Indian J Anim Health (2024), 63(2): 194-206
DOI: https://doi.org/10.36062/ijah.2024.13923

Review Article

Major metabolic diseases in dairy animals, nutritional aspects and treatment – A review

P. M. Nair[1], M. S. Sivaprasad[2], A. T. F. Rahman[3], P. Chaudhary[4], S. Arulkumar[1], V. Mani[1] and G. Mondal[1*]

[1]Animal Nutrition Division, ICAR- National Dairy Research Institute, Karnal- 132 001, Haryana, India; [2]Department of Veterinary Public Health and Epidemiology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana- 141 012, Punjab, India; [3]Department of Veterinary Pathology, ICAR- Indian Veterinary Research Institute, Izatnagar- 243 122, Uttar Pradesh, India; [4]School of Agriculture, Graphic Era Hill University, Dehradun- 248 002, Uttarakhand, India

Abstract

Modern dairy breeds are capable of producing enormous quantities of milk. Animals are subjected to stressful situations that can harm their health, effort to consume, digest and metabolize enough nutrients to meet lactation requirements. Metabolic illnesses like hypocalcemia, ruminal acidosis and ketosis are common problems and will completely affect the health and production of dairy animals. The majority of the health issues that result from such disorders are caused by the inability to metabolize enough nutrients. Proper nutrition can help minimize the prevalence of these illnesses. Furthermore, some specific measures provide extra benefits in the prevention of nutrition-related metabolic disorders. Basic physiological processes that must be preserved during the periparturient period to prevent metabolic disease include maintaining a strong immune system, adapting rumen and its microbes to lactation diets and maintaining calcium metabolism. Knowledge of these metabolic diseases and how to treat them must be known and updated for the successful management of dairy animals. This review aims to understand the significant nutritional metabolic changes that affect production and its appropriate mitigation strategies.

Keywords: Dairy animals, Metabolic disorder, Nutrition, Transition period

Highlights

- Metabolic disorders like hypocalcemia, ruminal acidosis, ketosis, etc are prevalent in modern dairy breeds and proper animal nutrition can reduce the occurrence of these disorders.
- Suitable nutrition and management of the high-yielding dairy animals especially during the transition phase is critical for the prevention of major metabolic disorders.

INTRODUCTION

Dairy animals are more susceptible to metabolic problems than other domestic animals, and metabolic diseases in animals involve disruptions of metabolic processes (Pryce *et al*., 2016). Metabolic illnesses like hypocalcemia, ruminal acidosis and ketosis are common and will completely affect the health and production of dairy animals. High yielders have a tendency to have more metabolic anomalies if proper feeding and care are not managed, especially between calving and until the peak of lactation is reached (Caixeta and Omontese, 2021). The most crucial stage of the transition period is generally outlined as the three weeks before and after calving. The period is associated with numerous changes including hormonal and behavioral changes resulting in increased stress levels and compromised immunity (Bertoni *et al*., 2008). Dairy animals go through significant metabolic and physiological changes during the transition period to prepare to produce milk. Transitional diseases may be more likely to develop if these metabolic changes are not adequately controlled, which may result in metabolic stress. Metabolic stress can be explained as a physiological condition that includes inflammation, oxidative stress and abnormal nutrient metabolism (Wisnieski *et al*., 2019).

Moving from the non-lactating to lactating phase along with a drop in feed intake and changing the diet from a more forage-based diet to a more concentrate-based diet enhances the chances of negative energy balance (NEB), thereby favoring the existence of metabolic diseases in dairy cows (Sundrum, 2015). Cows must use body reserves to make up the difference between the energy they get from food and the energy they need to produce milk while they are in an NEB. Energy scarcity and metabolic illness including hepatic lipidosis and ketosis are recognized to be interconnected. Dairy cows with energy deficits also suffer from reduced immune systems and are more prone to diseases (Lacasse *et al*., 2018). The complexity and

*Corresponding Author, E-mail: gmondal1075@gmail.com

extent of negative energy balance are directly related to dry matter intake (DMI). Periparturient diseases may develop as a result of unfavorable ruminal conditions brought on by a prepartum diet high in grains that may be made worse by crowding, heat stress, or any other type of stress (Cardoso *et al*., 2020). There are numerous metabolic diseases identified in dairy animals after parturition, and the most common ones are the following: subacute and acute ruminal acidosis, laminitis, hypocalcemia, ketosis, left displaced abomasum, fatty liver, hypomagnesemia. The incidence rate of these diseases based on recent studies is listed in Table 1. These kinds of diseases are called metabolic disorders associated with the fact that they

