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# Microelements in Colostrum and Blood of Cows and their Calves during Colostral Nutrition

L. PAVLATA, A. PECHOVÁ, R. DVOŘÁK

Clinic of Diseases of Ruminants, Faculty of Veterinary Medicine, University of Veterinary and Pharmaceutical Sciences, Brno, Czech Republic

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**Abstract**

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The goal of the study was to use evaluation of blood and colostrum selenium (Se), copper (Cu) and zinc (Zn) concentrations of cows and the same blood concentrations of calves during the period of colostral nutrition to study differences in the metabolism of the different microelements in the mother and its young. Blood was collected from 12 cows and their calves before first intake of colostrum on the calving day and then at the end of the period of colostral nutrition to determine Se, Cu and Zn concentrations. First colostrum was collected from all cows. Se concentration was determined from whole blood and colostrum samples using hydride technique AAS. Cu and Zn concentrations were determined from colostrum and blood serum using flame AAS.

The cows under examination were shown to have average concentrations of Se of 0.87 ± 0.30 and 0.47 ± 0.15 $\mu mol \cdot l^{-1}$ in whole blood and colostrum respectively, of Cu 8.95 ± 1.95 and 5.37 ± 1.80 $\mu mol \cdot l^{-1}$ in blood serum and colostrum respectively, and of Zn 11.62 ± 2.35 and 416.76 ± 120.07 $\mu mol \cdot l^{-1}$ in blood serum and colostrum respectively. Blood of calves before the first intake of colostrum was characterized by a significantly higher ($p < 0.001$) mean concentration of Zn (25.88 ± 8.79 $\mu mol \cdot l^{-1}$) and a significantly lower ($p < 0.001$) concentration of Cu (3.23 ± 1.08 $\mu mol \cdot l^{-1}$) compared with the mothers. Blood Se concentration of the calves (0.91 ± 0.26 $\mu mol \cdot l^{-1}$) was not significantly different from blood Se concentration of the cows. A significant increase ($p < 0.001$) in blood Cu concentration of the calves to 7.53 ± 1.98 $\mu mol \cdot l^{-1}$ and an insignificant increase in the mean Zn and Se concentrations to 26.40 ± 6.58 $\mu mol \cdot l^{-1}$ and 0.93 ± 0.32 $\mu mol \cdot l^{-1}$ respectively occurred during colostral nutrition. Correlation analysis showed a significant correlation ($p < 0.01$) between blood Se concentrations of the mothers and their newborn calves (r = 0.72). No significant correlation was found between Cu and Zn concentrations of cows and their calves. No significant relation between blood and colostrum concentrations of the different microelements of cows was found either.

We have shown major differences as to the parameters of the micromineral metabolism under examination at the level of the mother/young relationship. While the calf organism can accumulate Zn throughout the intrauterine development and Zn is cumulated in cow colostrum, too, serum Cu concentrations of newborn calves are significantly lower compared with the mothers and colostrum Cu concentrations reach just about 60% of serum Cu concentrations of the cows. Although blood Cu concentration of calves increases throughout the period of colostral nutrition, it does not reach the level of serum Cu concentration of the mother by the end of the period. The Se status of newborn calves is similar to that of the mother cows and just like with Cu, Se is not cumulated in colostrum to any significant extent.

*Selenium, zinc, copper, placental transfer, cattle, metabolism, mother-young relation*

Selenium (Se), copper (Cu), and zinc (Zn) are microelements ranking among substances with biological activity in intermediate metabolism. They get into the organism mainly as components of animal diet and their transplacental transfer is an important factor in the young. The level of absorption and retention of microelements is modulated by their actual levels in the organism and their concentrations in the diet and is generally higher for intake of their organic forms (Knowles et al. 1999; Cao et al. 2000; Pavlata et al. 2001;

**Address for correspondence:**
MVDr. Leoš Pavlata. Ph.D.
Clinic of Diseases of Ruminants
Faculty of Veterinary Medicine
University of Veterinary and Pharmaceutical Sciences Brno
Palackého 1-3, 612 42 Brno
Czech Republic

Phone: +420 541 562 407
Fax: +420 549 248 841
E-mail: pavlatal@vfu.cz
http://www.vfu.cz/acta-vet/actavet.htm

Kuricova et al. 2003). The main pathways for their loss from the organism include urine, excrements, milk, and, potentially also, exhaled air (McDowell 1992; Underwood and Suttle 1999; Leng et al. 2000; Arova et al. 2003).

