Review

Alimentary metabolic disorders in high-producing dairy cows: A review

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The aim of this review, which has been compiled on the basis of the available existing literature, is to summarise the basic information regarding alimentary metabolic disorders in high-producing dairy cows. The disorders included in this review are among the most commonly occurring in herds. Specifically, ketosis, acidosis and milk fever. It is known worldwide that high producing dairy cows are more susceptible to ruminal dysfunction – alimentary metabolic disorders. Causes of alimentary metabolic disorders can be of different nature, such as unbalanced feed ration, stress, inadequate management and environmental factors, genetic factors and various infections or diseases of the animals. The most frequent cause of metabolic disorders is considered to be the feeding of an inadequate ration with an excess or deficiency of the required nutrients. Dairy cows must be fed a ration containing all nutrients in the correct proportions to maintain optimum metabolic function. The physical structure of the forage itself has a major influence on the health status of dairy cows and the development of dysfunctions, where not maintaining the correct technique (structure) has a negative impact on the overall rumen complex of the dairy cow.

Keywords: dairy cows, alimentary metabolic disorders, ketosis, acidosis, milk fever

1 Introduction

Alimentary metabolic disorders are a very frequent problem in dairy cattle breeding affecting health and milk production. The occurrence of alimentary metabolic disorders is most often attributed to incorrect nutrition, stressful situations and last but not least to genetic factors. For the prevention of metabolic disorders, it is necessary to have adequate knowledge of the animals nutrition, health and of course, their behaviour. An important condition for ensuring the health and performance of dairy cows is the provision of an adequate ration, in terms of either nutritional composition or structure. Dairy cows are demanding in fibre composition, which works as an important component to ensure the health of the rumen complex. Fibre, by its size or particle size, stimulates rumination and helps to maintain rumen pH, thus helping to prevent unwanted metabolic disorders (acidosis). Breeders have an important role to play in providing suitable conditions for dairy cows that meet their needs. In this way, the health of the dairy cow is increased, her production is increased and in the other hand, the cost of treatment is reduced, leading to an increase in the efficiency of the breeding operation. The aim of this review article is to summarize basic information concerning alimentary metabolic disorders of high producing dairy cows that occur with inadequate management of the herd.

1.1 Ketosis

The disorder, which is characterized by reduced rumination activity of individuals called ketosis, can be classified into primary and secondary forms (Brandstetter et al., 2019; Lei and Simões, 2021). The metabolic disorder ketosis, according to Ning et al. (2022), is one of the disabilities with elevated BHBA (beta-hydroxybutyric acid) levels in the blood, and Djokovic et al. (2019); Wu et al. (2020) add that it is the BHBA content that is an element suggesting a simpler diagnosis and classification

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of ketosis in dairy cows. They also report that along with beta-hydroxybutyric acid, the amount of acetone and acetylacetic acid (acetoacetate) also increases. The above stated ketone bodies along with non-esterified fatty acids (NEFA) and triglycerides have a strong association with loss of appetite as described by Lei and Simões (2021); Raja et al. (2021). According to Kaufman et al. (2016), the above mentioned ketone bodies are formed as a result of fatty acid oxidation during the mobilization of fat reserves at the beginning of lactation, due to the negative energy balance. Djokovic et al. (2019) and Lei and Simões (2021) describe ketosis as the most devastating disorder of early lactating dairy cows causing reproductive and production losses and can lead to death or culling. Wu et al. (2020) stated that ketosis is also a lameness and metritis trigger and leads to significant economic losses.

