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The influence of dcad value in feed ration on hypocalcaemia during transition period in cows – Review

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Transition period (three weeks before calving and the first three weeks of lactation) is an intensive changes in the organism of cow which have to be accompanied by changes in feeding. One of the most important metabolic diseases of the periparturient and early lactation periods is hypocalcemia leading to postpartum paralysis. Among its many causes, there is high content of calcium in the feed ration during the dry period and the excess of cations, especially Na^+ and K^+, in relation to anions (Cl^- and S^{2-}) in the feed. It results in too high blood pH, which impairs the activity of parathyroid hormone. Research results show that feeding negative cation-anion difference (DCAD – Dietary Cation-Anion Difference) ration reduces hypocalcaemia in cows in the postpartum period.
In this review factors affecting DCAD values in the feed ration and possibilities of its optimization in the transition period has been discussed.
Keywords: Cows health, transition period, nutrition, DCAD**.**

INTRODUCTION

An intensive breeding efforts have resulted in significant growth in performance of dairy cows, especially of Polish Holstein-Frisian breed. Performance is still considered as the main factor determining milk production. For various reasons, this issue deserves a more comprehensive presentation. Growth in animals' performance requires adjusting the environment to their upkeep and nutritional requirements. Frequently, the suggested changes are unable to fulfill these growing demands of dairy cows. Consequently, the increased incidence of metabolic diseases resulting from difficulties in balancing feed rations – especially during the dry period and early lactation – is observed. Metabolic diseases reduce physiological possibilities of animal body, which translates into not only decrease their performance but also unfavorable changes in the physicochemical parameters of colostrum and milk that determine technological usefulness of raw milk and calf rearing. The current analysis of cow health may become a key element leading to improvements in health of herds of dairy cows (Fig. 1) (Hamman and Krömker, 1997; Rajaeerad *et al*. 2020).

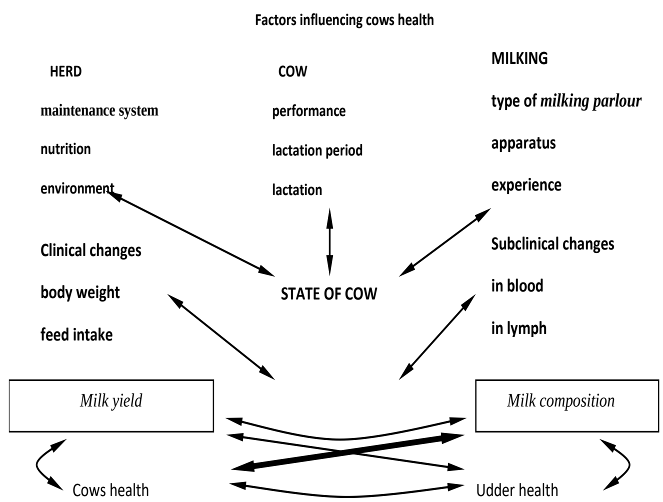

Figure 1. Possibilities of cow's health evaluation with regard to factors of influence and related analytical parameters (Hamman and Krömker, 1997).

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***Transition period and metabolic problems of cows*:** The transition period, that is the last three weeks of the dry period and the first three weeks of lactation, is of special interest. The dry period is a production cycle phase necessary for regeneration and development of cow's mammary gland which ensures better performance in the next lactation. It is also a period of intensive growth of the foetus. This phase allows for synthesis and accumulation of colostrum components, especially in the last two weeks before calving, and in consequence influences its quality and the level of passive immunity in calves (Capuco *et al*,. 2001; Annen *et al*., 2004). The dry period is connected with vital physiological and metabolic changes that have to be accompanied by adjustments in nutrition. Optimizing cow nutrition at that time reduces postparturient problems, improves cow's metabolic status, cow and calf health, cow fertility and performance, so all the parameters that determine the efficiency of milk production.