The importance, variety and great number of biological functions played by microelements imply the risk that any deficit present as early as during the pregnancy of the mother may have a negative impact on the development of the foetus and the health of the calf. It has been proved that microelements cross the placental and mammary barrier. Sufficient microelement saturation of pregnant animals is very important also with respect to the needs of the young during intrauterine and early postnatal development (Abdelrahman and Kincaid 1993; Underwood and Suttle 1999; Hostetler et al. 2003; Pavlata et al. 2003). Besides that, microelements affect milk and colostrum quality (Swecker et al. 1995; Gierus et al. 2003; Pavlata et al. 2004) as well as other mammary gland health indicators (Engle et al. 2001; Scaletti et al. 2003).

Knowing the microelement status of the different cattle categories and interpreting test results correctly is of major importance for determining potential therapeutic, but primarily preventive measures. The issue of evaluation of individual microelement deficits in the youngest calf categories has been discussed only superficially and evaluation is often made using the same values as for adult animals or knowledge of metabolism of a particular microelement is applied to other microelements. In our study we therefore set ourselves the task of studying and comparing the differences in microelement metabolism of cattle with respect to the mother/young relationship on the basis of determining blood and colostrum Se, Cu and Zn concentrations of cows and the same blood concentrations of calves during the period of colostral nutrition.

## Materials and methods

The trial was carried out at a selected farm whose capacity was 400 dairy cows with predominance of Red Holstein cattle blood. Dairy cows are stalled freely in boxes with bedding and divided into sections depending on lactation and reproduction stage. Calving takes place in a calving house with individual calving boxes and calves are kept in individual open-air boxes. Testing samples were collected from 12 clinically healthy dairy cows and their newborn calves within first hours after calving, before the first intake of colostrum by the calves. The cows were sampled for whole blood supplemented with heparin and blood free of any anticoagulation agent. After 24-hour coagulation at room temperature, blood serum was separated to be used for laboratory analysis. Two litres of collected first colostrum were sampled for the purposes of laboratory testing. All calves were sampled for blood once again, at the end of the period of colostral nutrition, i.e. when aged 4 to 6 days. All cows included in the trial were fed the same total mixed ration consisting of corn silage, grass haylage, and meadow hay and from three weeks before the expected calving they got besides 3 kg of grain. Calves were individually fed colostrum of their own mother 2 times a day, the total volume being 5 (6) litres.

In preparation for Se determination, samples of whole blood and colostrum were mineralized in a closed system using microwave digestion technology based on $HNO_3$ and $H_2O_2$, in MILESTONE MLS – 1200 equipment. After evaporation the mineralised sample was used to create water solution and 20% HCl was added. Thus prepared sample was tested for Se concentrations by the AAS hydride technique using the UNICAM 939 AA spectrometer. Serum Cu and Zn concentrations were determined by the flame AAS using the AA Series spectrometer SOLAAR M Thermo Electrocorporation. Colostrum concentration of these elements was established after mineralizing colostrum using microwave digestion technique and flame AAS. All tests were carried out in the laboratory of our institute.

Basic statistic parameters were calculated in Microsoft Excel XP. Statistical comparison of microelement concentrations between cows and their calves testing using the t-test and evaluation of the dynamics of blood microelement concentrations of calves during colostral nutrition using the pair t-test and correlation analysis of the results were performed in Microsoft Excel XP, too.

## Results

The obtained blood and colostrum microelement concentrations of cows and their calves are presented in Tables 1 to 3. The results show that concentrations of the elements under analysis in samples mapping the basic micromineral metabolism at the level of the mother/young relationship are characterized by relatively important differences.

