Bulgarian Journal of Agricultural Science, 20 (No 3) 2014, 715-720
Agricultural Academy

BLOOD SERUM LEVELS OF MACRO - AND MICRONUTRIENTS IN TRANSITION AND FULL LACTATION COWS

R. D. DJOKOVIC[1], V. S. KURCUBIC[1]* and Z. Z. ILIC[2]
[1] *University of Kragujevac, Faculty of Agronomy, Department for Animal Husbandry, 32000 Cacak, Republic of Serbia*
[2] *University of Prishtina - Zubin Potok, Faculty of Agriculture, Department of Animal Science, Jelene Anzujske bb, Republic of Serbia*

Abstract

DJOKOVIC, R. D., V. S. KURCUBIC and Z. Z. ILIC, 2014. Blood serum levels of macro - and micronutrients in transition and full lactation cows. *Bulg. J. Agric. Sci.,* 20: 715-720

The objective of this study was to determine blood levels of macro- and micronutrients in Simmental cows (n=45) during the transition period and full lactation. The experimental cows were assigned to three groups: Group A (n=15) including clinically healthy late gestation cows, Group B (n=15) comprising clinically healthy cows in the puerperium, and Group C (n=15) made up of clinically healthy full lactation cows. Blood samples were collected from all experimental cows. Blood serum samples were analysed for calcium, magnesium, inorganic phosphorus, iron, copper, manganese, zinc and cobalt levels using spectrophotometry. Blood levels of macro- and micronutrients were within the physiological range in all experimental cows. Blood concentrations of calcium, magnesium and inorganic phosphorus in cows in the puerperium were statistically significantly lower ($p<0.05$) compared with those in dairy cows during late gestation and full lactation, which may indicate the increased use of these macronutrients in early lactation for the mammary gland. Serum levels of iron, copper, manganese and cobalt showed no significant variation ($p>0.05$) across cows, whereas serum zinc levels were significantly lower ($p<0.05$) in puerperium cows compared with late gestation and full lactation cows. The results show that the homeostasis of the macro- and micronutrients tested in the blood of transition and full lactation dairy cows was maintained, suggesting their adequate supply from alimentary sources.

Key words: cows, transition period, macro- and micronutrients in blood

Introduction

Macro- and micronutrients are inorganic substances essential to maintain the normal function and living status in domestic animals (Sharma et al., 2006; Kurćubić et al., 2010; Soetan et al., 2010). These nutrients play a critical role in physiological processes related to health, growth and reproduction, and the adequate function of the immune and endocrine systems.

Blood levels of calcium, inorganic phosphorus and magnesium in dairy cows during the peripartal period and lactation reflect their metabolism or supply of these macronutrients through feed and their utilisation by peripheral tissues, the mammary gland in particular. Any decline in their blood levels below the physiological limit, any deficiency of these nutrients and their unfavourable ratio in lactating cows generally lead to subclinical and clinical manifestations that adversely affect animal health and fertility (Daniel, 1983; Curtis et al., 1983; Ivanov et al., 1993; Sevinc et al., 1997; Kupczynski et al., 2002; Lean et al., 2006; Liesegang et al., 2007).

Low blood levels of calcium and magnesium in dairy puerperium cows contribute to insufficient insulin production, leading to a disorder in organic nutrient metabolism and predisposition to ketosis and fatty liver (Goff and Horst, 1997). In dairy cows, milk production and reproductive performance are reduced, muscle tone in the uterus is impaired, placental retention is a frequent disorder, uterine involution is delayed, and the service period is prolonged (Daniel, 1983). Magnesium deficiency in feeds for dairy cows inhibits the synthe-

*Coresponding author: vkurcubic@open.telekom.rs

sis and secretion of parathormone, reduces the absorption of calcium and inorganic phosphorus in the digestive tract, and inhibits the production of the active form of vitamin D (1.25 $(OH)_2$ D_3). Raising dietary magnesium from 0.3 % to 0.4 % of dry matter before calving reduces the risk of milk fever (puerperal paresis) by 62% (Wang and Beede, 1992; Goff and Horst, 1997; Lean et al., 2006).

