermatogenesis disorders. It is highly probable that one of the main direct causes of body homeostasis disorders is increased production and concentration of reactive oxygen species, i.e. oxidative stress [Jóźwik *et al*. 2010a, 2012]. As it was already proved, Se is contained in various enzymes taking part in the destruction of reactive oxygen species and restoring the balance in redox processes. The results of numerous studies confirm as well that Se deficiency increases the risk of cancer of liver, prostate, large intestine and lungs [Knekt *et al*. 1998, Rayman *et al.* 2005].

It should be emphasized that Se assimilability by the human body, from both beef and milk, is very high and in the case of milk reaches ca. 80% [Cabrera and Lorenzo 1996], while for beef it is 80-91% [Ramos *et al*. 2012]. Consumption of these products do not pose a threat of Se overdose, as maximum daily intake is relatively high and amounts to 90 μg d^{-1} for children, 280 μg d^{-1} for adult women and 400 μg d^{-1} for adult men [FAO/WHO Report 2004]. In addition, as it was already mentioned, in the case of animals, an overdose of Se administered in the organic form is practically impossible. It is highly probable that similar processes of assimilation of organic Se also occur in humans. It is necessary to note the type of selenium compounds in products of animal origin. Some compounds, for example Se-methyl-selenocysteine and its γ-glutamyl derivatives, exhibit strong antitumor effects. Other compounds, e.g. selenocystamine, stimulate cancer development [Spallholz *et al*. 2004]. Identification of these compounds constitutes one of significant problems waiting to be solved in a thorough and radical way.

Zhao *et. al.* [2008] found that addition of 0.3 mg Se/kg to the dry matter of cow diet and 10 000 I.U./cow/d vitamin E resulted not only in an increase of Se in milk, but also in the daily yield of CLA (c.9 t.11) in milk fat, together with a simultaneous increase in the number of polyunsaturated fatty acids (PUFA) and decrease in the number of saturated fatty acids (SFA). In addition, Gabryszuk *et al*. [2007] showed an increase in CLA concentration of the meat and liver of lambs supplemented with 1 ml 0.1% Na2SeO4, 3 ml 10% ZnSO4 and 60 mg vitamin E daily during fattening.

REFERENCES

1. ANDRZEJEWSKI M., 2012 – Influence of the form of selenium in diet on its status in cows and calves. Doctoral Dissertation. National Research Institute of Animal Production.
2. ARTHUR J.R., BROWN K.M., FAIRWEATHER-TAIT S.J., CREW H.M., 1997 – Dietary selenium: why do we need it and how much is enough? ***Nutrition and Food Science*** 6, 225-228.

3. BAGNICKA E., JARCZAK J., KABA J., KOŚCIUCZUK E., CZOPOWICZ M., SŁONIEWSKA D., KRZYŻEWSKI J., 2014 – Effect of organic vs. inorganic selenium supplementation on milk production traits of Polish dairy goats. European Regional Conference on Goats, 8-12 April, Debrecen (Hungary) - Oradea (Romania).
4. BAUM M.K., CAMPA A., MINGUEZ BURBANO M.J., BURBANO X., SHOR-POSNER G., 2001 – Role of selenium in VIH/AIDS, in: Hatfield D.L. (Ed.). Selenium in Molecular Biology and Role in Human Health. Kluwer Academic Publisher.
5. BRZEZIŃSKA-ŚLEBODZIŃSKA E., MILLER J.K., QUIGLEY J.D., MOORE J.R., MADSEN F.C., 1994 – Antioxidant status in dairy cows supplemented prepartum with witamin E and selenium. ***Journal of Dairy Science*** 77, 3087-3095.
6. BRZÓSKA F., BRZEZIŃSKI W., BRZÓSKA B., 2003 – Mineral nutrients in Polish feedstuffs. Part I. Fodder plants. ***Annals of Animal Science*** 3, 115-126.
7. CABRERA C.C., LORENZO M.L., 1996 – Chromium, copper, iron, manganese, selenium and zinc levels in dairy products: in vitro study of absorbable fractions. ***International Journal of Food Sciences and Nutrition*** 47, 4, 331-339.