Table 1. Recent studies on the effect of various feed supplements on major metabolic diseases of dairy animals

Sl. No.	Nutritional aspect	Objective of the study	Observation recorded	References
1	Acidogenic diet	To find whether the feeding an acidogenic diet in late gestation influences the metabolism of cows with experimentally induced subclinical hypocalcaemia.	Giving cows with induced hypocalcaemia an acidogenic diet for 15 days changed other parameters besides calcium, demonstrating that it may not be healthy for animals.	Pizoni *et al*., 2022
2	Low DCAD diet supplemented with anions DCAD = -9 mEq/kg of DM	To determine the impact of rumination activity and low DCAD hypocalcaemia	In the first 36 hours following calving, low DCAD diet significantly increased plasma Ca concentrations and on the first day of lactation, it increased rumination.	Goff *et al*., 2020
3	β-sitosterol (BSS) at the level of 0.5 g/kg	To assess how dietary BSS supplementation affects ruminal fermentation and inflammatory response	BSS attenuates high grain diet-induced inflammatory response and modifies ruminal fermentation	Xia *et al*., 2020
4	*Saccharomyces cerevisiae* culture of 100 g of SC per cow per day	Study assessed the effects of SC supplement, on ruminal pH, volatile fatty acid, inflammatory cytokines and performance of high-yield dairy cows	High-yield cows receiving supplemental SC can produce more milk with more fat, more rumen acetate and fewer inflammatory cytokines.	Sun *et al*., 2021
5	High-concentrate diet with 200 mg of thiamine/kg of DM intake	Examine how thiamine affects the microbiota and intestinal inflammation caused by high-concentrate diets.	Reduced the SARA condition effects on intestinal tissue and microbial habitat.	Wen *et al*., 2021
6	Diet supplemented with pomegranate seed pulp (PSP; 400 g of seeds/cow per day + 1200 g of peels/cow per day)	Supplementation effects of pomegranate by-products on oxidative status, metabolic profile and performance in transition dairy cows	Dietary pomegranate by-products supplementation improves antioxidant status and has shown enhancement in glucose utilization.	Safari *et al*., 2018
7	Choline and L-Carnitine (60:50 gm/day/cow))	Effects of supplementation on development, production and indicators of ketosis and fatty liver during the transitional period	Improved liver health and reproductive indices	Pirestani and Aghakhani, 2018

Cont. Table 1.

Table 1., Cont. ...

Sl. No.	Nutritional aspect	Objective of the study	Observation recorded	References
8	Precursor of glucose powder was top dressed (300 g/cow)	Effects of a glucose precursor supplement on the prevalence of ketosis during the transition period	Having beneficial effect on health in transition period	Mitchell and Rossow, 2020
9	Rumen-protected capsicum oleoresin	Analyze the impact of subclinical ketosis susceptibility and lactational performance on dairy cows during the transition period	Increased serum insulin and decreased â-hydroxybutyrate concentrations prepartum, indicating a decrease in lipolysis	Oh *et al*., 2021
10	Total mixed ration (TMR)	To evaluate the metabolic disorders as well as the nutritional value of TMR	The frequency of clinical Ketosis, subclinical ketosis and hypocalcaemia were higher (4.5, 11 and 3%) during early lactation.	Kim and Cho, 2019

are related to the disturbance of one or more blood metabolites (Sundrum, 2015).

Health management approaches are required to prevent the above-mentioned diseases because they are interconnected and can occur in an animal or herd as a complex. One important aspect of domestication is the increased prevalence of different metabolic diseases in dairy animals, which not only affects the animal's productivity and health but may also have negative health effects on human consumers due to the increased use of drugs and antibiotics. In the near future, these factors will have an impact on economic and ethical factors (Zachut *et al*., 2020). Therefore, suitable nutrition and management of the high-yielding dairy animals especially during the transition phase become increasingly complex and critical. Nutritional influence on metabolic disorders during the transition period is given in Fig. 1.

