



SODIUM, POTASSIUM AND CHLORIDE HOMEOSTASIS IN COWS DURING PREGNANCY AND FIRST MONTHS OF LACTATION

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Accepted June 11, 2014

Growth and development of the fetus, preparation of mammary gland for lactation, reproductive system regeneration after parturition and preparation of an organism for new fertilization and pregnancy, force adaptive changes, both morphological and functional, in pregnant and lactating cow. This may result in variations in concentration of minerals in blood. That is why it is very important to monitor changes in concentration of main electrolytes of body fluids, such as sodium, potassium and chlorides, and resulting blood plasma osmotic pressure. Maintenance of water-electrolyte homeostasis, both during pregnancy and postpartum period, is essential to keep mother's health and to maintain proper development of embryo/fetus and newborn calf. According to many authors, homeostatic mechanisms, in healthy adult cows are efficient enough and concentration of sodium, potassium, chlorides in blood is maintained within relatively narrow frames. However, depending on physiological condition – for example during pregnancy or period of intensive milk production, large variations may be observed. Nevertheless, these changes usually does not exceed fairly broad limits of reference values. Relative stability of osmotic pressure, during last month of pregnancy and first month of lactation, despite variations in concentration of electrolytes, indicate efficiency of mechanisms controlling osmotic stability and electroneutrality of extracellular fluid.

Key words: pregnant cows, lactation, blood, sodium, potassium, chloride

INTRODUCTION

During pregnancy and first months of lactation, intensive adaptive morphological and functional changes occur in a female body. Changes are observed in intensity of metabolic processes and activity of its regulatory mechanisms, and they are connected with growth and development of fetus, with mammary gland preparation for lactation,

and after parturition – with reproductive system regeneration and preparation for new fertilization and pregnancy. Functional changes are also observed in other systems e.g.: cardiovascular, digestive, respiratory and excretory (KINDAHL et al., 2002; KORNMATITSUK et al., 2003; KINDAHL et al., 2004).

During pregnancy, especially in the third trimester, increased demand for energy and nitro-

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gen is observed. Increased fetal requirement for energy, protein and minerals is also observed during this period. These requirements are met by metabolic adaptations e.g.: increased hepatic gluconeogenesis, decreased peripheral tissue glucose utilization, increased fatty acid mobilization from adipose tissue, increased amino acid mobilization from muscle (BELL, 1995). The onset of lactation is associated with increased utilization of nutrients, and consumption does not always cover these increased demands. During first weeks of lactation, negative energy balance is often observed, which, according to many authors, becomes positive about 2 months after calving (BELL and BAUMAN, 1997; KNIGHT, 2001; STEC et al., 2006; NOGALSKI and GÓRAK, 2008).

Regeneration of reproductive system after pregnancy and preparation for new fertilization – which are the most intensive at early postpartum period – have significant impact on intensity of metabolic processes (MEIKLE et al., 2004).

Measurable effect of changes in intensity of metabolic processes in cows during pregnancy and lactation may be variations in concentration of biochemical parameters in blood. Knowledge about changes in concentration of these components, gives the possibility to assess: cows health status, the quality of nutrition or reproductive performance and milk productivity (BARANOW-BARANOWSKI et al., 1987; STEC et al., 2006; AL-MUJALLI, 2008; SZELAG-GRUSZKA and SKRZYPEK, 2009).

Maintenance of water-electrolyte homeostasis, both during pregnancy and postpartum period, is essential to keep mother's health and to maintain proper development of embryo/fetus and newborn calf. That is why it is very important to monitor changes in concentration of main electrolytes of body fluids, such as sodium, potassium and chlorides and resulting blood plasma molality (KNIGHT, 2001).

Changes in sodium concentration

Sodium is a major electrolyte of extracellular fluid. To a large extent is responsible for maintaining the volume and osmotic pressure of this fluid. Sodium absorption from gastrointestinal tract is effective, especially in the small intestine. The major route of elimination of sodium is via urinary system, and the main hormonal regulators

are: rennin-angiotensin-aldosterone system, vasopressin, atrial natriuretic peptide and prostaglandins (HOWARD and SCHRIER, 1990; ZACCARIA et al., 1998; JAIN et al., 2007).