Blood of calves collected before first intake of colostrum on calving day showed a significantly higher ($p < 0.001$) mean Zn concentration and a significantly lower ($p < 0.001$) Cu concentration. Blood Se concentration of calves did not significantly differ from blood Se

Table 1
Zn concentrations (μmol·l$^{-1}$) in blood serum of cows, first-collection colostrum, and blood serum of calves on calving day and at the end of colostral nutrition (n = 12)

| Zn | Cows | Colostrum | Calves before intake of colostrum | Calves at the end of colostral nutrition |
|---|---|---|---|---|
| Mean ± S.D. | 11.62 ± 2.35 | 416.76 ± 120.07 | 25.88 ± 8.79 | 26.40 ± 6.58 |
| Min. | 6.80 | 193.80 | 12.42 | 13.68 |
| Max. | 15.54 | 664.40 | 40.96 | 36.72 |
| v % | 20.22 | 28.81 | 33.96 | 24.92 |

Table 2
Cu concentrations (μmol·l$^{-1}$) in blood serum of cows, first-collection colostrum, and blood serum of calves on calving day and at the end of colostral nutrition (n = 12)

| Cu | Cows | Colostrum | Calves before intake of colostrum | Calves at the end of colostral nutrition |
|---|---|---|---|---|
| Mean ± S.D. | 8.95 ± 1.95 | 5.37 ± 1.80 | 3.23 ± 1.08 | 7.53 ± 1.98 |
| Min. | 6.76 | 3.24 | 1.93 | 4.19 |
| Max. | 13.16 | 10.45 | 6.03 | 10.47 |
| v % | 21.79 | 33.52 | 33.44 | 26.29 |

Table 3
Se concentrations (μmol·l$^{-1}$) in whole blood of cows, first-collection colostrum, and whole blood of calves on calving day and at the end of colostral nutrition (n = 12)

| Se | Cows | Colostrum | Calves before intake of colostrum | Calves at the end of colostral nutrition |
|---|---|---|---|---|
| Mean ± S.D. | 0.87 ± 0.30 | 0.47 ± 0.15 | 0.91 ± 0.26 | 0.93 ± 0.32 |
| Min. | 0.47 | 0.21 | 0.56 | 0.52 |
| Max. | 1.46 | 0.68 | 1.49 | 1.68 |
| v % | 34.48 | 31.91 | 28.57 | 34.41 |

concentration of their mothers. A significant increase in blood Cu concentration of calves ($p < 0.001$) and an insignificant increase in Zn and Se concentrations occurred during colostral nutrition (Fig. 1 to 3). The relations of concentrations of the different elements in samples tested are presented in Table 4.

Table 4
Ratios of microelement concentrations in analyzed samples collected from individual animals (n = 12) stated in per cent (DB – concentration of the element in blood or blood serum of dairy cows; DC – concentration of the element in colostrum; C0 – concentration in blood or blood serum of calves before first intake of colostrum; C5 – concentration in blood or blood serum of calves at the end of colostral nutrition)

| | | C0:DB (%) | C5:DB (%) | C5:C0 (%) | DC:DB (%) |
|---|---|---|---|---|---|
| Se | Mean ± S.D. | 110 ± 32 | 114 ± 37 | 108 ± 40 | 60 ± 29 |
| | Min. | 72 | 50 | 54 | 27 |
| | Max. | 189 | 179 | 203 | 117 |
| Cu | Mean ± S.D. | 38 ± 16 | 86 ± 22 | 257 ± 95 | 62 ± 23 |
| | Min. | 21 | 56 | 67 | 42 |
| | Max. | 86 | 125 | 451 | 125 |
| Zn | Mean ± S.D. | 228 ± 78 | 240 ± 87 | 112 ± 42 | 3829 ± 1476 |
| | Min. | 109 | 109 | 59 | 1247 |
| | Max. | 364 | 426 | 211 | 6611 |

Besides that, significant differences were found in the ratios of colostrum and blood microelement concentrations of cows. While colostrum Zn concentration was on average more than thirty times higher than serum Zn concentration; Cu and Se concentrations reached no more than 60% of blood or serum concentrations (see Table 4).

No statistically significant correlation between colostrum and blood concentrations of the individual elements has been found (Fig. 4 to 6). The figures however indicate that colostrum Cu concentration is, despite relatively different serum concentrations of this element, relatively stable and does not grow under 6 μmol·l$^{-1}$, no matter what the serum concentration was. Also Se concentrations in colostrum does not grow up under 0.50 μmol·l$^{-1}$. We did not find any correlation between concentration of Zn in blood and colostrum.