Type first ketosis, i.e. primary (clinical) ketosis (Ning et al., 2020), is typically present mainly between 3 and 6 weeks postpartum, when lactation is on maximum level. It is characteristic that milk production is greater than the amount of glucose available, and the authors Zhang and Ametaj (2020) and Lei and Simões (2021) also add that there is an inadequate supply of propionate to the body – resulting in a state of chronic hypoglycaemia. In dairy cows, clinical ketosis is less frequent according to Lei and Simões (2021) and is diagnosed on the basis of symptoms, including blood BHBA concentrations above ≥3.0 mmol.l^{-1} according to Djokovic et al. (2019) and Lei and Simões (2021). Ketosis secondary, also called subclinical (Ning et al., 2020), represents a second type of ketosis that affects dairy cows in early lactation (Cocco, Canozzi and Fischer 2021). Lei and Simões (2021) add that also in the prenatal period and at parturition due to excess mobilization of fat and adipose fat tissue, respectively. Increased adipose fat tissue, high BCS (body condition score) and overfeeding during the dry standing period rank among the most critical factors influencing the possibility of the beginning of ketosis. Based on Eastridge (2019), BCS values should not exceed a score of 3.5. The authors Lei and Simões (2021) describe secondary ketosis as a disorder that has no evident clinical symptoms i.e. the dairy cow will not reduce feed intake even if its condition corresponds to hyperketonaemia. It is for this reason that Djokovic et al. (2019) describe subclinical ketosis compared to clinical ketosis as a condition inducing greater losses. Many times, in order for intervention to be sufficient in terms of curing a persistent or incipient metabolic disorder, early identification of the problem is necessary, which is usually done by laboratory testing of the blood for the BHBA, non-esterified fatty acids and also glucose content, which is quite under-represented (Hofírek et al., 2009), the increased BHBA concentrations mentioned above. Djokovic et al. (2019) adds that BHBA values indicative of subclinical ketosis range from 1.2 mmol.l^{-1} or 1.4 mmol.l^{-1}.

Animals or dairy cows which suffer from ketosis for a long period of time are characterized not only by a change in overall look, i.e. upright dull coat, but also apathy, ataxia and in some individuals it can develop into a state where they are inactive or unable to stand up and the rumen motility is reduced or negatively affected (Lei and Simões, 2021). The authors also describe that the faeces of "ketotic" animals are characterized by a drier consistency compared to faeces from healthy individuals and also state that if the ketone body content is too high it is possible to smell the so called fruity odour of said ketone bodies in the breath, in the milk and also in the urine (Lei and Simões, 2021).

Experiments based on the study of subclinical ketosis have concluded that there is a strong relationship between the subclinical ketosis studied and the overall locomotion or organism of the dairy cow. Authors Lei and Simões (2021) and Antanaitis et al. (2020) describe findings such as a reduction in water intake, furthermore a reduction in the number of bites swallowed and of course also report a rapid decrease in rumination time. They observed these above findings five to six days prior to the diagnosis of ketosis. The authors Antanaitis et al. (2020) also found a reduction in rumination and drinking and described a reduction in the number of intake or regurgitated (swallowed and returned) bites. The authors Antanaitis et al. (2020) also found a reduction in rumination and drinking and described a reduction in the number of intake or regurgitated (swallowed and returned) bites. A reduction in daily dry matter intake (DMI) during the week before a diagnosis of ketosis of 3 kg from the original quantity was also observed. Schirmann et al. (2013) also researched rumination behaviour and the association with subclinical ketosis, finding that affected animals or those that developed ketosis after parturition spent a shorter time rumination in the prepartum period compared to healthy dairy cows. Soriani, Trevisi and Calamari (2012) describe that dairy cows without health disorders before and during parturition were characterized by a longer rumination time after parturition (more than 520 min per day) compared to dairy cows affected by subclinical ketosis, in which rumination time was reduced to less than 450 min per day. The authors Hanušovský et al. (2018) observed that milk production was reduced by 14.08% at increased pH values compared to cows that had normal pH values, which in turn had an increasing effect on milk fat content by up to 2.54%. The authors in addition observed an increase in fat content as well. The previously mentioned studies suggest, as also described by Soriani, Trevisi and Calamari (2012), that rumination time can be used as a potentially hopeful indicator of metabolic disorders such as ketosis, as significant changes in rumination and feed intake can be observed around one week before parturition.