Sodium concentration in cows blood plasma ranges within broad reference values from 134 to 156 mmol/l (WINNICKA, 2008). According to many authors, regulation of sodium balance in healthy adult cows is effective and sodium concentration in blood is maintained within relatively narrow frames. However, depending on physiological condition or period of life, large variations may be observed.

Our studies on pregnant heifers revealed stable sodium concentration in blood plasma during entire pregnancy. The lowest value (136.06 mmol/l) was noted 7 days before insemination, the highest (139.09 mmol/l) in 6th month of pregnancy. However, these changes were statistically insignificant (JAROSZ, 2013). Also during last weeks of pregnancy, sodium concentration in blood plasma was relatively stable (no statistically significant changes) and fluctuated from 136.34 to 138.15 mmol/l. An increase in concentration of sodium in last week of pregnancy was observed and the highest concentration (140.64 mmol/l) was noted at the day of delivery. During first two weeks after calving, sodium concentration decreased statistically significantly to the value of 132.71 mmol/l and stabilized at a similar level until the end of second month of lactation (KURPIŃSKA, 2013).

YOKUS and ÇAKIR, (2006) reported that mean sodium concentration in blood serum from pregnant cows was 138.85 mmol/l and slightly increased with time during pregnancy. The lowest value was observed in first trimester (138.67 mmol/l) and the highest in third trimester of pregnancy (140.00 mmol/l). DVORÁK et al., (1980) showed that mean sodium concentration in blood plasma from cows during last 6 months of pregnancy was 147.12 mmol/l. Similar sodium concentration in blood plasma from pregnant cows – 143.00 mmol/l – was reported by GRÜN WALDT et al., (2005).

High stability of sodium concentration in blood from cows during pregnancy and postpartum period was reported by e.g. (DVORÁK et al., 1980; KUPCZYŃSKI and CHUDOBA-DROZDOWSKA, 2002; YOKUS and ÇAKIR, 2006; OZGO et al., 2008; DODAMANI et al., 2009). KUPCZYŃSKI and CHUDOBA-DROZDOWSKA, (2002) reported that sodium concentration in blood plasma from Holstein-

Friesian, black-and-white variety cows (aged 4-6 years), one month before delivery was 138.00 mmol/l (135.1-140.6 mmol/l), one week after parturition – 138.7 mmol/l (134.2-144.5 mmol/l), one month after parturition – 137.7 mmol/l (134.1-149.1 mmol/l). Our other studies showed similar values (OŹGO et al., 2008). Sodium concentration in blood plasma from Holstein-Friesian cows, between 30th day before parturition and 30th day of lactation ranged from 139.2 to 147.1 mmol/l. One month before parturition, mean sodium concentration was 146.3 mmol/l, two weeks before delivery – 143.4 mmol/l, one week before delivery – 144.7 mmol/l, 3 days before delivery – 144.3 mmol/l, and on last day of pregnancy was 139.2 mmol/l. Concentration of this electrolyte was immediately after parturition 141.7 mmol/l, on first day of lactation was 143.2 mmol/l, 3 days after delivery – 145.1 mmol/l, 7 days after delivery – 140.3 mmol/l and one month after delivery – 147.1 mmol/l. Also BOMBIK et al., (2009) revealed high stability of sodium concentration in cows blood serum during drying-off and first nine weeks of lactation (140.0-142.0 mmol/l). High stability of sodium concentration in cows blood (aged 4-7 years), during transition period was observed by MORDAK and NICPOŃ, (2006). The authors reported that during last week before delivery, mean sodium concentration was 142.7 mmol/l and during first week of lactation was 141.1 mmol/l.