Evaluation of the link between blood concentrations of the elements of cows and their calves using correlation analysis revealed a statistically significant correlation ($p < 0.01$, r = 0.72) between blood Se concentrations of mothers and their newborn calves only. For the other elements no such statistically significant correlation was shown (Fig. 7 to 9). However, a trend towards positive correlation can be observed between blood Se concentration of cows and calves at the end of colostral nutrition (r = 0.49) and between blood Se concentration of calves on calving day and at the end of colostral nutrition (r = 0.48).

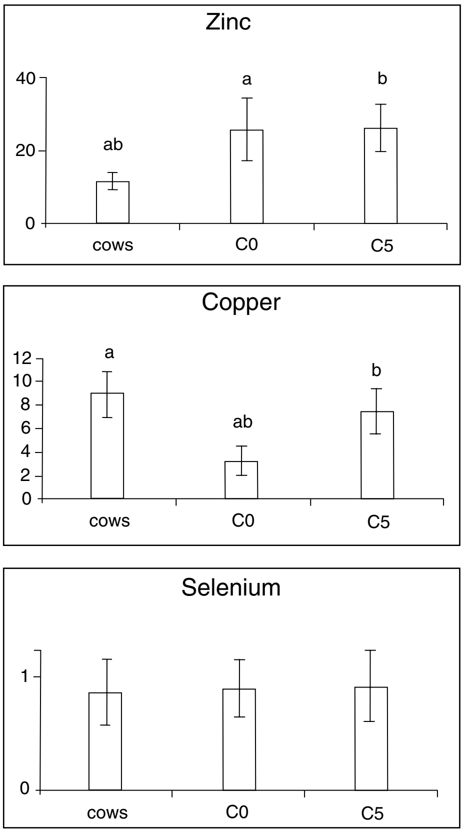


Fig. 1 to 3. Concentrations of zinc, copper, and selenium (μmol·l$^{-1}$) in blood of cows and their calves on calving day (C0) and in blood of calves at the end of colostral nutrition (C5) (n = 12; a:a, b:b p < 0.001).

A certain trend towards increase of blood Zn concentration of newborn calves accompanying increasing blood Zn concentration of their mothers (r = 0.43), towards positive correlation between blood Cu concentration of the cow and the calf at the end of colostral nutrition (r = 0.41), and also between colostral and blood Cu concentration of calves at the end of colostral nutrition (r = 0.42).

## Discussion

Using the determined mean concentrations of the individual elements, the milk cows under analysis can be assessed as deficient in all parameters tested. The concentrations of Cu and Se we found were lower than the recommended values of 12.6 μmol·l$^{-1}$ and 100 μg·l$^{-1}$ or 1.27 μmol·l$^{-1}$ for copper and selenium respectively (Jagoš et al. 1981; Pavlata et al. 2000). There was only a mild Zn deficit compared with the recommended value of 12.2 μmol·l$^{-1}$ (Jagoš et al. 1981).

The absolute values of colostrum concentrations of the individual elements found by us are in agreement with values quoted in literature. E.g. Roy (1980) states colostrum Cu concentration of 0.6 mg·l$^{-1}$ and colostrum Zn concentration of 5 – 20 mg·l$^{-1}$, i.e. 9.4 μmol·l$^{-1}$

