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Mini Review

Blood Ions and Total Calcium in Dairy Cows: A Correlation Paradox

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ABSTRACT

This review introduced shortly blood Ionised Calcium (IC), Total Calcium (TCA) and their association with clinical and subclinical hypocalcemia in dairy cows. Calcium receptors in the parathyroid cells inactivate when serum calcium levels fall, triggering an increase in PTH secretion. This increase in PTH balances serum calcium by activating the parathyroid receptors in the bones and kidneys, increasing overall calcium resorption. In the kidney, increased PTH secretion enhances calcium-restorative effects by increasing secretion of 1,25-dihydroxyvitamin D (1.25D), the vitamin D receptor in the gut, and increases active calcium absorption by the bone Furthermore, the paradox between IC and TCA correlation and their threshold values for hypocalcemia were discussed.

Keywords: Dairy cow; Hypocalcemia; Ionised calcium; Total calcium

INTRODUCTION

Calcium is one of the most important constituents for the organism of vertebrates since it is a major part of the skeletal. More than this, its physiologically active form called Ionised Calcium (IC) has numerous functions in muscle contraction, nerve impulse transmission and hearth contraction [1]. Dairy cows require enough calcium supply at calving and in the early lactation. Especially just after calving, because lactating cows excrete roughly 0.91-0.97 g phosphorus and 1.28-1.45 g calcium for each kg milk that depends on the breed and parity of the dairy cows [2]. This means roughly excretion of 44.8-50.8 g calcium via milk by a lactating cow producing 35 kg milk/day. The well-known and one of the most important metabolic diseases of lactating cows is hypocalcemia or subclinical hypocalcemia caused by the deficiency of blood calcium, especially ionised form in the blood [3]. The ionised, physiologically active and diffusible form constitutes half of blood Total Calcium (TCA) level out of three fractions (anions salts, protein-bound and ionised form). Screening the blood calcium level in early lactation can be performed based on the serum or plasma total calcium test or ionised calcium measurements with ion-selective electrodes such as with blood gas devices. Many reports defined the thresholds for blood TCA of lactating cows to detect hypocalcemia and subclinical hypocalcemia [1,3,4], but defining the sensitive threshold level for IC was always a critical and difficult point in the correlation of blood TCA level [5]. This review work evaluated critically blood TCA and IC in dairy cows in terms of their correlation and threshold levels for hypocalcemia and subclinical hypocalcemia and associated postpartum health disorders.

LITERATURE REVIEW

Hypocalcemia in dairy cows

Hypocalcemia is a metabolic disease of dairy cows, also called milk fever or per parturient paresis. The disease is associated with decreased levels of blood TCA and IC at calving and in fresh cows. TCA and IC drop immediately at calving and can hardly increase within 2-3 days. Hypocalcemia was most frequently observed in the first 72 h after calving [3,6]. The disease can be manifested in Sub-Clinical Hypocalcemia (SCH) or Clinical Hypo-Calcemia (CHC) forms, thus the last one related more to the paresis, lie-down and unable to stand just after calving. The economic impact of milk fever was estimated to be more than 300 EUR for cows due to production loss, treatment cost and culling [7, 8]. The incidence of CHC and SCH was 10% and 50% in mature fresh cows just after calving respectively [3,9,10]. Reduced blood calcium levels such as SCH without clinical signs can still be harmful for the immune function and reproduction parameters and it can trigger postpartum metabolic disorders [4-6,11,12]. Hypocalcemia was observed frequently in multiparous lactating cows than a primiparous cow, especially SCH affects 41 to 54% of multiparous cows [10], the reasons are higher daily milk production and consequently low blood TCA and IC of multiparous cows than primiparous cows, or maybe other reasons that might be subjects for further studies. Thus due to increased demand on milk consumption, the milk production per cow increased from roughly 2.000 kg to 10.300 kg in last year's worldwide [13]. This required a prophylactic treatment with calcium supplements at calving and in early lactation,

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especially in Holstein [14,15]. The awareness about CHC and SCH increased among producers and veterinarians in the last years. The disease will be a major challenge for the producer to prevent and consequently to increase the profitability of the farm, as well as for the scientists to find the best prophylactic measurements and clarify the interaction between TCA, IC and their thresholds with postpartum health disorders. A summary of literatures for the fluctuation of TCA and IC as well as the incidence CHC and SCH around calving was presented in Figure 1.

