Selenium Metabolism in Cattle: Maternal Transfer of Selenium to Newborn Calves at Different Selenium Concentrations in Dams

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Abstract

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The aim of the study was to investigate the selenium metabolism in the maternal transfer of selenium to newborn calves. For a study, a total of 24 high-pregnant dairy cows at dry-off from two herds with different selenium status were used. While Herd I cows suffered from selenium deficiency, selenium status in cows of Herd II were adequate. Herd I cows were divided into three groups: E1, E2 and C. Selenium-and-vitamin supplement (Selevit inj. a.u.v.) was administered intramuscularly to cows of the E1 group 4 weeks before expected parturition, and the same supplement was administered to cows of the E2 group 8 and 4 weeks before expected parturition. The C group cows were controls, and received no supplement. On parturition days, samples of blood and of the first colostrum were collected from all of the cows. Blood samples were also collected from their newborn calves before they were given any colostrum. A statistically significantly higher selenium blood concentrations ($p < 0.05$) on parturition days were found in the E2 group cows compared with the control group (61.63 ± 8.23 $\mu g \cdot l^{-1}$ and 41.13 ± 11.08 $\mu g \cdot l^{-1}$, respectively). Higher selenium blood concentrations were also found among cows in the E1 group. A similar trend was ascertained when a comparison between calves of groups E1 and E2 (63.96 ± 20.10 $\mu g \cdot l^{-1}$ and 66.86 ± 15.53 $\mu g \cdot l^{-1}$) and group C calves (51.98 ± 16.02 $\mu g \cdot l^{-1}$) was made. There was, however, no demonstrable difference in the glutathione peroxidase (GSH-Px) activity between groups from Herd I. Selenium concentrations in Herd II cows and their calves were 264.17 ± 48.71 $\mu g \cdot l^{-1}$ and 222.34 ± 52.95 $\mu g \cdot l^{-1}$, respectively. Regression and correlation analyses demonstrated a statistically very close relationship ($p < 0.01$) between selenium blood concentrations of dams and their calves and blood GSH-Px activity of dams and their calves ($y = 0.6489x + 28.049$; $r = 0.91$, and $y = 0.8033x + 91.169$; $r = 0.93$, respectively). Because no significant correlation between blood and colostrum concentrations in cows was demonstrated ($r = 0.21$), colostrum should not be considered a suitable medium for the evaluation of selenium status in cows. The results showed the need to provide for a sufficient selenium saturation of dams also from the point of view of preventing selenium deficiency in calves.

glutathione peroxidase, colostrum, dairy cow, placental transfer, prevention

Selenium (Se) deficiency has been linked to a number health problems in a majority of animal species, including nutrition myopathy, exudative diathesis, pancreatic fibrosis, reproductive disorders, erythrocytic haemolysis, immunity function disorders, and even cancer and cardiovascular diseases in people (Shamberger 1983; Salonen and Huttunen 1986; Comstock et al. 1992; Underwood and Suttle 1999; Holovská et al. 2003; Leng 2003). The best-known clinical form of Se deficiency in cattle is nutritional muscular dystrophy. Other symptoms of Se deficiency in cattle include reproductive disorders (retained placenta, higher embryo mortality, higher incidence of endometritis and ovarian cysts), higher somatic cell counts in milk and mastitis, reduced resistance to, and a higher incidence of, respiratory and gastrointestinal infections in calves (Blood and Radostits 1989; Smith 1996; Underwood and Suttle 1999;

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Pavlata et al. 2001a). Higher Se concentration in calves has a positive effect on the prevention of muscle dystrophy and on thermoregulation abilities, because by influencing the thyroid gland hormonal activity it facilitates the maintenance of body temperature particularly of individuals born during cold spells (Cartens 1994).

For the evaluation of the Se status, results of laboratory analysis of biological material collected in herds investigated are decisive. The Se status is most frequently assessed either directly from Se concentration levels, or indirectly from GSH-Px activity assessment (Harapin et al. 2000; Pavlata et al. 2000; 2001b; 2002a).