High performance of cows and the extension of periods between calvings result in drying off cows when they still yield large quantities of milk – its synthesis is abruptly stopped. During this time, there is an increased risk of intramammary infection with pathogens, which cause inflammation of the udder (Dingwell *et al*., 2003). In the dry period, resorption of milk and regression of glandular tissue takes place in the mammary gland. The functions of neutrophils and lymphatic response are weaker and the production of cytokines by the immune cells drops (Stefano *et al*., 2002; Kehrli *et al*., 2006). Dysfunctions of immune response may be caused by the stress accompanying advanced pregnancy and the approaching calving. An increased release of stress hormones, such as corticosteroids, and oxidative stress may cause higher susceptibility to mastitis in cows (Sordillo *et al*., 2005, Laliotis *et al*., 2020).

Growth of genetic potential and better milk performance make balancing both nutrients and minerals in feed rations more important (Seymour, 2001). It is vitally important to properly balance feed rations for macroelements, especially in the prepartum period and during early lactation. They ensure complete fulfillment of animals' requirements but they may also improve their proportions in colostrum and milk. This balance may be responsible for the transport of minerals to the embryo, thus improving health condition of newborn calves (Iwańska *et al*., 1999).

Problems with metabolism of mineral components, especially in high-producing cows, still need addressing since they result in high incidence of some metabolic dysfunctions and diseases. Their pathogenesis is extremely complex, all the more so because macroelements –unlike microelements – are not efficiently stored in tissues, so their supplementation is inadvisable and ineffective until the requirements increase (Goff *et al*., 1995). One of the important roles in the pathogenesis of minerals metabolism in cows is played by interactions (antagonism and synergism) between particular mineral components (Goff and Horst, 1993; Kinal *et al*., 1996).

One of the most serious periparturient and early lactation diseases of metabolic background is a dysfunction of calcium metabolism (hypocalcaemia) leading to postparturient paralysis (milk fever). Blood levels of calcium (Ca) in adult cows range from 2.1 to 2.5 mM and fall during gestation: it is connected with the growth of embryo towards the end of the gestation period and its increased use for colostrums and milk production. In order to replenish calcium, cows absorb more Ca from feeds and bone, which in this case may result in lactation-induced osteoporosis when the loss of bone calcium is 0,09-0,13mM. Increased absorption of calcium from bone is influenced by parathormone produced when blood level of calcium falls (Goff and Horst, 1997; Goff, 2006) observed a correlation between concentrations of calcium and potassium in the feed ration: in cows fed high concentration of calcium and potassium the incidence of milk fever was higher than in cows given low concentration of calcium and potassium feed. This may suggest that calcium does not function separately but in conjunction with other elements.

***Dietary cation anion difference and its consequences*:** The results of research conducted by Sanchez and Baluwickel (2001) suggest that 2/3 cows in the second or later lactation suffer from subclinical hypocalcaemia, which leads to retained placenta and displaced abomasums. Among its many causes, there is high concentration of calcium in the ration fed in the dry period, but research does not always confirm it (Goff *et al*., 1995; Goff *et al*., 2020). One of the conditions conducive to this disease is excess of cations in feeds, mainly Na^+ and K^+, as compared to anions (Cl^- and S^{2-}). It causes too high blood pH, which impairs the activity of parathormone and disrupts hormonal parathormone-calcitonin-1.25 dihydroxycholecalciferol system. Reducing the incidence of these dysfunctions is not easy and the lowering of calcium level advised in the dry period is not always favorable, but may sometimes be harmful, especially immediately before calving. However, research proves that negative cation-anion balance in feed ration (DCAD – Dietary Cation-Anion Difference) reduces the severity of hypocalcaemia in postparturient cows (Joyce *et al*., 1997). Some of the earliest results which linked milk fever to acidic and alkaline properties of feed ration (not just the proportion of calcium in diet) were those published by Ender *et al*. (1971). They established that milk fever may occur in animals fed naturally alkaline feeds while administering 'acidic' components may reduce its incidence. Concerning strong ions, on which DCAD is based, says that net supply of particular cations or anions may disturb the cation-anion balance in animal body. That led to the conclusion that metabolic status of cows has been determined by the levels of cations and anions in the body (Sarwar *et al*., 2000).