1.2 Acidosis

Metabolic disorder – acidosis is one of the causes of deficient rumination. Acidosis is classified as a disorder that causes the pH of the rumen environment to decrease to 5.1–6. The occurrence of this disability is attributed to over-feeding of high rations of roughage in an attempt to increase the supply of non-structural carbohydrates (NFC), which include not only sugar but also starch (Bramley et al., 2008). Šimko et al. (2009) describe that starch, which is classified as the main energy component of grain crops, has different variability depending on the species. Starch and readily digestible sugars are subjected to fermentation to produce lactic acid, which subsequently lowers pH values in the rumen complex to non-physiological levels (Lean, 2007; Bramley et al., 2008).

Acute rumen acidosis described by Hofírek et al. (2009) as lactoacidosis, lactic acid intoxication or also as rumen toxemia occurs in individuals that have received a high quantity of a new feed or have been fed a new ration. The high content of non-structural carbohydrates, especially in the transition phase, furthermore also influences the development of acidosis. During this period, dairy cows are not adapted and used to higher rations of sugars and starch too, which can cause problems. Calsamiglia et al. (2008) describe that feeding high rations of concentrated feeds (starch) is responsible for a reduction in daily dry matter intake and therefore rumen motility is affected (through a reduction in fibre). There is a reversal of the volatile fatty acid content, which together with lactic acid, causes the aforementioned decrease in rumen pH and then negatively affects the ability of rumen fluid i.e. reduces its buffering capacity (Abdela, 2016; Zhang, et al., 2023). The rationale for feeding rations formulated in this way is that farmers are trying to supply sufficient energy to dairy cows after parturition especially during the milking phase (Abdela, 2016). However, as indicated by Zhang et al. (2023) ruminal papillae are too short during this period to absorb the amount of organic acids required. As mentioned above, the fermentation of starch into lactic acid occurs when a ration composed of feeds characterized by a higher concentrate content and, on the other hand, a low structural fibre content is fed for a long period of time. The lactic acid in turn inhibits the growth of cellulolytic bacteria and promotes the presence of streptococci and lactobacilli, which produce even greater amounts of the above mentioned lactic acid (Morar et al., 2022). Hofírek et al. (2009) show concentrations of lactic acid that do not exceed 3.0 mmol.l^{-1} under normal conditions. However, if the concentration increases and even exceeds 80 mmol.l^{-1} it indicates ongoing acute acidosis. Beauchemin and Penner (2009) attribute acute acidosis to a drop in pH (<4.8), which holds its value for more than 24 hours.

Symptoms showing ongoing acute acidosis, which is less common in practice, are quite distinct and, according to Šlosárek, Skřivánek and Fleischer (2015), are manifested by restlessness, which subsequently develops into apathy in the dairy cow. Furthermore equally important typical symptom is watery and light-coloured faeces.

Subacute ruminal acidosis (SARA) as described by Li et al. (2012); Szenci et al. (2020); Morar et al. (2022) and Plaizier et al. (2022) is known to be a negatively impacting nutritional disorder affecting in the first place to the health, in the second place to the performance and besides also welfare of dairy cows. The authors mention further that no typical symptoms are attributed to this disorder, but it is usually accompanied by diarrhea, which as authors Kleen et al. (2003) and Krause and Oetzel (2006) add, contains intact – undigested grains and further long fibers of roughage (1–2 cm) (Plaizier et al., 2022), due to gastrointestinal lesions. The authors Szenci et al. (2020) also add that the faeces are light yellowish in colour characterized by a sweet and sour smell moreover with containing bubbles of frothy gas. Another typical symptom is reduced feed intake and also reproductive disorders. The effect is also promoted on rumen fermentation (Li et al., 2012), where the pH of the rumen fluid is reduced to values ±5.2 (Humer, Bruggeman and Zebeli 2019). Author Mottram (2016) describes that a pH as low as 5.5 is generally accepted as the starting acidosis level. Morar et al. (2022) and authors Zhang et al. (2023) report that SARA is characterized by a repeated decrease in reticuloruminal pH for more than 3 hours per day.