Micronutrients (trace elements) such as iron, zinc, manganese, copper, cobalt, selenium, iodine and chromium play an important role in dry matter intake, energy metabolism, mastitis incidence, reproduction, immune functions, and hoof health. Micronutrient deficiency in dairy cows results in reduced animal performance, such as impaired reproduction, a high incidence of mastitis, reduced milk yield, impaired immunity, and an increased degree of lameness due to laminitis (Miller, 1975; Dvořák et al., 1980; Olson et al., 1999; Stanton et al., 2000; Ballantine et al., 2002; Spears, 2003; Dobrzański et al., 2005; Nocek et al., 2006).

Limited information is available in the national published literature regarding serum levels of calcium (Ca), magnesium (Mg), inorganic phosphorus (P), iron (Fe), copper (Cu), zinc (Zn), manganese (Mn) and cobalt (Co) in dairy cows during the transition period and full lactation under increased metabolic demand for macro- and micronutrients. Therefore, the objective of this study was to determine the blood levels of macro- and micronutrients in Simmental dairy cows during transition and full lactation.

Material and Methods

Experimental animals

Serum levels of macro- and micronutrients: calcium (Ca), magnesium (Mg), inorganic phosphorus (P), iron (Fe), copper (Cu), zinc (Zn), manganese (Mn) and cobalt (Co) were determined in experimental animals (heifers and cows) on FARMAD Dairy Farm located at Vrdila, Kraljevo. The farm housed 132 dairy cows (a total of 221 animals, all types of cattle). The experimental animals were Simmental cows imported from Bavaria, Germany and housed on a closed-type farm. The farm raises its own replacement stock, and uses a loose housing system (lying boxes). Forty-five experimental animals of different ages (year of birth 2003-2006) were selected and allocated to 3 experimental groups viz. Experimental Group (A), composed of 15 clinically healthy cows from day 15 to day 1 before calving; Experimental Group (B), made up of 15 clinically healthy puerperium cows, until day 15 after calving; and Experimental Group (C) including 15 clinically healthy dairy cows in full lactation (90-120 days).

The average body weight of dairy cows was 694.4 ± 41.8 kg in late pregnancy, and 637.7 ± 37.9 kg during lactation. The average 305-day milk yield was 6950 ± 448l. The experiment was established in the same season, in mid-April. Cow diet was formulated in accordance with feeding and energy requirements. Late pregnant cows were fed a daily diet of 8 kg alfalfa hay, 5 kg maize silage (30% dry matter, DM), 3 kg coarse meal, 1 kg sunflower meal, 3 kg supplementary feed with 30% total protein (TP). During lactation, cows received 3 kg alfalfa hay, 15 kg maize silage (30% DM), 5 kg coarse meal, 2 kg dry pulp, 3 kg sunflower meal, 4 kg supplemental feed (30% TP). The feed ingredients included in daily diets for dairy cows in late gestation and lactation are given in Table 1.

A database was created for each experimental dairy cow to cover the following information: CS/RS identification numbers, dam ID, sire ID, date of birth, milk performance, date of last artificial insemination, date of last calving, data on treatments, incidence of placental retention, incidence of abortions, and reproductive disorders.

Sampling

Blood samples from all experimental dairy cows (n=45) were taken from the tail vein (v. coccygica) using a vacu-

Table 1
Nutrient composition of the daily diets used for dairy cows during late gestation and lactation

	Late gestation	Lactation
Dry matter (DM), kg	14.90	19.70
Net energy of lactation (NEL), MJ	86.28	122.17
Total protein (TP), % DM	20.07	18.69
Undegradable protein, % UP	38.21	29.83
Fat, % DM	3.40	3.17
Fibre, % DM	20.28	17.52
Ca %	0.64	0.90
P %	0.42	0.52
Na %	0.13	0.36
Cl %	0.17	0.29
Mg %	0.27	0.34
K %	1.30	1.18
S, ppm	0.22	0.22
Mn, ppm	129.36	82.40
Cu, ppm	39.81	25.64
Zn, ppm	168.24	96.90
Co, ppm	1.03	1.54
J, ppm	3.16	1.64
Fe, ppm	228.38	220.53
Se, ppm	1.14	0.70

tainer system (Terumo® Venoject) and sterile needles. Upon sampling, blood underwent spontaneous coagulation at room temperature. The blood sera were centrifuged at 3000 rpm. Then, they were stored at – 20⁰C until analysis.