Similarly to our studies KUME et al., (1998), observed an increase in blood plasma sodium concentration in heifers at the end of pregnancy from 143.0 to 145.2 mmol/l and statistically significant decrease to the value of 140.4 mmol/l in the first week after calving and the value – 138.7 mmol/l – in tenth week of lactation. Sodium gradual decrease in cows blood after calving was also highlighted by KUREK and STEC, (2005). The authors showed that sodium concentration in blood from cows (aged 3-4 years), 7 days before delivery was 149.2 mmol/l, within 6 hours after calving – 145.9 mmol/l, on 7th day of lactation – 143.3 mmol/l. The authors showed similar values in older cows (aged 6-10 years), respectively: 145.1 mmol/l, 145.7 mmol/l, 142.9 mmol/l.

Periparturient changes in electrolytes concentration, especially sodium variations, result from high activity of rennin-angiotensin-aldosterone system at the end of pregnancy and from synergis-

tic cooperation with vasopressin, what may lead to positive sodium balance. Lower excretion of sodium and water via urinary tract may cause an increase in extracellular fluid volume. An increase in sodium concentration immediately before parturition may be connected with an increase in aldosterone concentration observed immediately before calving and during first week of lactation (SIEGIEL et al., 1981; BADDOURI and QUYOU, 1991; OŹGO et al., 2008; SKRZYP CZAK et al., 2009). Decrease in sodium concentration during first weeks of lactation may be a consequence of decreased plasma rennin activity in cows after calving and result in sodium loss (OŹGO et al., 2008). SAFWATE et al., (1981) observed during postpartum period decrease in aldosterone concentration in cows blood. ASIF et al., (1996) explained that decrease in sodium concentration in blood may also be influenced by high concentration of prostaglandins, what causes an increase in sodium excretion with urine.

Changes in potassium concentration

Potassium is a major cation of intracellular fluid (about 98% body stores). Potassium is absorbed in intestines via simple diffusion and 90% of absorbed potassium is excreted with urine, 8% with feces (YEPERSELE DE STRIHOU, 1977; ASIF et al., 1996). Potassium is responsible for maintenance of intracellular osmotic pressure. It also takes part in systemic processes e.g. – maintenance of acid-base balance, conduction of nerve impulses, contraction and relaxation of muscles, activity of many enzymes, glycogen and protein synthesis (HARRIS et al., 1994; SILANIKOVE et al., 1997; JAIN et al., 2007; HASSABO, 2008).

According to many authors, potassium concentration in cows blood during pregnancy and the beginning of lactation is stable and range within reference values from 3.8 to 5.1 mmol/l (WINNICKA, 2008).

Our studies on pregnant heifers and primiparous, lactating cows showed stable potassium concentration in blood plasma, which varied during pregnancy from 3.86 to 4.20 mmol/l. Slightly higher values were observed in non-pregnant heifers (4.15 mmol/l), a decrease in concentration of this electrolyte in first month of pregnancy and high stability in subsequent months of pregnancy

was also noted (JAROSZ, 2013). The lowest potassium concentration in cows blood was observed 4 weeks before delivery (3.91 mmol/l). During last two weeks of pregnancy and first 8 weeks of lactation, concentration of this electrolyte did not vary statistically significantly and ranged from 4.22 to 4.71 mmol/l (KURPIŃSKA, 2013).

YOKUS and ÇAKIR, (2006) showed that potassium concentration in cows blood serum was the lowest in second trimester (4.31 mmol/l) and the highest in third trimester (4.85 mmol/l).