8. CALAMARI L., PETRERA F., ABENI F., BERTIN G., 2011 – Metabolic and hematological profiles in heat stress lactating dairy cows fed diets supplemented with different selenium sources and doses. ***Livestock Science*** 142, 128-137.
9. CALAMARI L., PETRERA F., BERTIN G., 2010 – Effects of either sodium selenite or Se-yeast (ScCNCM I-3060) supplementation on selenium status and milk characteristics in dairy cows. ***Livestock Science*** 128, 154-165.
10. CARLSON B.A., MINHYUK YOO M-H., SHRIMALI R.K., IRONS R., GLADYSHEV V.N., HATFIELD D.L., PARK J.M., 2010 – Role of selenium containing proteins in T-cell and macrophage function. ***Proceedings of the Nutrition Society*** 69, 300-310.
11. CEBALLOS A., SANCHEZ J., STRYHN H., MONTGOMERY J.B., BARKEMA H.W., WICHTEL, 2009 – Meta-analysis of the effect of oral selenium supplementation on milk selenium concentration in cattle. ***Journal of Dairy Science*** 92, 324-342.
12. CHLADEK G., KOUTNIK V., SIMEK J., STEINHAUSER L., 2002 – Selenium content of beef and its effect on drip and fluid losses. ***Animal Science Papers and Reports*** 20, 1, 49-53.
13. COMBS G.F., COMBS S.B., 1986 – The role of selenium in nutrition. Orlando, FL: Academic Press.
14. DEAGEN J.T., BEILSTEIN M.A., WHANGER P.D., 1991 – Chemical forms of selenium in selenium containing proteins from human plasma. ***Journal of Inorganic Chemistry*** 41, 261-268.
15. Official Journal of the European Communities. 2006 – Commission Regulation (EC) No. 1750/2006 of 27 November 2006 (English version), L. 330, 28.11.2006, pp. 9-11.
16. ENJALBERT F., 2009 – The relationship between trace elements status and health in calves. ***Revue de Médecine Vétérinaire*** 160, 429-435.
17. ENJALBERT F., LEBRETON P., SALAT O., 2006 – Effects of copper, zinc and selenium status on performance and health in commercial dairy and beef herds: retrospective study. ***Journal of Animal Physiology and Animal Nutrition*** 90, 459-466.
18. FAO/WHO, 2004 – Vitamin and mineral requirements in human nutrition: Report of a Joint FAO/WHO Expert Consultation, 2nd edn. Food and Agriculture Organization/World Health Organization, Bangkok, Thailand.
19. GABRYSZUK M., CZUDERNA M., BARANOWSKI A., STRZAŁKOWSKA N., JÓŹWIK A., KRZYŻEWSKI J., 2007 – The effect of diet supplementation with Se, Zn and vitamin E on cholesterol, CLA and fatty acid contents of meat and liver of lambs. ***Animal Science Papers and Reports*** 25, 25-33.

20. GABRYSZUK M. HORBAŃCZUK K.,KLEWIEC J., 2009 – Rearing, fattening performance and slaughter indicators of lambs after selenium, zinc and vitamin E supplementation. ***Archiv Fur Tierzucht-Archives of Animal Breeding*** 52, 309-320.
21. GERLOF B., 1992 – Effect of selenium supplementation on dairy cattle. ***Journal of Animal Science*** 12, 3934-3940.
22. GERTIG H., PRZYSŁAWKI J., 2007 – Food science – an outline. PZWL, Warszawa.
23. GIERUS M., SCHWARZ F.J., KIRCHGESSNER M., 2002 – Selenium supplementation and selenium status of dairy cows fed diets based on grass, grass silage or maize silage. ***Journal of Animal Physiology and Animal Nutrition*** 86, 74-82.
24. GIVENS D.I., ALLISON R., COTTRILL B., BLAKE J.S., 2004 – Enhancing selenium content of bovine milk through alteration of the form and concentration of selenium in the diet of dairy cows. ***Journal of the Science of Food and Agriculture*** 84, 811-817.