In the Czech Republic, the incidence of Se deficiency in cattle is high (Pavlata et al. 2002a). Selenium deficiency is most frequently diagnosed in heifers, feeder bulls, grazed beef cattle and dairy cows in the dry period. In this unfavourable situation, parenteral administration of selenium-and-vitamin supplements is often used in this country. Such supplements are used both for the therapy of deficiency and as a preventive measure, particularly for high-pregnant cows in the prepartum period (Pavlata et al. 2001c; 2002b). Because selenium is transferred through the placenta to the foetus, an adequate supply of selenium to cows is also very important from the point of view of meeting the needs of their calves in the period of their intrauterine development (Abdelrahman and Kincaid 1993; 1995; Enjalbert et al. 1999).

For that reason, the aim of the present study was to investigate the selenium metabolism in the maternal transfer of selenium to newborn calves following an administration of a selenium-and-vitamin supplement to dams in the prepartum period.

Materials and Methods

A total of 24 dairy cows from two herds with different selenium status were used in the present study.

Herd I (selenium deficiency identified): A herd of Czech Red-and-White dual purpose breed crossed with Red Holsteins up to 80% on a farm with loose housing and cubicle beds with bedding for 400 cows was used in the study. Previous tests showed selenium deficiency in this herd (whole blood selenium concentration < 45 $\mu g \cdot l^{-1}$). A total of 19 late-pregnant cows from among cows at dry-off were randomly divided into three groups for the tests:
1. Control group **C** (5 cows): without any selenium supplementation prepartum.
2. Experimental group **E1** (7 cows): SELEVIT inj. a. u. v. (Natrii selenis 2.2 mg, Tocoferoli acetas 25 mg in 1 ml solution) was administered intramuscularly in the dry-off period (4 weeks prepartum) in a single dose of 20 ml (i.e. 44 mg Natrii selenis) as recommended by the manufacturer for prepartum administration.
3. Experimental group **E2** (7 cows), SELEVIT inj. a. u. v. was repeatedly administered intramuscularly at dry-off (8 and 4 weeks prepartum), i.e. a total of 88 mg Natrii selenis was administered.

The cows were fed total mixed ration consisting of 15 kg canned roughage (5 kg maize silage and 10 kg hay silage) and 4 kg meadow hay. Three weeks prepartum, 3.5 kg of grain mixed feed (wheat, barley, extracted soya meal, rape seed cake, limestone) were added to the diet.

Newborn calves of the dams were also included in the trial.

Herd II (sufficient selenium concentrations): Five cows and their newborn calves from a herd where sufficient selenium concentrations were found in previous tests (whole blood Se concentrations >150 $\mu g \cdot l^{-1}$) were included in the present study of maternal transfer of selenium in order to provide for a better assessment and interpretation of the results obtained.

Blood samples from all the cows in Herds I and II were collected on parturition day. Samples of the cows' first colostrum and blood samples of newborn calves before they were fed any colostrum were collected and tested. Samples of whole heparinized blood were used to determine of glutathione peroxidase (GSH-Px) activity and selenium concentration levels. Selenium concentrations were also determined in colostrum.

For selenium concentration tests, specimens of whole heparinized blood and colostrum were mineralized in a closed system by microwave digestion equipment at the presence of HNO_3 and H_2O_2 (MILESTONE MLS – 1200). The mineralised sample was prepared for the determination of selenium by evaporation, dissolution in water in which 20% HCl was added. These samples were then tested for selenium concentrations by the AAS hydride technique using the UNICAM 939 AA spectrometer. The same samples of whole heparinized blood were analyzed for GSH-Px activity by the Paglia and Valentine method (1967) using the RANSEL set (Randox) and the COBAS MIRA automatic analyzer.

Basic statistical parameters of results (means, standard deviations) in individual groups, the regression and correlation analysis of results, and a comparison between results of groups (using the two-tailed Student t-test after F-test for equality of variations) were computed using Microsoft Excel 97.