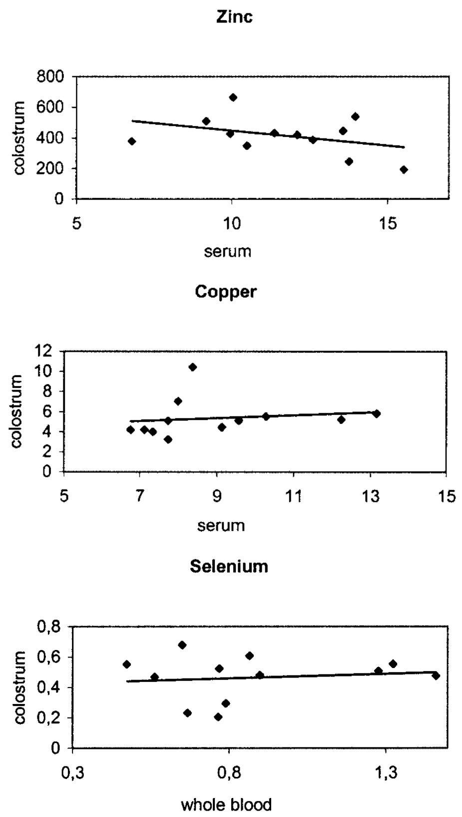


Fig. 4 to 6. Correlations between concentrations of the elements ($\mu mol \cdot l^{-1}$) in blood of cows and in their colostrum (n = 12).

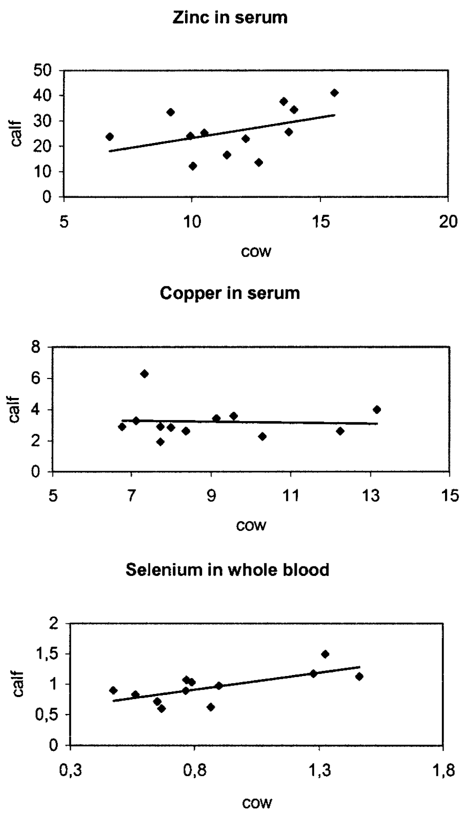


Fig. 7 to 9. Correlations between concentrations of the elements ($\mu mol \cdot l^{-1}$) in blood of cows and their calves before first intake of colostrum by calves on calving day (n = 12).

and 76 – 306 $\mu mol \cdot l^{-1}$ for Cu and Zn respectively. Muehlbein et al. (2001) found 0.22 – 0.30 $mg \cdot l^{-1}$ of Cu (i.e. 3.46 – 4.72 $\mu mol \cdot l^{-1}$) and 27 – 32 $mg \cdot l^{-1}$ of Zn (i.e. 413 – 489 $\mu mol \cdot l^{-1}$) in colostrum of cows with different microelement status. Kráčmar et al. (2003) found goat colostrum Zn concentration to be 106.07 $\mu mol \cdot l^{-1}$ while the goat colostrum Se concentration they found was relatively low – 7.82 $\mu g \cdot l^{-1}$ (i.e. around 0.10 $\mu mol \cdot l^{-1}$). Abdelrahman and Kincaid (1995) determined colostrum Se concentration of cows with different Se status to be 40 or 56 $\mu g \cdot l^{-1}$ (i.e. 0.51 or 0.71 $\mu mol \cdot l^{-1}$).

Slanina (1991) sets the limit for Cu and Zn deficit in calves at 8 and 15 $\mu mol \cdot l^{-1}$ respectively. Using these reference values, the calves involved in our trial can be assessed as having a Cu deficit, but sufficient Zn status both on calving day and at the end of the period of colostral nutrition. The blood Se concentrations found by us, too, are significantly lower than the recommended value of 1.25 $\mu mol \cdot l^{-1}$ in whole blood (Kováč 1991).

Although the general rule is that the microelement status of newborn calves is a result of the status of their mother during gestation since microelements are transferred through the placenta to the foetus (Hostetler et al. 2003), our own results show that the situation is different for each individual microelement and therefore no generalizations should be made.