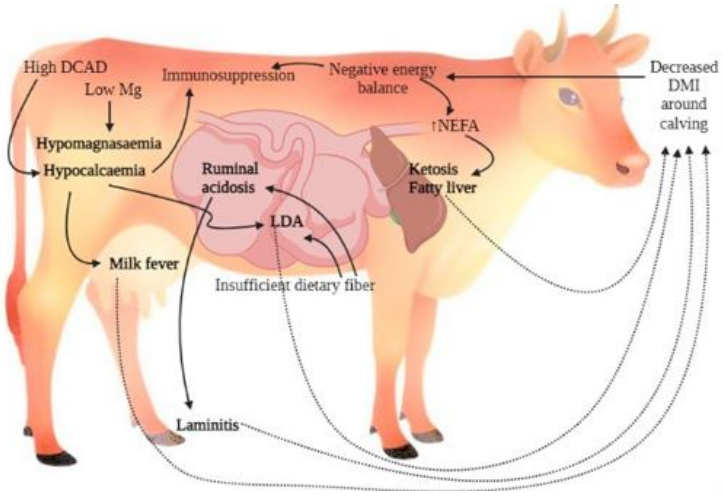

Fig. 1. Nutritional influence on metabolic disorders during transitional cow diseases (Source: Goff, 2006)

Ruminal acidosis

Ruminal acidosis is characterized by a decline in ruminal pH, indicating an imbalance among microbial production, microbial utilization and ruminal absorption of volatile fatty acids (VFA) subsequent to the consumption of a substantial amount of fermentable carbohydrates. This condition typically arises in cattle that inadvertently ingest significant quantities of easily digestible carbohydrates, especially grains. An observable shift in the microbial population, particularly an increase in Gram-positive bacteria like *Streptococcus bovis*, is evident in such cases. The interaction between the ruminal microbiota and the host immune system plays a pivotal role in initiating this disorder (Elmhadi *et al*., 2022). The elevation of lactic acid leads to a reduction in pH to around 5, resulting in the detriment of protozoa, cellulolytic bacteria and lactate-utilizing organisms. This, in turn, impairs rumen motility. Concurrently, the rise in osmotic pressure triggers the movement of an excessive quantity of fluid within the rumen, ultimately leading to dehydration (Jaramillo-López *et al*., 2017).

Both Subacute Rumen Acidosis (SARA) and Acute Rumen Acidosis (ARA) are prevalent metabolic disorders commonly

observed in the field, particularly among high-producing cows fed high-concentrate rations (Sundrum, 2015). The inclusion of a high-concentrate diet leads to a reduction in rumen pH and changes in the relative concentrations of ruminal VFAs (Lee *et al*., 2019). Notably, cows in early lactation with a significant grain intake are at the greatest risk. SARA, referred to as chronic ruminal acidosis, manifests when the rumen pH falls within the range of 5.5 to 6.2. On the other hand, ARA occurs when the rumen pH drops below 5.5, often accompanied by reduced or absent rumen motility (Neubauer *et al*., 2018). SARA poses a substantial threat to the well-being of lactating dairy animals, potentially affecting up to 20% of them during the early to mid-lactation period (Crnkic and Hodzic, 2012). While acute and subacute rumen acidosis may occasionally be mistaken for each other, they differ in their underlying causes. Acute ruminal acidosis usually arises from excessive concentrate consumption or the accumulation of lactate in the digestive tract. In contrast, SARA results from the overproduction of VFAs that surpass the absorptive capacity of the rumen papillae. This often becomes apparent around calving when the rumen papillae, adapted to a high-fiber diet during the dry period, struggle to adapt to a high concentrate ration (Abdela, 2016). Ruminal acidosis disrupts the balance of the ruminal microbiome, leading to a decline in certain Gram-negative bacteria populations in the rumen. Moreover, an increase in free lipopolysaccharides enhances their susceptibility to lysis (Monteiro and Faciola, 2020).

During the dry period, the rumen microbial population is prepared to digest high fiber-containing feed and when the animal enters the transition period and consumes increased amounts of highly fermentable carbohydrates, due to lack of prior adaptation the normal fermentation will be disrupted (Monteiro and Faciola, 2020). Dairy cows under SARA will eat less feed to reduce the amount of acid in the rumen and resume feeding when the rumen pH rises above 5.6. Additionally, moderate diarrhea, decreased rumination, foamy feces and the presence of undigested grain in dung may be seen during SARA (Abdela, 2016).

Lower rumen pH can cause rumenitis, reduced ruminal efficiency, laminitis, lung and liver abscesses, pneumonia and even death. But, signs of subclinical acidosis are not well defined. Due to its chronic nature and subtle presentation, subclinical acidosis is primarily characterized by inconsistent or reduced feed intake, which is the most typical clinical sign (Bramley *et al*., 2008; Antanaitis *et al*., 2024). Additional associated indicators encompass diminished milk fat content, decreased milk production, compromised body condition scores, diarrhea and even laminitis. It's important to note that subclinical acidosis can manifest even within well-managed herds.