25. GRACE N.D., 1997 – Use of biochemical criteria to diagnose trace element deficiencies in sheep and cattle. Proceedings of the 9th Internationa Conference on Animal Production, Berlin, 11-14.09. 1997. Verlag Stuttgart.
26. GRESAKOVA L., COBANOVA K., FAIX S., 2013 – Selenium retention in lambs fed diets supplemented with selenium from inorganic or organic sources. ***Small Ruminant Research*** 111, 76-82.
27. GRILLI E., GALLO A., FUSTINI M., FANTINATI P., PIVA A., 2013 – Microencapsulated sodium selenite supplementation in dairy cows: effects on selenium status. ***Animal*** 7, 12, 1944-1949. DOI: http://dx.doi. org/10.1017/S1751731113001547.
28. GUNTER S.A., BECK P.A., PHILLIPS J.M., 2003 – Effects of supplementary selenium source on the performance and blood measurements in beef cows and their calves. ***Journal of Animal Science*** 81, 856-864.
29. HARRISON G.A., TRICARICO J.M., ELLIOT S.A. 2005 – Effect of Sel-Plex supplementation on milk production, composition, and somatic cell counts of lactating dairy cows in commercial dairy herds: herd and individual cow responses. ***Journal of Dairy Science*** 88 (1), 60.
30. HARRISON J.H., CONRAD H.R., 1984 – Effect of calcium on selenium absorption by the non-lactating dairy cow. ***Journal of Dairy Science*** 67, 1860-1864.
31. HU Y., MCINTOSH G.H., LE LEU R.K., WOODMAN R., YOUNG G.P., 2008 – Suppresion of colon oncogenesis by selenium – enriched milk proteins: Apoptosis and K-ras mutations. ***Cancer Research*** 68,4936-4944.
32. IP C., DONG Y., 2001 – Methylselenocysteine modulates cell proliferation and apoptosis biomarkers in premalignant lesions of the rat mammary gland. ***Anticancer Research*** 21, 863-867.
33. JÓŹWIK A., BAGNICKA E., STRZAŁKOWSKA N., ŚLIWA-JÓŹWIK A., HORBAŃCZUK K., COOPER R.G., PYZEL B., KRZYŻEWSKI J., ŚWIERGIEL A.H., HORBAŃCZUK J.O., 2010a – The oxidative status of milking goats after *per os* administration of N-acetylcysteine. ***Animal Science Papers and Reports*** 28 (2), 143-152.
34. JÓŹWIK A., STRZAŁKOWSKA N., BAGNICKA E., ŁAGODZIŃSKI Z., PYZEL B., CHYLIŃSKI W., CZAJKOWSKA A., GRZYBEK W., SŁONIEWSKA D., KRZYŻEWSKI J., HORBAŃCZUK J.O., 2010b – The effect of feeding linseed cake on milk yield and milk fatty acid profile in goats. ***Animal Science Papers and Reports*** 28 (3), 245-251.
35. JÓŹWIK A., KRZYŻEWSKI J., STRZAŁKOWSKA N., POŁAWSKA E., BAGNICKA E., WIERZBICKA A., NIEMCZUK K., LIPIŃSKA P, HORBAŃCZUK J.O., 2013 – Relations between the oxidative status, mastitis, milk quality and disorders of reproductive functions in dairy cows - a review. ***Animal Science Papers and Reports*** 30, 297-307.
36. JUGOLA E., HAKKARAINEN J., SALONIEMI H., 1996 – Blood selenium, vitamin E, witamin A and β-carotene concentrations and udder health, fertility treatments and fertility. ***Journal of Dairy Science*** 79, 838-845.

37. JUNIPER D.T., PHIPPS R.H., GIVENS D.I., JONES A.K., GRIN C., BERTIN G., 2008 – Tolerance of ruminant animals to high dose in-feed administration of a selenium-enriched yeast. ***Journal of Animal Science*** 86, 197-204.
38. JUNIPER D.T., PHIPPS R.H., JONES A.K., BERTIN G., 2006 – Selenium supplementation of lactating dairy cows: Effect of selenium concentration in blood, milk, urine and feces. ***Journal of Dairy Science*** 89, 3544-3551.