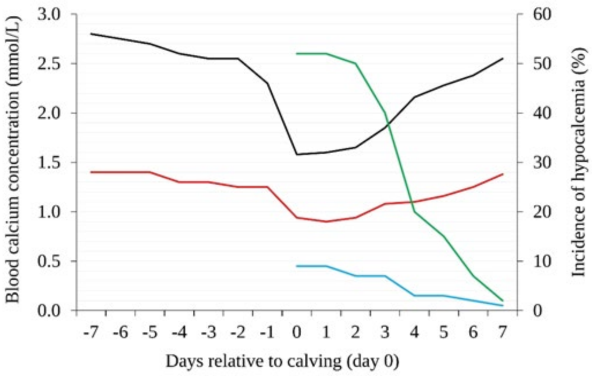

Figure 1: Illustration for the fluctuation of Total Calcium (TCA), Ionised Calcium (IC) Concentrations, Incidence of Clinical (CHC) and Subclinical Hypocalcemia (SCH) around calving of dairy cows (summary of the literature worldwide).

Note: TCA; IC; Incidence CHC; Incidence of SCH.

Total calcium in dairy cows

Blood TCA concentration constitutes different fractions such as protein-bound (35%-49%), salt bound (5%-8%, bound on anion complexed) and IC (43%-57%). The proportion of the fractions given in the literature differs among scientists [16,17]. Blood TCA was the most tested parameter to monitor the calcium status and haemostasis in lactating dairy cows [3,6] because it gives an overview of the total status of calcium in the organism. However, blood TCA was affected by the blood protein concentration [18]. Hypoalbuminemia can be a reason for the low TCA because a huge part of TCA is bound on plasma protein, mainly on albumin. Thus, TCA cannot show the true calcium status of the organism in hypoproteinemia and a correction of TCA was needed to the normal physiological blood protein levels [17,18]. Furthermore, changes in dietary cation-anion difference via ration adaptation in close-up can also be a reason for the TCA fluctuation because the biggest fraction of TCA was IC and it can be affected by blood pH [3,17,19]. On the other side, cations and anions differences due to ration change or physiological changes between prepartum and calving may affect the salt bound fraction of TCA thus the blood levels may be affected. This part remained still unqualified. The threshold of blood TCA for CHC was various in the literature. It was much easier to set a threshold for CHC because clinical signs such as paresis, lie-down on the ground were typical for milk fever or per parturient paresis just after calving within 72 h. Blood TCA levels of 1.25 to 1.50 mmol/L were reported in severe and CHC in dairy Holstein [18,20,21]. The difference in the thresholds can be probably due to different ration, feed supplements, stages and severity of the diseases reported. The threshold of blood TCA for SCH definition was reported frequently to be 2.0 mmol/L [3,10]. But, recent studies indicated that blood TCA concentrations below 2.10, 2.12, 2.15 and 2.20 mmol/L are associated with higher incidences of production and reproduction health disorders [4,6,11,15,22,23]. The reference ranges of blood TCA were between 2.10-2.50 [3], 2.10-2.80 mmol/L in lactating dairy cows. This currently increased threshold of TCA for SCH definition related frequently and created significant risk for postpartum health disorders and production parameters and probably also the enforcement for higher milk production of dairy cows required higher calcium supply to the organism in the recent years.