Feeding high concentrate doses brings additional negatives as described by Beauchemin and Penner (2009); Atkinson (2014); Neubauer et al. (2020); Gianesella (2023) and Zhang et al. (2023) i.e. pH reduction due to increased production of volatile fatty acids, besides too deterioration of health status, furthermore formation of abscesses, and signs of laminitis may also occur. Khafipour et al. (2009) add that in such formulated diets there is an increased content of bacterial species such as *Lactobacillus*, *Streptococcus* bovis and also *Escherichia coli*, which is ranked among the main possible sources causing the above mentioned disorder. Šimko et al. (2009) found that starch and its origin largely influence rumen fermentation. Wheat starch, as opposed to corn starch, is characterized by higher concentrations of propionic, butyric and lactic acids. This finding suggests that a higher content of propionic acid in particular has a more rapid decrease in rumen pH.

Kleen et al. (2003) attributed subacute acidosis and its occurrence to errors caused by feeding rations whose composition was not balanced for the nutrient requirements of dairy cows in each production cycle. The authors Beauchemin and Penner (2009) and Humer, Bruggeman and Zebeli (2019) attribute to subacute acidosis, in addition to the already mentioned reduced milk production, besides a reduction in milk fat content and also a decrease in protein. This view is also shared by Hanušovský et al. (2018), who found and describe during their research that milk production was reduced by 6.80% in dairy cows with reduced pH compared to cows with normal pH values. They also observed the reduced milk fat and protein content based on low pH mentioned above. Monitoring of sub-acute acidosis is also possible based on rumen temperature, with temperatures above 39.4 °C indicating a problem, and it should also be noted that the metabolic disorder mentioned above only very rarely affects individuals and is more likely to occur as a herd disorder (Kleen et al., 2003). The authors Beauchemin and Penner (2009) indicate that to reduce the risk of acidosis, it is very necessary to adapt the rumen environment to changes concerning ration composition, i.e. formulating rations with a low rate of carbohydrate digestion and increasing the amount of physically effective dietary fibre.

1.3 Milk fever

The susceptibility of high-producing dairy cows to the above-mentioned alimentary metabolic disorder – milk fever (hypocalcemia) is mainly related to the feeding of inadequate amounts of nutrients such as calcium and phosphorus in the ration. Mistakes contained in the feed during the dry standing period are the biggest influencing factor for the occurrence of hypocalcemia (Wubishet et al., 2016; Al-Rabadi and Alhijazeen, 2018). The authors Nurye and Animut (2022) describe that some minerals are so-called reaction catalysts and their need is also attributed for the proper function of enzymes. Erickson and Kalscheur (2020) indicate the importance of mineral nutrition also in terms of lactation efficiency and they attribute great importance to calcium because of its need for proper and healthy functioning of the nervous system. Authors Nurye and Animut (2022) describe the necessity of adequate levels of ionized calcium within the dairy cows body and bloodstream to ensure proper body processes. Several authors (Wubishet et al., 2016; Al-Rabadi and Alhijazeen 2018; Erickson and Kalscheur (2020); Nurye and Animut, 2022) state that for the prevention of the above metabolic disorder, it is necessary to feed diets with adequate calcium content, also a balanced calcium-phosphorus ratio that affects the utilization of calcium in the body. Another factor that can be mentioned is the regular monitoring and evaluation of the body condition of dairy cows, which can help to identify a possible problem occurring or already in progress early on.

The peripartum period, a period related to calving, is characterized by a higher susceptibility to milk fever in dairy cows, mainly due to colostrum secretion, where the dairy cow tries to meet the increased calcium requirement at the expense of the blood level (Horst et al., 1997; Wubishet et al., 2016; Nurye and Animut, 2022). Authors DeGaris and Lean (2008) and Engdawork (2008) describe that the susceptibility of dairy cows to milk fever is associated with factors such as age (higher lactation order) also breed and last but not least nutrition. According to Horst et al. (1997), a dairy cow producing 10 litres of colostrum loses about 23 g of calcium resulting in low blood calcium levels (Engdawork, 2008).