39. KACHUE R., MOEINI M.M., SOURI M., 2013 – The effect of dietary organic and inorganic selenium supplementation on serum Se, Cu, Fe and Zn status during the late pregnancy in Merghoz goats and their kids. ***Small Ruminant Research*** 110, 20-27.
40. KNEKT P., MARNIEMI J., TEPPO L., HELIÖVAARA M., AROMAA A., 1998 – Is low selenium status a risk factor for lung cancer? ***American Journal of Epidemiology*** 148, 10, 975-982.
41. KNOWLES S.O., GRACE N.DE., WURMS K., LEE J., 1999 – Significance of amount and form of dietary selenium on blood, milk and casein selenium concentrations in grazing cows. ***Journal of Dairy Science*** 82, 429-437.
42. KORNILUK K., CZAUDERNA M., KOWALCZYK J., 2007 – The influence of dietary conjugated linoleic acid isomers and selenized yeast on the fatty acid profile of the spleen, pancreas and kidneys of rats. ***Journal of Animal and Feed Sciences*** 16, 121-139.
43. KUREK Ł., KLECZKOWSKI M., LUTNICKI K., BANACH A., GOŁYŃSKI M., 2011 – Participation of selenium in the course of chosen dairy cattle diseases. ***Życie Weterynaryjne*** 86, 604-608.
44. LIAO S.F, BROWN K.R., STROMBERG A.J., BURRIS W.R., BOLING J.A., MATTHEWS J.C., 2011 – Dietary supplementation of selenium in inorganic and organic forms differentially and commonly alters blood and liver selenium concentrations and liver gene expression profiles of growing beef heifers. ***Biological Trace Element Research*** 140, 151-169.
45. MAHIMA A., KUMAR V., AMIT K., ANU R., VINOD K., DEBASHIS R., 2012 – Inorganic versus organic selenium supplementation: A review. ***Pakistan Journal of Biological Sciences*** 15, 418-425.
46. MCINTOSH G.., DUNSHEA F., MCKENNA T., WALKER G., HU Y., HEARD J., STOCKDALE R., SHIELDS M., YOUNG G., DOYLE P., 2008 – A dairy source of organic selenium for health and wellbeing. ***Food Australia*** 60, 132-134.
47. MISTRY H.D., BROUGHTON PIPKIN F., REDMAN C.W.G., POSTON L., 2012 – Selenium in reproductive health. ***American Journal of Obstetrics and Gynecology*** 206, 21-30.
48. MUELLER E., MILLER J., RAMSEY N., DELOS R., MADSEN F., 1989 – Effects of vitamin E and excess iron on placental retention and subsequent milk yield in dairy cow. ***Journal of Dairy Science*** 72 (Suppl.), 564.
49. MUTH O.H., OLDFIELD J.E., REMMERT L.F., SCHUBERT J.R., 1958 – Effects of selenium and vitamin E on white muscle disease. ***Science*** 128, 1090-1095.
50. NEVE J., 1996 – Selenium as a risk factor for cardiovascular disease. ***Journal of Cardiovascular Risk*** 3, 42-47.
51. OLDEREID N.B., THOMASSEN Y., PURVIS K., 1998 – Selenium in human male reproductive organs. ***Human Reproduction*** 13, 2172-2176.
52. ORTMAN K., PEHRSON B., 1997 – Selenite and selenium yeast as feed supplements for dairy cows. ***Journal of Veterinary Medicine*** A, 44, 373-380.
53. ORTMAN K., PEHRSON B., 1999 – Effect of selenate as a feed supplement in dairy cows in comparison to selenite and selenium yeast. ***Journal of Animal Science*** 77, 3365-3370.
54. PAPPAS A.C., ZOIDIS E., SURAI P.F., ZERVAS G., 2008 – Selenoproteins and maternal nutrition. ***Comparative Biochemistry and Physiology*** B 151, 361-372.