Table 1
Selenium concentrations (μg·l^{-1}) in whole blood of cows and calves from individual groups studied in Herd I
(Se deficiency herd) and Herd II (with sufficient Se status)

		Cows (Mean ± SD)	Calves (Mean ± SD)
I-C	(n = 5)	41.13 ± 11.08	51.98 ± 16.02
I-E1	(n = 7)	51.64 ± 16.42	63.96 ± 20.10
I-E2	(n = 7)	61.63 ± 8.23	66.86 ± 15.53
II	(n = 5)	264.17 ± 48.71	222.34 ± 52.95

Results and Discussion

Following the administration of Selevit inj., higher selenium concentrations were found in samples collected on parturition day from cows in experimental groups (E1 a E2) compared with controls (Table 1). The difference was statistically significant for cows in group E2 ($p < 0.05$). In spite of increased blood selenium concentration, selenium deficiency was not corrected entirely: the maximum blood selenium concentrations in cows of groups E1 and E2 increased to 70.96 and 78.28 μg·l^{-1} respectively, and, in calves from the two groups, to 101.20 and 84.56 μg·l^{-1}, respectively.

This shows that not even a repeated administration of a selenium-and-vitamin supplement to high-pregnant cows at the dose used was able to sufficiently correct selenium deficiency. This, to some extent, is contrary to the results obtained in our previous study (Pavlata et al. 2002b), which suggested that selenium deficiency may be sufficiently corrected by the administration of selenium-and-vitamin supplements. It must be borne in mind, however, that initial mean concentrations in individual experimental groups in the previous study referred to were 59.5 μg·l^{-1}, 66.6 μg·l^{-1} and 74.2 μg·l^{-1}, respectively, compared with less than 45 μg·l^{-1} in the present study. These results indicate that it is important to always base prevention and therapy of selenium deficiency on good knowledge of selenium data in the herd investigated, and to adjust the type of selenium administration and its doses accordingly.

Table 2
GSH-Px activity (μkat·l^{-1}) in whole blood of cows and calves in different groups of animals examined

		Cows (Mean ± SD)	Calves (Mean ± SD)
I-C	(n = 5)	269.80 ± 90.56	348.30 ± 124.22
I-E1	(n = 7)	240.30 ± 49.42	276.06 ± 77.77
I-E2	(n = 7)	241.86 ± 51.81	280.45 ± 75.17
II	(n = 5)	1056.63 ± 202.91	1010.46 ± 236.25

The differences in selenium concentrations in cows from different groups were not, however, associated with corresponding changes in GSH-Px activity (Table 2). GSH-Px activity in experimental groups remained the same as in the control group, i.e., as it was at the beginning of the study.

These results seem to confirm the theory that the onset of increased GSH-Px activity in deficiency animals receiving supplemental selenium is considerably delayed, and that GSH-Px activity is an indication of a long-term level of selenium intake by animals, or, in other words, of the level of biologically active selenium in the organism, while blood selenium levels reflect immediate selenium intake levels more promptly. Selenium is being

incorporated into erythrocyte GSH-Px during erythropoiesis, which means that the enzyme activity depends on the presence of utilizable selenium during the production of erythrocytes. Increased GSH-Px activity after selenium supplementation is usually observed for a period of 90 to 120 days (Hoffman et al. 1978; Ková č and Sankari 1988; Gerlof 1992; Enjalbert et al. 1999). It clearly follows that if necessary GSH-Px activity levels in blood are to be attained, an adequate supply of selenium to cows needs to be provided well in advance to allow some time for the biological effect of selenium through GSH-Px activity to take place. In this experiment, even an 8-week period may not be sufficient to allow for a higher GSH-Px activity in dams and their calves.

Table 3
Correlation coefficients (r) between Se concentrations and GSH-Px activity in whole blood of dams and their calves in Herds I and II (** $p < 0.01$; * $p < 0.05$)

	Se Calves I+II	Se Calves I	GSH-Px Calves I+II	GSH-Px Calves I
Se Cows I+II	0.91**			
Se Cows I		0.59*		
GSH-Px Cows I+II			0.93**	
GSH-Px Cows I				0.57*

The assessment of selenium concentrations and GSH-Px activity showed that selenium status in newborn calves corresponded quite closely to selenium status in the dams. It follows from results in Tabs 1 and 2 that in Herd I (where selenium deficiency was found), the mean selenium concentration and GSH-Px activity of newborn calves were higher that those of the dams (by 20% on average). In Herd II with adequate selenium saturation, the mean selenium concentration and GSH-Px activity in calves were slightly lower, averaging 85% and 96% of selenium concentration and GSH-Px activity of the dams, respectively. These differences in selenium concentrations and GSH-Px activity between calves and dams were not, however, statistically significant. The correlation analysis revealed a statistically significant relationship between blood Se concentrations and GSH-Px activity of dams and their calves on parturition day (Table 3).