Blood Zn concentration of newborn calves is significantly higher than that of their mothers, which means that the calf organism can accumulate Zn during intrauterine development. Despite the fact that the dairy cows involved in the trial were assessed as suffering from a mild Zn deficit, Zn concentrations found in the calves were high enough. It is therefore highly probably that not even calves born to cows with Zn deficit will be found to have low concentrations of this element. Assessing individual animals, we can e.g. observe that calves from cows with Zn deficit (serum Zn concentrations of 6.80 or 9.18 $\mu mol \cdot l^{-1}$) had high Zn concentrations after calving (23.70 and 33.80 $\mu mol \cdot l^{-1}$). Another important source of Zn for calves is colostrum, where zinc concentrations reach more than 30 times the level found in blood serum of cows, implying a significant accumulation of the element. The demand for Zn in cows towards the end of gestation and at the beginning of lactation is therefore much higher compared with the other elements dealt with in the trial because the developing foetus and colostrum production represent significant loss/high output of Zn from the mother organism.

In contrast to this, serum concentrations of newborn calves are significantly lower compared with those of their mothers and colostrum Cu concentration reaches just about 60% of serum concentrations in cows. Blood Cu concentration increases quite rapidly during colostral nutrition, but still fails to reach the level of serum Cu concentration of the mother at the end of the period. Selenium status of newborn calves is similar to that of their mothers and similarly to Cu, selenium is not cumulated in colostrum.

Considering the fact that no significant correlation was proved between blood Zn and Cu concentrations of cows and their calves, Zn and Cu concentrations of calves cannot be used to infer the corresponding microelement status of the cows. This finding is in line with results obtained e.g. by Gengelbach et al. (1994), who found no differences between serum Cu concentrations of 7-week-old calves from mothers with Cu deficit and calves from mothers with adequate Cu status. A significant linear correlation between the nutritional status of calves and their mothers was shown for Se only and even the absolute values of Se concentrations are very similar for cows and calves. This finding supports our older results: we have described a significant correlation between whole blood Se concentrations and GSH-Px activity of cows and their calves at different nutritional status of this element (Pavlata et al. 2003). If therefore cows or calves are found to have adequate nutritional status or deficit of Se, the result may be used to infer results for the other animal category.

Our results evidencing low blood Cu concentration of newborn calves are in line with results by Enjalbert et al. (2002), who also report low plasma Cu concentrations in calves during the first week of life compared with their mothers. Based on these results, one could hypothesize that transplacental transfer of Cu, or the ability of the developing foetus to exploit Cu from the mother organism, is partly limited. This is however in contrast with results suggesting that organ Cu concentrations of calves during gestation and early after calving are higher than those of their mothers (Gooneratne and Christensen 1989; Illek and Suchý 1993; Muehlenbein et al. 2001). The lower blood Cu concentrations of calves compared with their mothers may be due to the fact that in newborn calves ceruroplasmin, the main form of Cu transport in blood, is not produced to a sufficient extent (Roy 1980; Underwood and Suttle 1999). The mean blood Cu concentration of mothers was generally relatively low in our trial, not reaching even the recommended 12.6 $\mu mol \cdot l^{-1}$ in blood plasma (Jagoš et al. 1981), which indicates that the feeding rations fed to the dairy cows under analysis did not provide adequate copper supplementation. Inadequate copper supplementation can therefore be expected in calves, too. Nevertheless assessing the concentrations determined for individual animals we may state that very low Cu concentrations were found even in calves whose mothers had sufficient serum Cu concentrations. E.g. a calf from a cow whose serum Cu concentration was 13.16 $\mu mol \cdot l^{-1}$, had a serum Cu concentration of only 4.00 $\mu mol \cdot l^{-1}$ after birth, which suggests that low newborn calf Cu concentrations may be expected even in calves born to dairy cows with adequate Cu status.

The relatively important and fast increase in Cu concentrations during the period of colostral nutrition of calves may therefore be associated with the improving ability of the organism to produce ceruloplasmin and thus distribute Cu from the liver deposit to blood, but also with Cu resorption from colostrum. Despite the fact that according to our results, Cu, compared with Zn, is not cumulated in colostrum to any significant extent, the results pointing to a trend towards correlation between colostral and blood Cu concentration of calves at the end of the period of colostral nutrition suggest that colostrum is an important source of Cu for calves. A prominent upward trend in Cu concentration of calves in the first month after calving has been described by Muehlenbein et al. (2001), too.