The choice of treatment for ruminal acidosis hinges on the severity of the clinical manifestations. In cases of mild acidosis symptoms, such as diarrhea, a dietary adjustment involving a reduced proportion of grain and an increased allocation of roughage is recommended. For animals displaying more severe indications, a transition away from concentrated feed towards a roughage-based diet is advised, accompanied by prompt consultation with a veterinarian. Additionally, oral administration of approximately 120g of sodium bicarbonate and an electrolyte replacement solution dissolved in 4 to 5 liters of water is suggested. This treatment regimen should ideally be repeated three times daily, if feasible, with the encouragement of physical activity, such as walking (Ametaj, 2010; Santos *et al*., 2020). In instances of severe affliction, intravenous administration of sodium bicarbonate and fluid therapy may be considered as a treatment approach.

Similarly, it is best to avoid making abrupt changes to the feed, including feeding grain and molasses. Roughages must be given in sufficient amounts along with or right after concentrate feed is fed. In order to maintain a healthy rumen, diets must contain 45% non-fiber carbohydrates (g 100 g^{-1} of diet, DM basis) and sufficient forages and roughages (Wu, 2020). Acidosis is also combated by feed buffers like sodium bicarbonate and ionophores (Stone, 2004). Warm water consumption has been linked to improved rumen functionality in beef cattle, according to a recent study. Warm water consumption decreased the amount of time that the ruminal pH was below 5.8 or 5.5 and the temperature was below 37 or 39°C (Grossi *et al*., 2021). Data show that when animals are fed a high-concentrate diet, dietary thiamine supplementation can help reduce rumen epithelium inflammation (Ma *et al*., 2021).

Laminitis

Nutrient deficits and excesses can cause metabolic and infectious disorders in animals, compromising animal welfare and, as a result, lowering farm efficiency and income. The increased incidence of inflammatory illnesses in the transition era is due to the high occurrence of metabolic diseases (mostly after calving). This happens more frequently in high-yielding cows, particularly during the transition period, and the inadequate increase in DMI can be a significant causal

factor (Bakshi *et al*., 2017).

Due to a loss of attachment between the distal phalanx and the inner hoof wall, which forces the bone into the hoof and harms the nearby blood vessels, laminitis is characterized by a broken sole corium and coronet (Fig. 2) (Li *et al*., 2017). Lameness is a major animal welfare issue affecting dairy animals, its prevalence is more seen in high-producing, intensively managed dairy cows (Adams *et al*., 2017). The main cause of inflammation is the digital vasculature system's dysfunction, which leads to malnutrition and hypoxia of the delicate laminar structure in the hoof wall (Boosman *et al*., 1991; Ding *et al*., 2020). The pathogenesis of laminitis is influenced by key factors, notably including acidosis resulting from the consumption of diets rich in highly fermentable carbohydrates. Gastrointestinal disorders, encompassing alterations in bacterial flora within the digestive tract, instances of acidosis and the translocation of endotoxins into the bloodstream, serve to increase cattle's susceptibility to laminitis. Furthermore, diseases associated with gram-negative bacteria, such as metritis, mastitis and foot rot, indirectly contribute to the development of the condition by acting as significant sources of endotoxins. Various environmental elements, such as inadequate bedding, unyielding surfaces and inadequate or excessive physical activity, have also been implicated in the etiology of this disease (Ametaj, 2010).