It also follows from the data that the computed level of significance of the parameters would be lower if results from only Herd I were used in the calculation. This shows that there is a well-defined relationship between the parameters (Fig. 1 and 2) although it may not be an extremely close one. On the basis of a regression analysis of the relationship between selenium concentrations and GSH-Px activity in cows and in their calves, regression line equations were computed (Fig. 1 and 2). If a specific blood Se concentration of a cow is then used in the equation (e.g. 100 μg·l^{-1}), the expected blood Se concentration of the calf can be calculated. In this example, the results would be 92.94 μg·l^{-1}. The very small difference between the two figures indicates that, from the practical point of view, selenium concentration levels in dams during pregnancy are decisive for Se concentrations in their newborn calves.

Colostrum Se concentrations showed a distinct trend towards higher colostrum Se secretion levels following Selevit inj. administration (Fig. 3). A comparison between results from the selenium-deficient experimental Herd I and Herd II, however, clearly shows that even significantly higher selenium concentration in blood failed to have any substantially
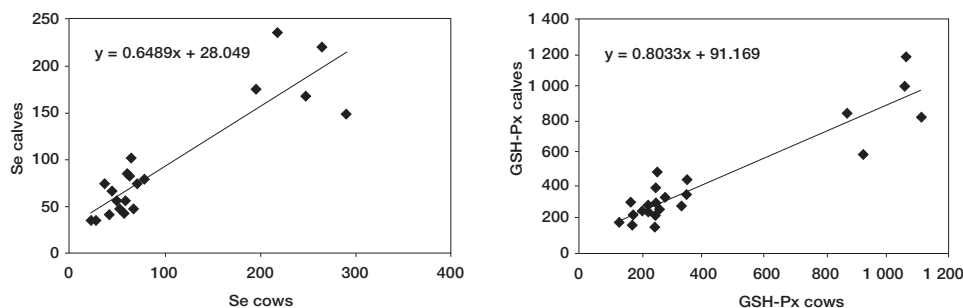
Fig. 1 and 2. Relationship between Se concentration (μg·l⁻¹) and GSH-Px activity (μkat·l⁻¹) in whole blood of cows and calves complete with the regression line equation
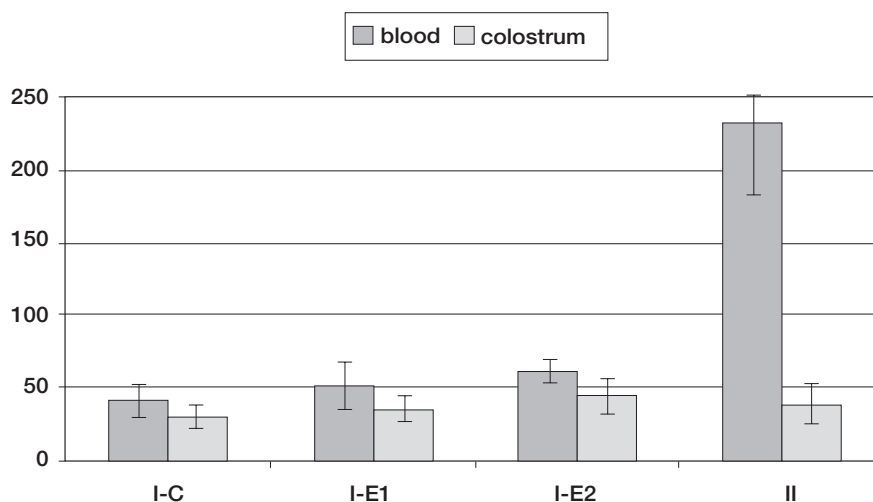

Fig. 3 Concentration of selenium in blood and colostrum of cows (μg·l⁻¹) in individual groups

effect on colostrum selenium concentration. This conclusion was supported by the results of correlation analysis, which showed no significant relationship between selenium concentrations in blood and in colostrum of the cows ($r = 0.21$). It seems that colostrum Se concentrations reach a plateau at already relatively low blood Se concentrations, and no further increases of its secretion take place.