Biochemical testing

Serum levels of Ca, Mg, P, Fe, Cu, Zn and Mn in experimental animals were determined by standard method (atomic absorption spectrophotometry - AAS) – Serbian SRPS ISO 6869:2002, using UNICAM 969, at the Chemical Laboratory, Veterinary Specialist Institute, Kraljevo. Cobalt (Co) levels were assessed by M034, a modified method developed at the Chemical Laboratory, Veterinary Specialist Institute, Kraljevo.

Statistical analysis

The data obtained were subjected to statistical analysis using the ANOVA procedure. The analysis of variance and LSD test were used to estimate the probability of the significance of statistical differences in means for blood parameters across experimental groups of cows at $P<0.05$ and $P<0.01$ (Microsoft STATISTICA ver.5.0 Stat.Soft.Inc. 1995).

Results and Discussion

Macro- and micronutrients are essential to maintain the normal function of vital biochemical processes in the dairy cow's body. Different degrees of deficiency of these inorganic substances can lead to clinical and subclinical symptoms, and significantly reduce productive and reproductive performance in dairy cows (Ballantine et al.; 2002; Spears, 2003; Dobrzański et al., 2005).

Results on serum levels of macro- and micronutrients in dairy cows during transition and full lactation are presented in Table 2.

In early lactation, the regulatory mechanisms for Ca and inorganic P homeostasis in dairy cows are adapted to markedly increased Ca and P demands placed by the mammary gland. Ca mobilisation from bone and Ca absorption from the gastrointestinal tract increase to enable the cow to create homeostasis. High-yielding cows were found to mobilise larger amounts of Ca and P from bone compared to low-yielding cows (Liesegang et al., 2007). Early lactation imposes sudden high demand for Ca and P vital for the synthesis of milk ingredients. Some cows exhibit a marked decrease in blood Ca and P levels in early lactation, resulting in a dramatic decline (<1.5 mmol/L), leading to hypocalcemia, reduced neuromuscular excitability and milk fever/puerperal paresis (Wang and Beede, 1992; Goff and Horst, 1997; Beede and Pilbeam, 1998; Sharma et al., 2006). Puls (1988) recommended classification of blood Ca, P and Mg values in dairy cows based on their concentrations, as deficient, limiting, adequate and high.

Table 3 shows that blood plasma concentrations of Ca and P were significantly lower ($p<0.05$) in pueperium cows than in late gestation and full lactation cows. The results suggest that blood Ca and P levels were within the physiological limits (adequate supply) in all experimental cows, with Ca levels approaching the limit values in puerperium cows due to a sudden increase in mammary gland activity and increase in Ca mobilisation from both the blood and the body depots. Similar results have been reported elsewhere (Jacobsen et al., 1971; Curtis et al., 1983; Puls, 1988; Ivanov et al., 1993; Sevinc et al., 1997; Stanton et al., 2000; Kupczynski et al.,

Table 2
Blood serum concentrations of macronutrients (Ca, P and Mg) and micronutrients (Fe, Cu, Zn, Mn and Co) in dairy cows during late gestation (from day 15 to day 1 prior to partus, group A, n=15), puerperium (from day 1 to day 15 after partus, group B, n=15) and full lactation (90-120 days, group C, n=15) and statistical significance between the means

	Late gestation	Puerperium	Full lactation		
Group	A	B	C		
n	15	15	15	P<0.05	P<0.01
Ca, mmol/L	2.35±0.24	2.17±0.22	2.53±0.29	A:B	B:C
P, mmol/L	2.09±0.34	1.97±0.39	2.41±0.38	A:C	B:C
Mg, mmol/L	1.10±0.26	1.02±0.32	1.28±0.20	B:C	
Fe, µmol/L	35.27±15.26	24.08±4.45	31.03±12.33		
Cu, µmol/L	8.36±1.34	9.44±2.22	8.78±1.63		
Zn, µmol/L	15.11±4.01	12.24±2.48	15.78±4.78	A:B;B:C	
Mn, µmol/L	3.54±1.68	3.75±1.79	3.76±1.94		
Co, µmol/L	0.68±0.09	0.63±0.09	0.66±0.79		

2002; Đoković et al., 2010). The results suggest the potential incidence of puerperal paresis in some animals.