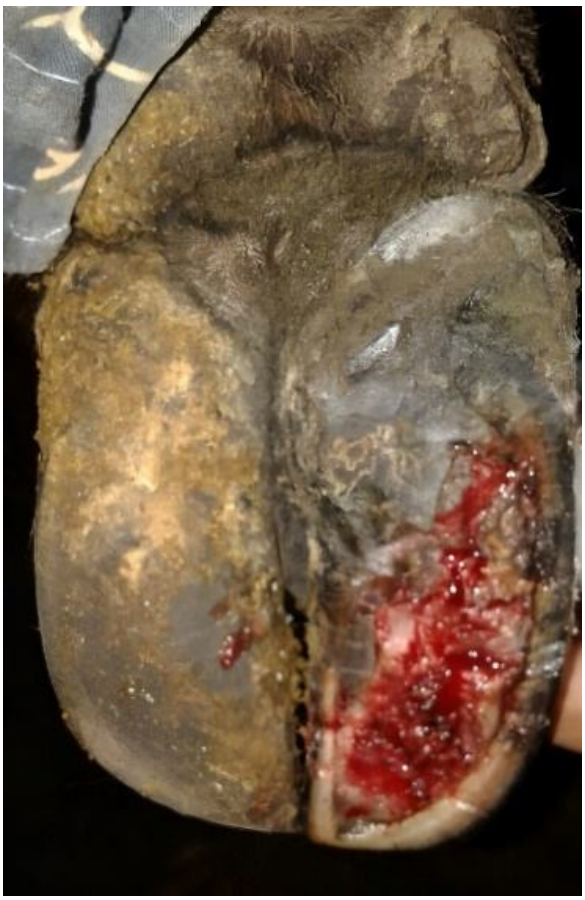

Fig. 2. Laminitis in cattle hoof

According to theories, acidosis damages the ruminal epithelium, allowing endotoxins and histamine to enter the bloodstream. These substances are produced when gram-negative bacteria in the rumen are lysed as a result of the lower pH. Laminitis is brought on by endotoxins and histamine, which inflame and constrict the blood vessels in the lamella of the hoof (Stone, 2004). Higher levels of CP fed to dairy animals may cause laminitis to last longer and occur more frequently. Lameness is thought to be caused by substances produced when too much protein is broken down in the rumen.

Development of laminitis has been suggested to go through 4 consecutive stages: (i) transferring of endotoxin from the GI tract into the systemic circulation and harm of blood vessels, (ii) dropping in the availability of oxygen to the foot tissue, (iii) degeneration and breakdown of the foot tissue and (iv) separation of soft tissue and bone with bleeding and development of inflammation, that is called laminitis (Ametaj, 2010).

Studies have demonstrated that nutritional supplements like Zn and biotin can help to enhance the quality of claw horns and decrease lameness (Stone, 2004). Keratin protein synthesis, keratinization and lipogenesis all require biotin. The maintenance of claw integrity also depends on other vitamins like vitamin A and vitamin E as well as minerals like copper, iodine, manganese, cobalt and selenium (Socha *et al*., 2002; Langova *et al*., 2020). By providing high-quality roughages and adding buffers, it can be avoided. Lame animals benefit from foot baths with 2–5 per cent copper sulfate, mainly in moist environments (Sundrum, 2015).

Post-parturient hypocalcemia

Post-parturient hypocalcemia, commonly referred to as milk fever, stands as a metabolic disorder primarily affecting dairy cows. This condition is characterized by a diminished concentration of calcium in the bloodstream and predominantly manifests within the initial days of lactation. The underlying mechanism involves a scenario where the demand for calcium, essential for various functions including skeletal

muscle contractions, heart rhythm, nerve signal transmission and optimal milk production from lactating mammary glands, surpasses the body's ability to mobilize calcium from reserves, primarily the bones (Thilsing-Hansen *et al*., 2002). Contrary to its name, "fever" is a misleading term for this condition, as the body temperature during the illness tends to fall below the normal range. The reduced blood calcium level disrupts muscle function across the entire body, resulting in symptoms such as lethargy, overall weakness, paralysis, loss of consciousness and potentially fatal outcomes (DeGaris and Lean, 2008). This disorder exhibits a higher prevalence among high milk production breeds during the later stages of the lactation cycle, mainly due to depleted calcium reserves and the decreased ability of older dairy animals to mobilize calcium from their bones (Aiello *et al*., 2016).

Theoretically, a delay in the operationalization of the calcium homoeostatic mechanism is the vital etiological factor for hypocalcemia (Fig. 3). Postpartum hypocalcemia is a condition that is frequently seen and is regarded as a gateway disease that can lead to other illnesses. Dairy animals in transition must contend with a greater need for minerals, particularly calcium, to support lactogenesis in the early lactation period (Goff, 2014). Homeorhetic mechanisms are activated to adapt to this condition (Martín-Tereso and Martens, 2014). Hypocalcemia, decreased milk production, increased culling risk (Roberts *et al*., 2012), and impaired reproductive performance occurs around parturition as a result of unsuccessful homeorhetic adaptation (Martinez *et al*., 2012; Caixeta *et al*., 2017).

In situations of dietary calcium deficiency, the body's skeletal calcium reserves typically compensate through the action of the parathyroid hormone. However, during the dry period, calcium mobilization is temporarily impaired due to reduced parathyroid activity. Hypocalcemia often presents as a subclinical condition, exhibiting minimal to no discernible symptoms yet leading to significant losses. Whether or not clinical signs of paresis are evident, hypocalcemia is defined by a blood total calcium level below 2 mmol L^{-1} (Caixeta *et al*., 2017).