Our findings thus confirm that selenium is an element that is transferred across the placenta to the foetus, and that it is also transferred through the mammary barrier to colostrum and milk. Contrary to previously published assumptions about the restrictive effect of placenta on the selenium exchange, Van Saun et al. (1989) found higher liver selenium concentrations in calves than in the dam in 99% of samples analyzed, which is evidence of its good placental transfer effect. Abdelrahman and Kincaid (1995) studied effects of the administration of an intraruminal selenium bolus to cows. They demonstrated that the type of administration had a positive effect on higher blood Se concentrations in dams at parturition, and that Se concentrations in blood and liver of their calves at birth were higher. The mean blood Se concentrations they found in control and experimental cows at parturition were 106 and 134 μg·l⁻¹ respectively; and mean blood Se concentrations in

newborn calves of the two groups were the 82 and 114 µg·l⁻¹, respectively. An increase was also found in the Se concentration in the colostrum of supplemented cows (40 and 56 µg·l⁻¹, respectively). The highest increase in Se concentrations was ascertained in the colostrum casein fraction (70 vs. 90 µg·l⁻¹). When comparing the effects of Se supplementation before and after calving to selenium reserves in Se deficient cows and calves, Enjalbert et al. (1999) concluded that the placental selenium exchange is more effective than the transfer of selenium to suckling calves in milk. When selenium was administered to high-pregnant cows, their calves had sufficient Se reserves. Subnormal values of Se reserves, however, were found in calves if the dams were being supplemented with selenium only after calving, although the calves were given Se injections. A significant correlation (r = 0.78) between Se concentrations in blood of cows and calves, and also between milk Se concentrations in cows and Se concentrations in whole blood, plasma and even GSH-Px activity in erythrocytes in their calves (r = 0.59 – 0.68) were demonstrated by Pehrson et al. (1999).

Although data on the relationship between dietary intakes of selenium and its concentrations in blood and milk are available (Conrad and Moxon 1979; Maus et al. 1980; Grace et al. 1997; 2001) and milk selenium concentration assessments are used in the diagnostics of Se status (Koutník et al. 1996; Grace et al. 2001), our results lead us to believe that this method of deficiency diagnostics is questionable, at last in the period of colostrum production, because examinations of the cows in this study revealed only minimum differences in colostrum Se concentrations at widely different selenium concentrations in blood. Moreover, the form of selenium supplemented is also known to significantly influence Se concentration in milk: milk secretion levels of selenium supplemented in organic selenium   is much higher those of inorganic selenium (Knowles et al. 1999; Orthman and Pehrson 1999).

Metabolismus selenu u skotu ve vztahu matka – mládě při různé úrovni saturace organismu tímto prvkem