Lower values of potassium concentration in blood plasma from cows (aged 2.5-4 years) before and after delivery, compared to our results, were observed by KUREK and STEC, (2005). The authors showed that mean potassium concentration, 7 days before delivery was 3.60 mmol/l, 48 hours before delivery – 3.65 mmol/l, within 3-6 hours after parturition – 3.58 mmol/l, 24 hours after delivery – 3.82 mmol/l and on 7th day of lactation – 3.87 mmol/l. It is worth noting that the authors reported higher potassium concentration in blood of older cows (aged 6-10 years). Mean potassium concentration was respectively at the same points of analysis: 4.02 mmol/l, 3.94 mmol/l, 4.12 mmol/l, 3.97 mmol/l, 3.73 mmol/l. Our other studies also revealed in Holstein-Friesian cows low but stable concentration of potassium in blood plasma (Ozgo et al., 2008). It ranged from 3.48 to 3.79 mmol/l. The highest value was observed one month before parturition and the lowest on first day after calving. KUPCZYŃSKI and CHUDOBA-DROZDOWSKA, (2002) reported that potassium concentration in blood plasma from Holstein-Friesian, black-and-white variety cows (aged 4-6 years), one month before delivery was 4.07 mmol/l (3.71-4.39 mmol/l), one week after parturition – 4.06 mmol/l (3.18-4.73 mmol/l), one month after parturition – 3.99 mmol/l (3.48-4.66 mmol/l). Similar and stable potassium concentration in blood of dairy cows was observed by MORDAK and NICPOŃ, (2006). The authors reported that during last week before delivery, mean potassium concentration was 3.82 mmol/l and during first week of lactation was 3.80 mmol/l.

Slightly higher values were reported by KUME et al. (1998) in primiparous cows. The authors showed that blood plasma potassium concentration, one week before delivery was 4.49 mmol/l, at the day of delivery – 4.54 mmol/l, one week after calving – 4.05 mmol/l, 4 weeks after calving

– 4.21 mmol/l, in tenth week of lactation – 3.82 mmol/l. The authors highlight that concentration of this electrolyte in blood of cows in lactation is significantly lower in primiparous than in multiparous cows. Lower potassium concentration in blood serum from cows during lactation (compared to prepartum values) was observed by MEGLIA et al., (2001). One month before calving, mean potassium concentration was 4.19 mmol/l, at the day of delivery – 4.18 mmol/l, one month after calving – 3.64 mmol/l. Also MCADAM and O'DELL, (1982) observed lower concentration of this electrolyte in cows blood plasma on the beginning of lactation.

Higher values of this electrolyte in cows blood were observed by BOMBİK et al., (2009). The authors reported that during drying-off and first 9 weeks of lactation, potassium concentration in blood serum from Holstein-Friesian cows ranged from 5.04 to 5.26 mmol/l, and between 3rd and 15th week of lactation from 4.61 to 5.26 mmol/l. GOFF, (2006) suggested that high potassium concentration in blood may be connected with occurrence of metabolic acidosis and in turn, low concentration of this electrolyte with high insulin concentration, what promotes cellular uptake of potassium.

High stability in potassium concentration in blood from cows during lactation was observed by SATTLER et al., (2001). The authors showed that concentration of this electrolyte in first three months of lactation was high and stable (4.5 mmol/l). Similar results in cows during lactation were observed by GRÜN WALDT et al., (2005) and NOZAD et al., (2012).

Changes in chloride concentration

Chlorides are abundant mainly in extracellular fluid. In healthy cows chloride concentration in blood serum range from 93 to 107 mmol/l (WINNICKA, 2008). Regulation of chloride concentration in blood is associated with regulation of sodium concentration – it means that changes in sodium concentration may influence changes in chloride concentration (BATCHELDER et al., 2007; OZGO et al., 2008).

Our studies on pregnant heifers and primiparous, lactating cows showed high stability of chloride concentration in blood, which ranged

from 93.75 to 96.00 mmol/l (JAROSZ, 2013). At the end of pregnancy an increase was observed to the value of 99.20 mmol/l (7 days before calving) and then gradual decrease was noted with time in lactation to the value of 90.90 mmol/l (8 weeks after calving) (KURPIŃSKA, 2013). It is worth to emphasize that chloride concentration in blood from cows during transition period had similar tendency to changes observed for sodium – higher concentration and stability was observed before delivery and lowering concentration during first weeks of lactation.

DODAMANI et al., (2009) noted statistically significant decrease in chloride concentration in cows blood until ninth month of pregnancy and slight increase at the end of pregnancy. Also VAN SAUN et al., (2004) showed that chloride concentration during last month of pregnancy (103.10 mmol/l) was higher than in first month of lactation (99.70 mmol/l). Other authors also observed higher values before the delivery, compared to postpartum period (SWENSSON et al., 2007).