The primary causal factors generally stem from dietary sources. Elevated calcium intake for dry cows, imbalanced calcium-to-phosphorus ratio and phosphorus-rich diets at the onset of lactation all contribute to an increased risk of milk fever (Radostits *et al*., 2000). A surplus of dietary phosphorus suppresses the synthesis of 1,25-dihydroxy vitamin D_3, subsequently impeding mechanisms responsible for intestinal calcium absorption (Christakos, 2012). Pre-partum diets characterized by high cation content, such as sodium (Na) and potassium (K), correlate with elevated milk fever incidence, whereas diets rich in anionic components, particularly sulfides and

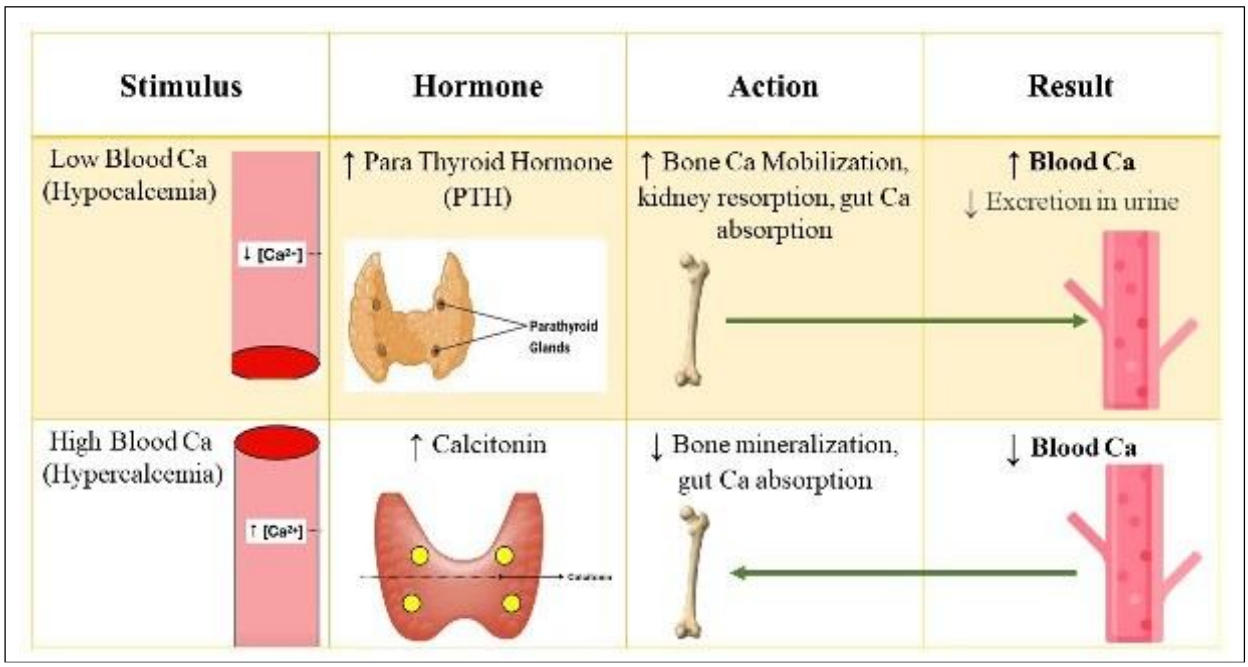

Fig. 3. Regulation of blood calcium levels (Source: Mallette, 1989)

chlorides, are linked to reduced occurrences. The introduction of anions into the pre-parturition diet creates metabolic acidosis, maintaining active parathyroid hormone and lowering the likelihood of milk fever. Incorporating vitamin D_3 and its metabolites into the feed also proves effective against parturient paresis (Safdar, 2015).

A ruminal calcium bolus, containing approximately 43 g of calcium, can raise blood calcium levels (Hernandez-Castellano *et al*., 2020). Addressing this condition involves achieving a balanced dietary cation-anion equilibrium, administering intravenous calcium gluconate, or providing intramuscular vitamin D supplementation (Wu, 2020).

Ketosis

Ketosis arises from the excessive utilization of body fat in cattle, a common occurrence during the initial stages of lactation. This metabolic disorder is characterized by hyperketonemia and hypoglycemia. Subclinical ketosis exhibits a high prevalence within the first two weeks of lactation due to reduced dry matter intake and a negative energy balance, both of which contribute to both clinical and subclinical manifestations of the disorder (Safdar, 2015). Cattle experience ketosis primarily during periods of negative energy balance (NEB) immediately after calving. In response to higher energy requirements, the body releases non-esterified fatty acids (NEFA) into the bloodstream. However, when the oxidation of fatty acids to acetyl-CoA exceeds the oxidation of acetyl-CoA to CO_2 and water within the mitochondria, it leads to elevated levels of ketone bodies in the blood, namely acetoacetate, acetone and β-hydroxybutyrate (Wu, 2018). Furthermore, the increased concentration of circulating NEFA in the early postpartum phase can potentially exacerbate uterine inflammation by delaying uterine involution and hindering successful conception (Pascottini and LeBlanc, 2020).