Cílem práce bylo studovat metabolismus selenu u skotu ve vztahu matka – mládě u zvířat s různou úrovní saturace organismu selenem. Do sledování bylo zařazeno 24 vysokobřezích, zaprahlých dojnic ze 2 chovů s rozdílnou úrovní saturace zvířat selenem. V chovu I byla zjištěna karence selenu. V chovu II byla zvířata saturována selenem dostatečně. Zvířata chovu I byla dále rozdělena do 3 skupin (C, E1, E2). Kravám skupiny E1 byl 4 týdny před očekávaným porodem aplikován i. m. selenovitaminový preparát (Selevit inj. a.u.v.), kravám skupiny E2 byl stejný preparát aplikován 8 a 4 týdny před očekávaným porodem a zvířata skupiny C sloužila jako kontrola bez aplikace preparátu. U všech krav byla v den porodu odebrána krev a první kolostrum k laboratornímu vyšetření. Dále byla odebrána krev od jejich narozených telat před napojením kolostrem. U krav skupiny E2 bylo v den porodu zjištěno statisticky průkazné zvýšení koncentrace selenu v krvi (p < 0,05) v porovnání s kontrolní skupinou (61,63 ± 8,23 µg·l⁻¹ vs. 41,13 ± 11,08 µg·l⁻¹). Trend ke zvýšení koncentrace selenu v krvi byl při odběru v den porodu zjištěn také u krav skupiny E1 a u telat skupiny E1 a E2 v porovnání s telaty ze skupiny C. Aktivita glutathionperoxidázy (GSH-Px) se však mezi skupinami chovu I průkazně nelišila. U krav chovu II byla koncentrace selenu 264,17 ± 48,71 µg·l⁻¹ a u jejich telat 222,34 ± 52,95 µg·l⁻¹. Pomocí regresní a korelační analýzy byl prokázán statisticky významně těsný vztah (p < 0,01) mezi koncentrací selenu v krvi krav a jejich telat i aktivitou GSH-Px v krvi krav a jejich telat (rovnice regresní přímky y = 0,6489x + 28,049; r = 0,91, resp. y = 0,8033x + 91,169; r = 0,93). Mezi koncentrací selenu v krvi krav a jejich kolostru nebyl významný korelační vztah prokázán (r = 0,21) a kolostrum se tak nejeví jako vhodný materiál pro hodnocení stavu zásobení krav selenem. Výsledky ukazují nutnost zajištění dostatečné saturace organismu krav selenem i z hlediska prevence karence selenu u telat.

Acknowledgement

References

ABDELRAHMAN, MM, KINCAID, RL 1993: Deposition of cooper, manganese, zinc, and selenium in bovine fetal tissue at different stages of gestation. J Dairy Sci **76**: 3588-3593

ABDELRAHMAN, MM, KINCAID, RL 1995: Effect of selenium suplementation of cows on maternal transfer of selenium to fetal and newborn calves. J Dairy Sci **78**: 625-630

BLOOD, DC, RADOSTITS, OM 1989: Veterinary medicine. A textbook of the diseases of cattle, sheep, pigs, goats and horses. Seventh edition, English Language Book Society/Baillìòre Tindall, 1502 p.

CARTENS, G 1994: Cold thermoregulation in the newborn calf. Vet Clin North Am Food Anim Pract **10**: 69-106

COMSTOCK, GW, BUSH, TL, HELZLSOUER, K 1992: Serum retinol, beta-carotene, vitamin E, and selenium as related to subsequent cancer of specific sites. Am J Epidemiol **135**: 115-121

CONRAD, HR, MOXON, AL 1979: Transfer of dietary selenium to milk. J Dairy Sci **62**: 404-411

ENJALBERT, F, LEBRETON, P, SALAT, O, SCHELCHER, F 1999: Effect of pre- or postpartum selenium supplementation on selenium status in beef cows and their calves. J Anim Sci **77**: 223-229

GERLOF, BJ 1992: Effect of selenium supplementation on dairy cattle. J Anim Sci **70**: 3934-3940

GRACE, ND, ANKENBAUER-PERKINS, K, ALEXANDER, AM, MARCHANT, RM 2001: Relationship between blood selenium concentration or glutathione peroxidase activity, and milk selenium concentrations in New Zealand dairy cows. New Zeal Vet J **49**: 24-28

GRACE, ND, LEE, J, MILLS, RA, DEATH, AF 1997: Influence of Se status on milk Se concentrations in dairy cows. New Zeal J Agr Res **40**: 75-78

HARAPIN, I, BAUER, L, BEDRICA, L, POTOCNJAK, D 2000: Correlation between glutathione peroxidase activity and quality of selenium in whole blood of beef calves. Acta Veter Brno **69**: 87-92

HOFFMAN, CH, RIVINUS, B, SWANSON, L 1978: Effect of intramuscular administration of selenium and vitamin E in dairy heifers on erytrocyte glutathione-peroxidase activity and blood selenium levels. J Anim Sci **47**: 192-197

HOLOVSKÁ, K, Jr., HOLOVSKÁ, K, BOLDIŽÁROVÁ, K, ČEKONOVÁ, S, LENÁRTOVÁ, V, LEVKUT, M, JAVORSKY, P, LENG, L 2003: Antioxidant enzyme activities in liver tissue of chickens fed diets supplemented with various forms and amounts of selenium. J Anim Feed Sci **12**: 143-152