The authors Engdawork (2008) and DeGaris and Lean (2008) describe the occurrence of milk fever by symptoms reported in the so-called clinical and subclinical forms. This division is based on the symptoms that accompany the disorder. Wubishet et al. (2016) indicate that the clinical form of milk fever is one of the more severe types of metabolic disorders with a blood calcium concentration of less than 5 $mg.dl^{-1}$. The subclinical type and its blood calcium concentration ranges between 5.5 and 8.0 $mg.dl^{-1}$. Milk fever has a significant impact on the health and performance of the dairy cow, where affected individuals are characterized by a significant decrease in the milk production curve. Calcium deficiency can also affect muscle function and mobility, leading to weakness to apathy. In severe cases, milk fever can cause collapse and lead to further complications. Other signs that describe the possible occurrence of milk fever include behavioural changes as well as restricted to reduced rumen function (Engdawork, 2008; Goff, 2008). Furthermore, authors add signs such as reduced feed intake, secondly tetany, thirdly low body temperature which in cases of non-treatment can lead to coma and death.

From the economic point of view, milk fever is a disorder that reduces the productive life of a dairy cow and in addition, it has also been suggested that each occurrence of milk fever increases the risk of other disorders such as ketosis, abomasum dislocation and retained placenta (Engdawork, 2008). Losses in terms of economics are also attributed to premature culling and treatment costs for dairy cows (Engdawork, 2008; Khan et al., 2015). To prevent hypocalcemia, the most proven method, according to authors DeGaris and Lean (2008) and Oetzel (2011), is to feed an acidogenic diet approximately 3 weeks prior to planned calving, which increases gastrointestinal calcium absorption and also mobilizes more calcium from the bones. The formulation of such a pre-partum diet is based on selected feed ingredients that are characterized by a low Dietary

Cation-Anion Difference (DCAD) in order to promote the balance necessary for disorder prevention. The creation of a negative DCAD is required to mobilize calcium from the bodys own reserves (bone) which will achieve normal blood levels (Oetzel, 2021). The addition of supplemental anions to correct low potassium or high chloride content is understood to mean, for example, mixed hydrochloric acid or anionic salts (calcium chloride, magnesium chloride or magnesium calcium) (Oetzel, 2021). Great attention should be paid to possible changes in minerals during feeding and for this reason, it is necessary to monitor urine pH to obtain information regarding the degree of acidification or super acidification to prevent metabolic disorders such as acidosis and alkalosis (Thilsing et al., 2002).

When milk fever is present, Oetzel (2011) describes the treatment, which he divides in terms of the condition of the dairy cow, where, for example, an oral calcium supplement (bolus) is used in standing dairy cows and an intravenous infusion is used in dairy cows with a more severe course.

4 Conclusions

This article is devoted to the characterization of the most common alimentary metabolic disorders that occur in high-producing dairy cows. Alimentary metabolic disorders in high-producing dairy cows are considered to be the most serious problem affecting overall breeding and management. These disorders have a negative impact on the health and overall production of dairy cows, leading to a reduction in milk production, a reduction in milk quality and, last but not least, a reduction in reproductive performance. These negative effects add to the cost of veterinary treatments, feed and other necessary interventions, which have a negative impact on the overall economics of the farm. Prevention of alimentary metabolic disorders is an important key to ensure maximum productivity and profitability of the breeding stock. Risk reduction in high producing dairy cows can be achieved by ensuring a balanced ration and by feeding quality forages that are adapted to the exact requirements of the dairy cow. Furthermore, health maintenance, proper reproductive management and regular health monitoring are also very important. It is the above health monitoring that could help to detect and minimise the occurrence of metabolic disorders early on.

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