Magnesium is responsible for the activation of more than 300 enzymes. As a Mg-ATP complex, magnesium is essential for all biosynthetic processes (glycolysis, energy-dependent membrane transport, formation of cyclic AMP, and genetic code transmission). Magnesium is involved in the maintenance of the membrane electrical potential (across nerve and muscle membranes) and nerve impulse transmission (Wacker, 1980). Magnesium homeostasis depends on an optimal supply from alimentary sources; accordingly, Mg concentration is dependent on Mg absorption in the rumen (Fontenot et al., 1989; Kurćubić et al., 2010). Blood Mg concentration in this study was lowest in puerperium cows, with no significance ($p>0.05$) observed compared to cows before calving, whereas it was significantly lower ($p<0.05$) compared to full lactation cows. Peripartal dairy cows were found to have the lowest values for blood Mg, which were within the physiological limits (adequate supply), suggesting a somewhat higher degree of Mg utilisation in the blood by the mammary gland during early lactation. The results are in agreement with the findings reported in a number of studies (Jacobsen et al., 1971; Fontenot et al., 1989; Wang and Beede, 1992; Ivanov et al., 1993, Sevinc et al., 1997; Puls, 1988; Kupczynski et al., 2002; Sharma et al., 2006).

Iron plays a major role in the transport of oxygen through hemoglobin in the blood and myoglobin in skeletal muscles. Fe is an integral part of cytochromes and Fe-dependent proteins involved in electron transport; it is also a constituent of a number of Fe-activated enzymes (Spears, 2003; Theil, 2004; Nocek et al., 2006). Fe concentrations in all experimental groups were within the physiological range (12.5-44.8 μmol/l, Cvetković et al., 1986), with no statistical significance ($p>0.05$) observed, suggesting an optimal supply of this micronutrient in the cows tested. Namely, conventional diets mostly contain sufficient amounts of Fe, and Fe deficiency in dairy cows rarely occurs, except in cases of some parasitic and infectious diseases (Stanton et al., 2000; Spears, 2003; Theil, 2004).

Copper is a component of a number of enzymes including lysyl oxidase, superoxide dismutase, tyrosinase, ceruloplasmin and cytochrome oxidase. These enzymes are important in the structural integrity of collagen and elastin, detoxication of superoxide radicals, pigmentation, Fe transport, and energy metabolism. Molybdenum and sulphur are potent copper antagonists and can greatly increase Cu requirements. Moreover, high dietary Fe concentrations also reduce Cu status in the body (Ward 1996; Mullis et al., 2003). Copper concentrations were within the physiological range in all experimental cows (7.8-23.6 μmol/L, Cvetković et al., 1986) and showed no statistical difference ($p>0.05$), indicating an optimal supply of this micronutrient in the cows tested. Similar findings were reported by other authors who found no significant change in blood Cu values in both high-productive and low-productive cows. Blood Cu values also remain unchanged during pregnancy, in early lactation and during lactation, with low Cu status found in cows fed diets high in Fe (Ward et al., 1996; Stanton et al., 2000; Ballantine et al., 2002; Sharma et al., 2006).

Zinc is an essential component of over 70 enzymes in mammals. These enzymes are involved in protein, nucleic acid, carbohydrate, and lipid metabolism. Zinc is also required for normal development and functioning of the immune system, in cell membrane stability, and gene expression (Miller, 1970; Olson et al., 1999; Ballantine et al., 2002; Kellogg et al., 2004). Blood Zn levels in experimental cows were within the physiological range (10.71-19.89 μmol/L, Cvetković et al., 1986), and significantly lower ($p<0.05$) values for Zn were found in puerperium cows, compared to late gestation and full lactation cows, suggesting that Zn requirements in early lactation are higher in dairy cows. Literature data show that different dietary Zn amounts cause high variability in blood Zn values, with the effect of diet composition on blood zinc values being undefined, except for the fact that high dietary Ca concentrations reduce blood Zn concentrations in cattle (Miller, 1970; Olson et al., 1999; Mullis et al., 2003; Spears, 2003; Kellogg et al., 2004; Noaman, 2010).