KNOWLES, SO, GRACE, ND, WURMS, K, LEE, J 1999: Signifikance of amount and form of dietary selenium on blood, milk, and casein selenium concentrations in grazing cows. J Dairy Sci **82**: 429-437

KOUTNÍK, V, KOUREK, B, HAVLÍČEK, Z 1996: Selenium content in milk of some dairy cattle herds in the South Moravian region. Živočišná výroba **41**: 473-474

KOVÁČ, G, SANKARI, S 1988: Glutathione peroxidase activity, selenium concentration in the blood and the masticatory muscle of cattle. Folia Veter **32**: 79-94

LENG, L, BOBCEK, R, KURICOVÁ, S, BOLDIŽÁROVÁ, K, GREŠÁKOVÁ, L, ŠEVČÍKOVÁ, Z, RÉVAJOVÁ, V, LEVKUTOVÁ, M, LEVKUT, M 2003: Comparative metabolic and immune responses of chickens fed diets containing inorganic selenium and Sel-Plex^{TM} organic selenium. In: Nutritional Biotechnology in the Feed and Food Industries. Proceedings of Alltech`s Nineteenth Annual Symposium, Nottingham University Press, Notingham, UK, 131-145

MAUS, RW, MARTZ, FA, BELYA, RL, WEISS, MF 1980: Relationship of dietary selenium to selenium in plasma and milk of dairy cows. J Dairy Sci **63**: 532-537

ORTMAN, K, PEHRSON, B 1999: Effect of selenate as a feed supplement to dairy cows in comparison to selenite and selenium yeast. J Anim Sci **77**: 3365-3370

PAGLIA, DE, VALENTINE, WN 1967: Studies on the quantitative and qualitative characterisation of erythrocyte glutathione peroxidase. J Lab Clin Med **70**: 158-169

PAVLATA, L, ILLEK, J, PECHOVÁ, A 2001c: Blood and tissue selenium concentrations in calves treated with inorganic or organic selenium compounds – a comparison. Acta Vet Brno **70**: 19-26

PAVLATA, L, ILLEK, J, PECHOVÁ, A, MATĚJÍČEK, M 2002a: Selenium status of cattle in the Czech Republic. Acta Vet Brno 71:3-8

PAVLATA, L, PECHOVÁ, A, BEČVÁŘ, O, ILLEK, J 2001b: Selenium status in cattle at slaughter: analyses of blood, skeletal muscle, and liver. Acta Vet Brno **70**: 277-284

PAVLATA, L, PECHOVÁ, A, ILLEK, J 2000: Direct and indirect assessment of selenium status in cattle – a comparison. Acta Vet Brno **69**: 281-287

PAVLATA, L, PECHOVÁ, A, ILLEK, J 2001a: Muscular dystrophy in dairy cows following a change in housing technology. Acta Vet Brno **70**: 269-275

PAVLATA, L, PODHORSKY, A, VAVŘIČKOVÁ, Z, MUSILOVÁ, L, PECHOVÁ, A 2002b: Treatment of selenium deficiency in dairy cows with injectable combinations of selenium and vitamins (in Czech). Veterinářství **52**: 240-242

PEHRSON, B, ORTMAN, K, MADJID, N, TRAFIKOWSKA, U 1999: The influence of dietary selenium as

selenium yest or sodium selenite on the concentration of selenium in the milk of suckler cows and on the selenium status of their calves. J Anim Sci **77**: 3371-3376

SALONEN, JT, HUTTUNEN, JK 1986: Selenium in cardiovascular disease. Ann Clin Res **18**: 30-35

SHAMBERGER, RJ 1983: Biochemistry of Selenium. Plenum Press, New York, 334 p.

SMITH, BP 1996: Large animal internal medicine: diseases of horses, cattle, sheep, and goats. Second edition, Mosby – Year Book, Inc, 2040 p.

UNDERWOOD, EJ, SUTTLE, NF 1999: Selenium. In: Mineral Nutrition of Livestock. CAB International, 421-475

VAN SAUN, RJ, HERDT, TH, STOWE, HD 1989: Maternal and fetal selenium concentrations and their interrelationships in dairy cattle. J Nutr **119**: 1128-1137