55. PAVLATA L., MISUROVA L., PECHOVA A., DVORAK R., 2011 – The effect of inorganic and organically bound forms of selenium on glutathione peroxidase activity in the blond of goats. ***Veterinarni Medicina*** 56, 75-81.
56. PECHOVA A., MISUROVA L., PAVLATA L., DVORAK R., 2007 – Monitoring of changes in selenium concentration in goat milk during short – term supplementation of various forms of selenium. ***Biological Trace Element Research*** 121, 180-191.
57. PETRERA F., CALAMARI L., BERTIN G., 2009 – Effect of either sodium selenite or Se-yeast supplementation on selenium status and milk characteristics in dairy goats. ***Small Ruminant Research*** 82, 130-138.
58. PHIPPS R.H., GRANDISON A.S., JONES A.K., JUNIPER D.T., RAMOS-MORALES E., BERTIN G., 2008 – Selenium supplementation of lactating dairy cows: effects on milk production and total selenium content and speciation in blood, milk and cheese. ***Animal*** 2, 11, 1610-1618.
59. RAMOS A., CABRERA M.C., SAADOUN A., 2012 – Bioaccessibility of Se, Cu, Zn and Fe, and heme iron content in unaged and aged meat of Hereford and Braford steers fed pasture. ***Meat Science*** 91, 116-124.
60. FAO/WHO Report, 2004 – Common report of FAO/WHO experts on human demand for vitamins and minerals (in English) 2nd ed. Geneva. World Health Organization, ss. 194-216.
61. RAYMAN M.P., 2005 – Selenium in cancer prevention: review of the evidence and mechanism of action. ***Proceedings of the Nutrition Society*** 64, 527-542.
62. RAYMAN M.P., 2004 – The use of high-selenium yeast to raise selenium status: how does it measure up? ***British Journal of Nutrition*** 92, 557-573.
63. SCHRAUZER G.N., 2006 – Selenium yeast: Composition, quality, analysis, and safety. ***Pure and Applied Chemistry*** 78, 105-109.
64. SCHRAUZER G.N., 2009 – Selenium and selenium-antagonistic elements in nutritional cancer prevention. ***Critical Review in Biotechnology*** 29, 10-17.
65. SEKO Y., SAITI Y., KITAHARA J., IMURA N., 1989 – Active oxygen generation by the reaction of selenite with reduced glutathione in vitro. In: Wendel A. (Ed.). Selenium in Biology and Medicine. Springer-Verlag, Berlin, Germany, pp. 33-70.
66. SHRIFT A., 1973 – Metabolism of selenium by plants and microorganisms. In: Klaiman D.L., Günter W.H.H. (Eds.) Organic S1elenium Compounds: Their Chemistry And Biology. John Wiley and Sons. New York, pp. 763-814.
67. SLAVIK P., ILLEK J., BRIX M., HLAVICOVA J., RAJMON R., JILEK F.. 2008 – Influence of organic versus inorganic dietary selenium supplementation on the concentration of selenium in colostrum, milk and blood of beef cows. ***Acta Veterinaria Scandinavica*** 2008, 50, 43-55.
68. SPALLHOLZ J.E., PALACE V.P., REID T.W., 2004 – Methioninase and selenomethionine but not Se-methylselenocysteine generate methylselend and superoxide in an in vitro chemiluminescent assay: implications for the nutritional carcinostatic activity of selenoamino acids. ***Biochemical Pharmacology*** 67, 547-554.
69. STOCKDALE C.R., GILL H.S., 2011a – Effect of duration and level of supplementation of diets of lactating dairy cows with selenized yeast on selenium concentrations in milk and blood after the withdrawal of supplementation. ***Journal of Dairy Science*** 94, 2351-2359.
70. STOCKDALE C.R., SHIELDS P.M., MCKENNA A., WALKER G.P., DUNSHEA F.R., DOYLE P.T., 2011b – Selenium levels in cows fed pasture and concentrates or a total mixed ration and supplemented with selenized yeast to produce milk with supra-nutritional selenium concentrations. ***Journal of Dairy Science*** 94, 262-272.