Ionised calcium in dairy cows

The major fraction of blood TCA concentration is IC so called the physiologically active and diffusible form of TCA. The function of IC was well described in terms of muscle and heart contraction and nerve impulse transmission [1]. Excessive excretion of calcium into milk at calving and early lactation reduce the calcium blood levels, so that the organism is not always be able to substitute the lost calcium amount immediately. The need for calcium depends on the milk yield of dairies as well as on the parity, thus multiparous can produce more milk than primiparous. However, blood IC was influenced by pH [16,17,24], chloride and lactate concentrations [17]. The fluctuations in those parameters can directly effect on blood IC concentration which may mislead the interpretation of blood IC levels. The correlation between blood IC and pH is negative [17,24] and therefore the test devices deliver pH 7.40-corrected IC values to eliminate the pH effect on IC concentration. The low pH stimulates the mobilisation of calcium from the calcium containing tissues such as bones so that by lowering blood pH with anion additions in the ration (e.g. chloride, Sulphate and phosphate) in the close-up period of the pregnant cows can increase blood IC levels in early lactation [3,21]. This programme was called anionic feeding (more anion than cation in the ration) to prevent from milk fever and SCH in early lactation and it will cause a low urine pH between 6.2-6.8 at calving for Holstein due to acidification of the blood, however it will also result in locational osteoporosis due to mobilisation of calcium from bones [3]. The correlation between IC and blood lactate and chloride was reported to be positive in clinically ill calves [17]. However, this needs to be evaluated in detailed because some diseases may cause certainly deviations in blood parameters. Elevated blood lactate level can be an indicator for illnesses. Blood chloride levels can be elevated with negative cation-anion difference in the ration. Furthermore a weak correlation was reported between IC and albumin [17, 19]. Blood IC threshold of <1.0 mmol/L for the definition of SCH was reported previously [11]. This threshold associated with the reduced immune function and altered energy metabolism in Holstein cows. Another IC threshold of 1.17 mmol/L for SCH definition was reported based on blood TCA concentration of 2.12 mmol/L only [5]. However, this was unsatisfactory level due to low correlation and deviation in the postpartum period. The average IC concentration in various farms was 1.02–1.12 mmol/L in different lactation stages [25]. Identification of optimum threshold of IC for defining of SCH may be difficult based on the TCA threshold due to influences by other blood parameters on both TCA and IC as well as by ration changes and feeding. Thus, this may be defined in connection with harmful effect of IC deficiency in different lactation stage.

Correlation of blood ionised calcium with total calcium

The ratio of IC/TCA and consequently the correlation between TCA and IC in dairy cows were always a discussion point in the last years. This correlation changes during the transition period of dairy cows, the change was especially remarkable at calving within first 2 days post-calving [26]. The proportion of IC of TCA was much higher in the first days postpartum in fresh cows, and can increase to 57% [16,26]. The overall ratio IC/TCA independent from the lactation stage was reported to be 43-52% [19,27,28] in dairy cows. This ratio was similar for calves such as 47%-50% [17,29]. The correlation coefficients between TCA and IC cannot be expected high because the level of both calcium parameters are influenced by other blood parameters such as blood pH, albumin, total protein, chloride and lactate, as well as by the time of prepartum or postpartum period. Coefficient of the correlation was significant but not high (r=0.36, 0.20) [19,29]. The ratio of IC/TCA was roughly 52% in the close-up stage of transition period of dairy cows [26,27]. The IC levels were found to serve a valuable diagnostic tool in dairy cows [30]. The dairy cows need the physiologically active ionised fraction of calcium for the metabolic functions and milk production at calving and early lactation thus calcium mobilization from bones, reabsorption from kidney and gastrointestinal tract are regulated by hormones, especially parathormone to supply IC to the blood and milk. This quick interchangeable biological situation is a vicious cycle in the transition period of dairy cows which refer to prepartum and postpartum 3 weeks [31].

CONCLUSION

The importance of monitoring calcium haemostasis in dairy cows will remain as a critical point because of high demand on milk consumption and consequently enforcement of dairies for higher milk production. This might cause a higher incidence of SCH and CHC. Calcium supplements at calving and early lactation and an-ionic feeding in the close-up to increase calcium levels at critical stage may help but not interrupt the vicious cycle of the transition period. Influencers aforementioned on the levels of blood TCA, IC and their correlation, probably there will be more in the future can create paradox-like situations for interpretation of blood TCA and IC fluctuations in dairy cows additionally although they were intertwined. Therefore, blood TCA and IC should be interpreted separately for different lactation stage and parities of dairy cows in connection with their harmful deficiency effect on the production parameters and general health status.t.

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