Prolonged negative energy balance in the initial lactation phase has adverse effects on cattle reproduction efficiency and elevates the susceptibility to diverse metabolic ailments (Zhang *et al*., 2020). The liver's capacity to utilize fatty acids as an energy source and convert them into ketone bodies may be hindered by the excessive release of non-esterified fatty acids (NEFA) from adipose reserves (Pickett *et al*., 2003). Typically, feed intake undergoes a natural decline of approximately 20% at the time of parturition. This reduction in feed intake corresponds with heightened plasma NEFA and liver triglyceride levels. The risk of ketosis is augmented by factors exacerbating negative energy balance and reducing feed intake around parturition, particularly in over-conditioned cattle.

There exist four primary types of ketosis: classical or primary ketosis, secondary ketosis, butyric acid ketosis and underfeeding ketosis (Ingvartsen, 2006). Classical ketosis (production ketosis) is commonly observed within the first two months of lactation (Guliñski, 2021). It emerges when the demand for glucose surpasses the liver's gluconeogenesis capacity, leading to escalated ketogenesis and elevated levels of ketone bodies in the blood, urine and milk. Over-conditioned cows are especially susceptible to this disorder. Secondary ketosis arises when another illness hampers feed intake and amplifies body fat mobilization. Butyric acid ketosis results from silage with elevated butyrate concentrations, which subsequently elevate blood β-hydroxybutyrate levels. Underfeeding ketosis stems from inadequate cow feeding, causing increased ketogenesis due to insufficient glucogenic precursors (Ingvartsen, 2006).

The recent surge in milk production among dairy animals has led to a sharp rise in the incidence of clinical ketosis. The majority of high-yield dairy animals encounter borderline ketosis during early lactation, with most cases of ketosis emerging around 60 days post-calving. The cumulative lactational occurrence varies widely, with an average of about 40% and potential peaks reaching 80% in certain herds. The likelihood of the disease escalates from low prevalence at the first calving to a peak during the fourth calving (Duffield, 2000).

The first week of lactation should be used to monitor ketosis by identifying cows with glucose levels less than 50 mg/dL, followed by a BHB test to identify ketotic cows (Mitchell and Rossow, 2020). To raise blood sugar levels, 500 mL of 50 per cent glucose is typically administered as part of ketosis treatments. Veterinarians recommend an i/v injection of glucose with the combination of insulin (Pickett *et al*., 2003). Drenching gluconeogenic precursors increases plasma levels of glucose and insulin quickly (within 2 hours), making it a useful supplement for the treatment of clinical ketosis (Mann *et al*., 2017). To raise blood glucose levels for a few days after treatment, corticosteroids can be administered. Niacin can help prevent ketosis and fatty liver because it can decrease the mobilization of fatty acids from adipose tissue (Mandebvu *et al*., 2003). In ruminants, propylene glycol can be used as a crucial gluconeogenic agent and is highly effective at preventing the production of ketones. It can be supplemented during the perinatal period in order to reduce the negative energy balance

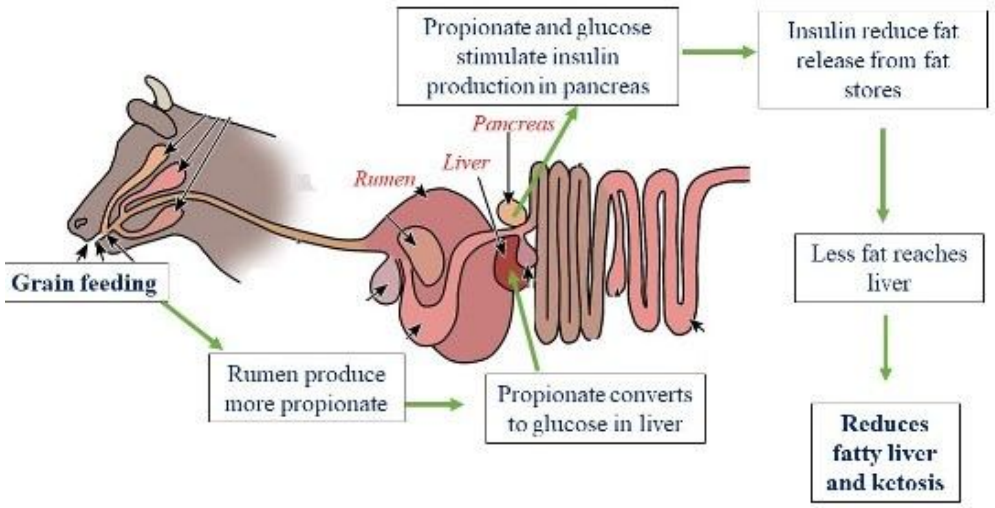

Fig. 4. The mechanism behind how grain feeding reduces ketosis and fatty liver (Source: Ross *et al*., 2013)