Manganese is an integral component of the enzymes: arginase, superoxide dismutase found in the mitochondria, and pyruvate carboxylase. In addition, a number of enzymes can be activated by manganese (Hansen et al., 2006a; Hansen et al., 2006b). Mn concentrations in all experimental cows were

Table 3
Classification of blood Ca, P and Mg concentrations in dairy cows (Puls, 1988)

Status	Calcium, mmol/L	Inorganic phosphorus, mmol/L	Magnesium, mmol/L
Deficient	0.25 - 1.5 mmol/L	0.16 - 1.28 mmol/L	0.473-0.516 mmol/L
Marginal	1.5 - 2.0 mmol/L	1.28 - 1.44 mmol/L	0.516 - 0.774 mmol/L
Adequate	2.0-3.0 mmol/L	1.44 - 2.56 mmol/L	0.774 - 1.505 mmol/L
High	> 3.0 mmol/L	2.56 – 3.84 mmol/L	> 1.505 mmol/L

within the physiological limits (2.73-4.55 μmol/L, Cvetković et al., 1986), and no significant differences (P>0.05) were observed, suggesting an optimal supply of this micronutrient in experimental cows, which is in agreement with literature data (Olson et al., 1999; Ballantine et al., 2002; Hansen et al., 2006a; Hansen et al., 2006b). At dietary Mn concentraitons below 16 mg/kg, which are insufficient for normal fetal development, newborn calves show signs of Mn deficiency such as stunted (dwarfed) growth. Dietary Mn concentrations of 50 mg/kg are believed to be optimal for normal fetal development (Dvořák et al., 1980; Legleiter et al., 2005; Hansen et al., 2006b).

Cobalt is a component of vitamin B_{12}. Vitamin B_{12} is important in the metabolism of propionate in the liver (the vitamin B_{12}-dependent enzyme methylmalonyl CoA mutase), as well as in the metabolism of methionine and folic acid in the liver (the vitamin B_{12}-dependent enzyme methionine synthase) (Ballantine et al., 2002; Spears, 2003; Theil, 2004). Recent studies show that Co requirements in the peripartal period range between 0.15-0.19 mg/kg dry matter, being sufficient for high milk production, as they provide adequate concentrations of vitamin B_{12} in the blood. Therefore, values greater than 0.10 mg/kg have been recommended by NRC (Schwarz et al., 2000; Tiffany et al., 2003). Low Co values in high concentrate diets reduce the production of propionic acid in the rumen (Tiffany et al., 2003; Tiffany and Spears, 2005; Nocek et al., 2006). Co levels in all experimental cows were within the physiological range (0.51-0.85 μmol/L, Cvetković et al., 1986), and showed no significant difference (P>0.05), suggesting an optimal supply of this micronutrient in the cows tested.

Conclusion

- Blood serum values for the macro- and micronutrients tested in dairy cows were within the physiological range during transition and full lactation.
- Blood serum concentrations of calcium and inorganic phosphorus were significantly lower (p<0.05) in puerperium cows compared to late gestation and full lactation cows.
- Blood levels of magnesium were lower, but no statistical significance (p>0.05) was observed, in cows in early lactation, compared to cows before calving, whereas they were significantly lower (p<0.05) compared to blood magnesium values in full lactation cows.
- Serum levels of iron, copper, manganese and cobalt showed no statistical variation (p>0.05) in experimental cows, whereas serum zinc levels were significantly lower (p<0.05) in puerperium cows, compared to late gestation and full lactation cows.
- The results show that the homeostasis of the macro- and micronutrients tested in the blood of transition and full lactation dairy cows was maintained, suggesting their adequate supply from alimentary sources.

Acknowledgements

This study is part of the project titled "Environmental Approach and Adoption of Modern Biotechnologies as a Basis for Improvement of Ruminant Production Technology", Ref. No. TR 31001, financially supported by the Ministry of Science and Technological Development, Republic of Serbia.