The physiological mechanism explaining the impact of anions on adequate calcium metabolism in the periparturient period has not been fully explained (Breves *et al*., 1999). It has been suggested that this impact may be direct – through the change of blood pH from mildly alkaline when the animals were fed cation-dominated rations (especially due to potassium content) (Fredeen, 1988), to mildly acidic – observed in cows fed negatively balanced rations (Goff and Horst, 1997; Joyce *et al*., 1997). Mild metabolic acidosis facilitates the release of calcium cation from bones, enlarges the supply of easily exchangeable bone calcium, increases the number of D_3 vitamin receptors in tissues, the level of parathormone, and the activity of osteoclasts and resorption of Ca in the intestine (Weiss *et al*., 2015; Martinez *et al*., 2018).

Therefore, more and more frequently in the transition period the anion-dominated diet is fed, i.e., the proportion of chloride and sulfide anions is higher (Delaquis and Block, 1991). Cation-anion difference in daily feed ration (DCAD) is calculated from the content of sodium and potassium as well as chlorides and sulfides expressed as percentage of dry matter. This difference (expressed in mEq/kg DM) may be easily calculated using several slightly different formulas (Lean *et al*., 2006). For ruminants, the most common formula is DCAD = (Na % DM0,0023 + K%DM/0,0039) – (S% DM/0,0016 + Cl% DM/0,00355) (Bodarski *et al*., 2010).

Assuming that the correct value of DCAD in the preparturient period is 0–100mEq/kg DM, it is virtually impossible to achieve such values without special mineral additives since plant-based feeds are characterized by a distinct predominance of cations, especially potassium; as a result, especially in grass silage, the value of DCAD will be decisively positive (Tauriainen *et al*., 2001). Large fluctuations in the content of elements in roughage determined in the research by Bodarski *et al.* (2010) complicate the problem. Two commonly used feeds – corn silage and haylage – contained, respectively: 0.10 (0.03-0.25) and 0.17 (0.08-0.41) sodium; 0.89 (0.29-1.47) and 1.90 (1.00-2,65) potassium; 0.12 (0.09-0.14) and 0.26 (0.19-0.44) sulfur; 0.29 (0.07-0.43) and 0.78 (0.49-1.14) chlorine in dry matter. The result of such unstable mineral compositions of both feeds were their varied DCAD values: 41-241 for corn and 24-311 mEq/kg DM for haylage. Total mixed ration (TMR) for lactating cows was characterized by much smaller fluctuations and its DCAD value ranged between 173 and 258, averaging 226mEq/kg DM. Evidently, for proper DCAD balancing of feed ration for preparturient cows, mineral supplements– strong anion salts – such as calcium and ammonium chlorides, and calcium, magnesium and ammonium sulfides, should be used (Boudon *et al*., 2016; Zhang *et al*., 2020). Such a solution would be a simple and effective method preventing milk fever if sulfides and chlorides were tastier and more "popular" with cows; hence their name – "bitter salts". It was suggested that because of its acidic properties calcium chloride should be the preferred choice for minimizing the proportions of potassium in the feed ratio for cows. Even though calcium chloride has very little impact on feed intake it may supply maximum dosage of sulfur, important not only because of DCAD value. The research carried out by Bodarski *et al*. (2013) and Martinez *et al*. (2018) proved effectiveness of hydrated magnesium sulfide ($MgSO_4 \times 7H_2O$) and cholecalciferol or calcidiol in acidizing the organism.

A special role in preventing hypocalcaemia is ascribed to sulfur (Tucker *et al*., 1991; Martins *et al*., 2016). Its lack not only reduce DCAD, but causes disturbances in fermentation processes in forestomach, restricts synthesis of bacterial protein and reduces cellulose digestibility (Martins *et al*., 2016). Moreover, during lactation and transition period, addition of sulfur in feed ration raises fat content in milk through improving fiber digestibility and synthesis of acetic acid in the rumen (Delaquis and Block, 1995; Martinez *et al.*, 2018).