71. STRZAŁKOWSKA N., JÓŹWIK A., BAGNICKA E., KRZYŻEWSKI J., HORBAŃCZUK J.O., 2009a – Studies upon genetic and environmental factors affecting the cholesterol content of cow milk. II. Effect of silage type offered. ***Animal Science Papers and Reports*** 27 (3), 199-206.

72. STRZAŁKOWSKA N., JÓŹWIK A., BAGNICKA E., KRZYŻEWSKI J., HORBAŃCZUK K., PYZEL B., HORBAŃCZUK J.O., 2009b – Chemical composition, physical traits and fatty acid profile of goat milk as related to the stage of lactation. ***Animal Science Papers and Reports*** 27 (4), 263-272.
73. STRZAŁKOWSKA N., JÓŹWIK A., BAGNICKA E., KRZYŻEWSKI J., HORBAŃCZUK K., PYZEL B., SŁONIEWSKA D., HORBAŃCZUK J.O., 2010 – The concentration of free fatty acids in goat milk as related to the stage of lactation, age and somatic cell count. ***Animal Science Papers and Reports*** 28 (4), 389-396.
74. SURAI P.F., 2006 – Selenium in food and feed, selenomethionine and beyond. Selenium in nutrition and health. Nottingham University Press. Nottingham U.K., pp. 151-212.
75. TINGGI U., 2005 – Selenium toxity and its adverse health effects. Ed: Taylor and Francis, Boca Raton, Precoly R., Watson R.R. Reviews in Food and Nutrition Toxicity. FL., pp. 29-55.
76. VILLAR D., ARTHUR J.R., GONZALEZ J.M., PALLARES F.J., CARSON T.I., 2002 – Selenium status in cattle: interpretation of laboratory results. ***Bovine Practice*** 1, 73-80.
77. WALKER G.P., DUNSHEA F.R., HEARD J.W., STOCKDALE C.R., DOYLE P.T., 2010 – Output of selenium in milk, urine and feces is proportional to selenium intake in dairy cows fed total mixed ration supplemented with selenium yeast. ***Journal of Dairy Science*** 93, 4644-4650.
78. WANG C., LIU Q., YANG W.Z., DONG Q., YANG X.M., HE D.C., ZHANG P., DONG K.H., HUANG Y.X., 2009 – Effects of selenium yeast on rumen fermentation, lactation performance and feed digestibility in lactating dairy cows. ***Livestock Science*** 126, 239-244.
79. WANG Y.B., XU B.H., 2008 – Effect of different selenium source (sodium selenite and selenium yeast) on broiler chickens. ***Animal Feed Science and Technology*** 144, 306-314.
80. WĄSOWICZ W., GROMADZIŃSKA J., RYDZYŃSKI K., TOMCZAK J., 2003 – Selenium status of low-selenium area residents: Polish experience. ***Toxicology Letters*** 137 (1-2), 95-101.
81. WEISS W. P., HOGAN J.S., 2005 – Effect of selenium source on selenium status, neutrophil function, and response to intramammary endotoxin challenge of dairy cows. ***Journal of Dairy Science*** 88, 4366-4374.
82. WEISS W.P., 2005 – Selenium sources for dairy cattle. Proc. Tri-State Dairy Nutrition Conference., Ft.Wayne, IN. The Ohio State Univ. Columbus, pp. 61-72.
83. WRIGHT P.L., BELL M.C., 1966 - Comparative metabolism of selenium and tellurium in sheep and swine. ***American Journal of Physiology*** 211, 6-10.
84. XUN W., SHI L., YUE W., ZHANG C., REN Y., LIN Q., 2012 – Effect of high-dose nano-selenium and selenium-yeast on feed digestibility, rumen fermentation and purine derivatives in sheep. ***Biological Trace Element Research*** 150, 130-136.
85. ZHAO L. LIU, DE P.YANG, PU CHEN, WEI X. DONG, DONG M., WANG, 2008 – Supplementation with selenium and vitamin E improves milk fat depression and fatty acid composition in dairy cows fed fat diet. Asian-Australasian ***Journal of Animal Sciences*** 21,6, 838-844.