References

Ballantine, H. T., M. T, Socha, D. J. Tomlinson, A. B. Johnson, A. S. Fielding, J. K. Shearer and S. R. Van Amstel, 2002. Effects of feeding complexed zinc, manganese, copper, and cobalt to late gestation and lactating dairy cows on claw integrity, reproduction, and lactation performance. *Prof. Anim. Sci.,* **18:** 211-218.

Curtis, C. R., H. N. Erb, C. J. Sniffen, R. D. Smith, P. A. Powers, M. C. Smith, M. E. White, R. B. Hillman and E. J. Pearson, 1983. Association of parturient hypocalcemia with eight periparturient disorders in Holstein cows. *J. Am. Vet. Med. Assoc.*, **183**: 559-561.

Cvetković, A., V. Ćirić, M. Jovanović, V. Litričin, Ž. Lješević, D. Marjanović, S. Paunović and M Petrović, 1986. Klinička dijagnostika unutrašnjih bolesti domaćih životinja. Univerzitet u Beogradu, Veterinarski fakultet, 1986, pp. 332 (Sr).

Daniel, R. C. W., 1983. Motility of the rumen and abomasum during hypocalcaemia. *Can. J. Comp. Med.*, **47**: 276-280.

Dobrzański, Z., H. Górecka, S. Opaliński, K. Chojnacka and R. Kołacz, 2005. Trace and ultratrace elements in cow´s milk and blood (in Polish). *Med. Wet.*, **61** (3): 301-304.

Dvořák, V., J. Bouda and J. Doubek, 1980. Levels of Macro- and Microelements in Blood Plasma of Late-pregnant Cows and Their Foetuses. *Acta Vet. Brno*, **49**: 199-201.

Đoković, R., Z. Ilić, V. Kurćubić and V. Dosković., 2010. The values of organic and inorganic blood parameters in dairy cows during the peripartal period. *Contemporary Agriculture*, **59** (1-2): 30-36.

Fontenot, J. F., V. C. Allen, G. E. Bunce and J. P. Goff, 1989. Factors influencing magnesium apsorption and metabolism in ruminants. *J. Anim. Sci.,* **67**: 3445-3455.

Goff, J. P. and R. L. Horst, 1997. Physiological changes in parturition and their relationship to metabolic disorders. *J. Dairy Sci.*, **80**: 1260-1268.

Hansen S. L., J. W. Spears, C. S. Whisnant and K. E. Lloyd, 2006a. Growth, reproductive performance, and manganese status of beef heifers fed varying concentrations of manganese. *J. Anim. Sci.,* **84**: 3375-3380.

Hansen, S. L., J. W. Spears, K. E. Lloyd and C. S. Whisnant, 2006b. Feeding a low manganese diet to heifers during gestation impairs fetal growth and development. *J. Dairy Sci*., **89**: 4305-4311.

Ivanov, I., Z. Damnjanović and S. Radojčić, 1993. Poremećaj metabolizma makroelemenata u visokom graviditetu i ranoj laktaciji (Sr). *Veterinary Bulletin*, **47** (4-5): 319-329.

Jacobsen, D. R., R. W. Hemken, F. S. Button and R. H. Hotton, 1971. Mineral nutrition, calcium, phosphorus, magnesium and potassium interrelationship. *J. Dairy. Sci*., **50** (7): 935-944.

Kellogg, D. W., D. J. Tomlinson, M. T. Socha and A. B. Johnson, 2004. Review: effects of zinc methionine complex on milk production and somatic cell count of dairy cows: twelve-trial summary. *Prof. Anim. Sci*., **20**: 295-301.

Kupczynski, R. and B. Chudoba-Drozdowska, 2002. Values of selected biochemical parameters of cows blood during their dryaing-off and the beginning of lactation. *Electronic Journal of Polish Agricultural Univerzities (EJPAU)*, **55:** 225-231.

Kurćubić, V., Z. Ilić, M. Vukašinović and R. Đoković, 2010. Effect of Dietary Supplements of Sodium Bicarbonate on Tissue Calcium (Ca) and Magnesium (Mg) Levels in Beef Cattle. *Acta Agriculturae Serbica,* **29** (15) : 55-76.

Lean, I. J., P. J. DeGaris, D. M. McNeil and E. Block, 2006. Hypocalcaemia in dairy cows: meta-analysis and dietary cation anion difference theory revisited. *J. Dairy Sci*., **89**: 669-684.