A larger proportion of cations (Na^+ and K^+) in feed rations for cows causes an increase in blood and urine pH, which leads to higher risk of milk fever (Goff and Horst, 1997). Tucker *et al*. (1988) demonstrated that urine pH increased with increasing dietary cation-anion balance. Moreover, Spranghero (2004) determined a positive correlation between DCAD value of feed ration and pH level of cow's urine. The research by Moore *et al*. (2000) showed that lowering the value of DCAD to -82mEq/ kg DM in feed ration for the period of 3 to 1 week before calving/parturition resulted in the fall in urine pH from 8.4 to 6.2. A significant decrease in urine pH level was also observed by Moore *et al*. (2000), who found that lowering the value of DCAD in feed ration to 0 leads to a fall in urine pH level to 7.3, which in turn prevents hypocalcaemia. Negative DCAD (-150mEq/kg DM) determined lower urine pH (pH=6), which effectively reduced the incidence of diseases. Cow's urine pH level helps to assess if the animal reacts to anion supplements in the feed ration: if a given anion supplement was beneficial, pH ranged between 5.5 and 6.2. Feeding rations with low DCAD led to a fall in urine pH in cows in experimental groups and with DCAD equal -50mEq/kg DM it was 6.3 while with -150mEq/kg DM it fell to 5.75. Higher urine pH was found in cows fed positive DCAD ration. DCAD equal +50mEq/kg DM determined pH=6.9, DCAD on the level +150mEq/kg DM increased urine pH to 7.67 (Wu *et al*., 2008). Similar consequences of decreasing DCAD ration in dry cows were observed by Wu *et al*. (2008).

With negative DCAD ration, the number of postparturient metabolic diseases fell drastically (Wu *et al*., 2008; Charbonneu *et al*., 2008; Ramos-Nieves *et al*., 2009; Rérat *et al*., 2009). Using feed ration of -82mEq/kg DM DCAD in cows in the last three weeks of the dry period, Siciliano-Jones *et al*. (2008) showed that it was possible to reduce the incidence of milk fever – as compared to cows fed +192mEq/kg DM DCAD – which reduced the risk of culling. No significant influence of a decreased cation-anion balance on energy metabolism and performance and reproduction indicators was observed. Wu *et al*. (2008) did not confirm milk fever, placenta retention or hypocalcaemia in cows fed negative DCAD ration (-50 and -150mEq/kg DM), which happened in cows fed positive DCAD (+50 and +150mEq/kg DM). Cows receiving negative DCAD had higher levels of calcium and magnesium in blood serum before and after calving, while the level of phosphorus was not affected. The proportion of calcium in colostrum of cows fed negative DCAD ration did not change. The proportion of calcium and phosphorus in colostrum decreased after subsequent calvings; beginning with the third lactation their content in colostrum stabilizes (Seifi *et al*., 2010; Iwaniuk *et al*., 2015).

The use of bitter salts to decrease DCAD value should be linked with feeding low potassium feeds. Rérat *et al* (2009) achieved two times lower values of DCAD feed ration using hay low in potassium. Feeding cows with low DCAD timothy hay decreased DCAD of the feed ration and caused positive changes in metabolic indicators (Charbonneu *et al*., 2008). Research and analyses classified grass and silages or hay as having high DCAD value; low DCAD values characterize some corn silages while spent grain, meadow hay, GPS, bran, and most feed concentrates have negative DCAD (Kume and Tanabe, 1993; Bodarski *et al*., 2010). However, as demonstrated earlier, roughage is characterized by high DCAD changeability, so its calculation should become a standard procedure in assessment of nutritional value of feeds. It is possible to conclude that DCAD values for cows in the last three weeks of the dry period should range between -100 and -150mEq/kg DM (Siciliano-Jones *et al*., 2008; Bodarski *et al*., 2010; Hassan *et al*., 2018).

Conclusions: The results of the research suggest that decreasing the DCAD (level between -50 to -150 mEq/kgDM) of the ration for preparturient cows improves calcium metabolism and has a positive influence on the animals' health.

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