KUPCZYŃSKI and CHUDOBA-DROZDOWSKA, (2002) reported that chloride concentration in blood plasma from Holstein-Friesian, black-and-white variety cows (aged 4-6 years), one month before delivery was 100.9 mmol/l (93.4-105.0 mmol/l), one week after parturition – 103.1 mmol/l (93.1-107.1 mmol/l), one month after parturition – 97.5 mmol/l (92.0-106.0 mmol/l). Our other studies showed that chloride concentration in blood plasma from Holstein-Friesian cows, one month before parturition was 101.1 mmol/l, and increased – two weeks before delivery reached 103.2 mmol/l, one week before delivery – 105.3 mmol/l, 3 days before delivery – 107.9 mmol/l, and on last day of pregnancy was 105.2 mmol/l, immediately after parturition was 106.7 mmol/l. We also reported statistically significant decrease in chloride concentration to the value of 101.9 mmol/l (1st day after calving), 100.2 mmol/l (3rd day after delivery), 99.05 mmol/l (7th day after delivery), and 99.55 mmol/l (one month after delivery) (OŹGO et al., 2008).

It is worth noting that higher chloride concentration in blood serum was observed in beef cattle (during lactation – 105.0 mmol/l) (GRÜN WALDT et al., 2005) as well as, no statistically significant differences between primiparous and multiparous cows (MCADAM and O'DELL, 1982).

Changes in blood plasma osmotic pressure

Sodium and chloride concentration in blood plasma determine its osmotic pressure. Our studies on pregnant heifers and primiparous, lactating cows showed that osmotic pressure of blood plasma ranged from 268.06 to 283.50 mmol/kg H₂O. Worth noting is an increase from 270.95 (4 weeks before calving) to 276.05 mmol/kg H₂O (at the day of delivery), its statistically significant decrease in first two weeks after calving (268.5 mmol/kg H₂O) and stabilization of this parameter on this level until 8th week of lactation (JAROSZ, 2013; KURPIŃSKA, 2013). Many studies showed a decrease in blood plasma osmotic pressure at the end of pregnancy. These changes were observed in women (DAVISON et al., 1988; STACHENFELD et al., 1998), rats (BEAUSEJOUR et al., 2003) and cows (OŹGO et al., 2008).

Many authors highlight that in periparturient period changes in blood plasma osmotic pressure are sparse. SHALIT et al., (1991) showed that blood plasma molality in Holstein cows, two weeks before delivery was 284.0 mmol/kg H₂O, in second week after calving – 273.0 mmol/kg H₂O, in 7th week of lactation – 281.0 mmol/kg H₂O. Our other studies showed that blood plasma molality, 30, 7 and 3 days before delivery was respectively: 258.60; 256.9; 258.3 mmol/kg H₂O, and on 3rd, 7th, 30th day after calving was respectively 257.7; 256.6; 255.1 mmol/kg H₂O (OŹGO et al., 2008).

Relative stability of blood osmotic pressure during last month of pregnancy and first month of lactation, despite changes in concentration of electrolytes, highlight the high efficiency of mechanisms controlling osmotic stability and electroneutrality of extracellular fluid (SKRZYPCZAK et al., 2009). LANDGRAF et al., (1983) showed that an increase in blood plasma osmotic pressure is connected with an increase in concentration of vasopressin (with the highest values observed at the delivery). OŹGO et al., (2008). also reported an increase in vasopressin concentration in blood and an increase in plasma rennin activity from 30 day before delivery, and then gradual decrease until 30th day of lactation. Oxytocin is also involved in regulation of osmotic pressure. WILLIAMS et al., (2001) reported that before delivery there is an increase in frequency and amplitude in oxytocin secretion (secretion

of oxytocin decreases after expulsion of the placenta). SOMPONPUN and SLADEK, (2003) showed in rats that oxytocin stimulates the release of atrial natriuretic peptide, what promotes excretion of water and electrolytes.

ACKNOWLEDGEMENTS

This work was supported by scientific grants from the Ministry of Science and Higher Education, Poland (Project No. N311 112538; 2010-2013).

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