These results in the above-described parameters of microelement metabolism found and described by us at the level of the mother/young relation in cattle and also the dynamics of change of their concentrations in the neonatal period should be taken into account when interpreting results in diagnostics of metabolic diseases of different bovine categories. Our results lead us to raise the question whether other trials should not be performed to provide a basis for reassessing or specifying the values of individual microelement concentrations sued for assessment of micromineral metabolism of calves and specifying more accurately the age at which this testing should be carried out for calves.


## Koncentrace mikroprvků v kolostru a krvi krav a jejich telat v období kolostrální výživy

Cílem práce bylo pomocí vyhodnocení vztahu koncentrace selenu (Se), mědi (Cu) a zinku (Zn) v krvi a kolostru krav a krvi telat v průběhu kolostrální výživy studovat rozdíly v metabolismu jednotlivých mikroprvků u skotu ve vztahu matka – mládě. U 12 krav v den porodu a jejich telat před napojením kolostrem a opakovaně na konci období kolostrální výživy byla odebrána krev pro stanovení koncentrace Se, Cu a Zn. Od všech dojnic bylo odebráno kolostrum z prvního nádoje. Koncentrace Se byla stanovena ve vzorcích plné krve a kolostra metodou hydridové AAS. Koncentrace Cu a Zn byla stanovena v kolostru a krevním séru metodou plamenové AAS.

U vyšetřených krav byla zjištěna průměrná koncentrace Se v plné krvi a kolostru 0,87 ± 0,30, resp. 0,47 ± 0,15 $\mu$mol·l$^{-1}$, Cu 8,95 ± 1,95 $\mu$mol·l$^{-1}$ krevního séra, resp. 5,37 ± 1,80 $\mu$mol·l$^{-1}$ kolostra a Zn 11,62 ± 2,35 $\mu$mol·l$^{-1}$ krevního séra, resp. 416,76 ± 120,07 $\mu$mol·l$^{-1}$ kolostra. V krvi telat před prvním napojením kolostrem byla v porovnání s jejich matkami zjištěna průkazně vyšší ($p < 0{,}001$) průměrná koncentrace Zn (25,88 ± 8,79 $\mu$mol·l$^{-1}$) a průkazně nižší ($p < 0{,}001$) koncentrace Cu (3,23 ± 1,08 $\mu$mol·l$^{-1}$). Koncentrace Se v krvi telat (0,91 ± 0,26 $\mu$mol·l$^{-1}$) se průkazně od koncentrace Se v krvi krav nelišila. V průběhu kolostrální výživy došlo v krvi telat k průkaznému zvýšení ($p < 0{,}001$) koncentrace Cu na 7,53 ± 1,98 $\mu$mol·l$^{-1}$ a neprůkaznému zvýšení průměrné koncentrace Zn a Se na 26,40 ± 6,58 $\mu$mol·l$^{-1}$, resp. 0,93 ± 0,32 mmol·l$^{-1}$. Korelační analýzou byl zjištěn statisticky významný vztah ($p < 0{,}01$) mezi hodnotami koncentrace Se v krvi matek a jejich narozených telat (r = 0,72). Mezi koncentrací Cu a Zn u matek a jejich telat nebyl statisticky významný korelační vztah zjištěn. Nebyla zjištěna ani průkazná závislost mezi koncentrací jednotlivých mikroprvků v krvi krav a jejich kolostru.

Prokázali jsme, že ve sledovaných parametrech mikrominerálního metabolismu jsou na úrovni vztahu matka – mládě výrazné rozdíly. Zatímco telata jsou schopna ve svém organismu koncentrovat Zn v průběhu intrauterinního vývoje a Zn je koncentrován i v kolostru krav, jsou koncentrace Cu v séru novorozených telat v porovnání s jejich matkami výrazně nižší a koncentrace mědi v kolostru dosahuje jen okolo 60 % hodnoty koncentrace tohoto prvku v krevním séru krav. V průběhu kolostrální výživy koncentrace Cu v krvi telat stoupá, ale přesto na konci tohoto období nedosahuje hodnot koncentrace Cu

v krevním séru matky. Stav zásobení novorozených telat Se je obdobný jako u jejich matek a stejně jako u Cu není selen v kolostru výrazně kumulován.

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