Legleiter, L. R., J. W. Spears and K. E. Lloyd, 2005. Influence of dietary manganese on performance lipid metabolism, and carcass composition of growing and finishingsteers. *J. Anim. Sci*., **83**: 2434-2439.

Liesegang, A., C. Chiappi, J. Risteli, J. Kessler and H. D. Hess, 2007. Influence of different calcium contents in diets supplemented with anionic salts on bone metabolism in periparturient dairy cows. *Journal of Animal Physiology and Animal Nutrition*, **91** (3-4): 120-119.

Miller, W. J., 1970. Zinc nutrition of cattle: a review. *J. Dairy Sci.,* **53**: 1123-1135.

Miller, W. J., 1975. New concepts and developments in metabolism and homeostasis of inorganic elements in dairy cattle. A review. *J. Dairy Sci*., **58**: 1549-1560.

Mullis, L.A., J.W. Spears and R. L. McCraw, 2003. Effect of breed (Angus Simmental) and copper and zinc source on mineral status of steers fed high dietary iron. *J. Anim. Sci.,* **81**:318-322.

Nocek, J. E., M. T. Socha and D. J. Tomlinson, 2006. The effect of trace mineral fortification level and source on performance of dairy cattle. *J. Dairy Sci.,* **89**: 2679-2693.

Olson, P. A., D. R. Brink, D. T. Hickok, M. P. Carlson, N. R. Schneider, G. H. Deutscher, D. C. Adams, D. J. Colburn and A. B. Johnson, 1999. Effects of supplementation of organic and inorganic combination of copper, cobalt, manganese, and zinc above nutrient requirement levels on postpartum two-year-old cows. *J. Anim. Sci.,* **77**: 522-532.

Puls, R., 1998. Mineral levels in animal health, diagnostic data. Sherpa international, British Columbia, Canada.

Sevinc, M., A. Basoglu, F. Birdane, M. Gokcen and M. Kucukfindik, 1997. The changes of metabolic profile in dairy cows during dry period and after. *Turk. J. Vet. Anim.Sci.,* **3**: 475-478.

Sharma, M. C., P. Kumar, C. Joshi and H. Kaur, 2006. Status of serum minerals and biochemical parameters in cattle of organized farms and unorganized farms of Western Uttar Pradesh. *J. Animal and Veterinary Advances*, **1** (1): 33-41.

Soetan, K. O., C. O. Olaiya and O. E. Oyewole, 2010. The importance of mineral elements for humans, domestic animals and plants: A review. *African J. Food Sci.,* **4**(5): 200-222.

Spears, J. W., 2003. Trace mineral bioavailability in ruminants. *J. Nutr.*, **133**: 1506S-1509S.

Stanton, T. L., J. C. Whittier, T. W. Geary and C. V. Kimberling, 2000. Johnson.Effects of trace mineral supplementation on cow-calf performance, reproduction,and immune function. *Prof. Anim. Sci.,* **16**: 121-127.

Tiffany, M. E. and J. W. Spears, 2005. Differential responses to dietary cobalt infinishing steers fed corn-versus barley-based diets. *J. Anim. Sci.,* **83**: 2580-2589.

Tiffany, M. E., J. W. Spears, L. Xi and J. Horton, 2003. Influence of dietary cobalt source and concentration on performance, vitamin B_{12} status, and ruminal plasma metabolites in growing and finishing steers. *J. Anim. Sci.,* **81**: 3151-3159.

Theil, E. C., 2004. Iron, ferritin and nutrition. *Annu. Rev. Nutr.*, **24**: 327-343.

Wacker, W. E. C., 1980. Magnesium and Mangan. Cambridge, Mass.: *Harvard University Press*.

Wang, C. and D. K. Beede, 1992. Effects of magnesium on acid base status and calcium metabolism of dairy cows fed acidogenic salts. *J. Dairy Sci.,* **75**: 829-836.

Ward, J. D., J. W. Spears and E. B. Kegley, 1996. Bioavailability of copper proteinate and copper carbonate relative to copper sulfate in cattle. *J. Dairy Sci.,* **79**: 127-132.

Received July, 27, 2013; accepted for printing February, 2, 2014.