(Zhang *et al*., 2020). However, according to recent research, heat stress during the transition period may negate the benefits of feeding gluconeogenic precursors on performance and metabolic health in early lactation (Rivas *et al*., 2021). Proper grain feeding can reduce the incidence of ketosis and fatty liver. The mechanism behind this is given in Fig. 4.

Fatty liver

Fatty liver, also known as fat cow syndrome, is a prevalent metabolic ailment in dairy cows during the transition phase. Contrary to its name, this condition is not triggered by excessive dietary fat or feed intake. Instead, it emerges when the animal faces challenges in meeting its energy requirements within the first four weeks post-calving, primarily due to negative energy balance and diminished dry matter intake. Additionally, fatty liver often coincides with other production-related disorders that either suppress appetite or heighten body fat mobilization. Indications of this syndrome encompass reduced appetite, lethargy and weight loss, leading to overall weakness (Radostits *et al*., 2000). Animals may exhibit nonspecific clinical signs such as decreased milk production and diminished rumen motility. The risk factors for fatty liver syndrome in dairy cows can stem from management practices, nutritional factors, or genetic predisposition (Ingvartsen, 2006). Affected animals are more prone to peri-parturient metabolic issues like ketosis, milk fever, compromised hepatic function, impaired lactation, reduced feed intake and compromised reproductive performance (Wu, 2018). In cows with obesity, the likelihood of heightened lipolysis in adipose tissue during the peripartum period is greater than in those with normal body conditions (Bobe *et al*., 2004).

During periods of negative energy balance, especially in the initial days post-calving, substantial amounts of body tissue, primarily fat reserves, are mobilized and metabolized by the liver into readily convertible energy sources like ketone bodies and glucose (Roche *et al*., 2013). Adipose tissue releases body fat into the bloodstream in the form of non-esterified fatty acids, with the severity of negative energy balance corresponding to the extent of fatty liver development. While the liver can uptake NEFA based on availability, its capacity to oxidize and utilize all NEFA for energy is limited. Consequently, when significant quantities of NEFA are released from adipose tissue, cows are compelled to accumulate NEFA as triglycerides within the liver (Overton and Waldron, 2004).

Effective nutritional strategies can prevent fatty liver by optimizing the metabolic state of animals during the peripartum phase. This involves providing supplementary sources of blood glucose (such as glucagon, monensin, propylene glycol, or sodium borate) and reducing the mobilization of NEFA from adipose tissue. Thus, adopting appropriate dietary practices with sufficient energy content and healthy fat sources can offer advantages.

Recent research provides fresh perspectives on the significance of serum biochemical parameters and oxidative stress biomarkers, specifically Aspartate Aminotransferase (AST), Non-Esterified Fatty Acids (NEFAs), Beta-Hydroxybutyrate (BHBA), and

Glutathione (GSH), when used in conjunction with digital measurements from ultrasound images. This combination of data enables the prompt application of minimally invasive techniques for diagnosing hepatic lipidosis in farm settings. Potential treatments encompass intravenous administration of glucose (60 g h^{-1}) and KCl, intramuscular administration of protamine zinc insulin (150-200 units) and oral administration of propylene glycol (as a glucose precursor; 0.5-1 L day^{-1}) alongside intramuscular administration of adrenocorticotropic hormone (600 units on day 1, 400 units on days 2 and 3, none on day 4 and 200 units on day 5). The latter aims to stimulate the release of amino acids from skeletal muscle, which can then be utilized for glucose synthesis (Haass and Eness, 1984; Besheer *et al*., 2023).

Displaced abomasum

When the abomasum becomes distended with gas and ascends to the upper part of the abdomen, it becomes 'displaced'. This displacement can occur either towards the left (left-displaced abomasum) or the right (right-displaced abomasum) of the stomach in relation to its normal position (Credille and Fubini, 2022). The lower left quadrant of the abomasum is a common site for displacement, often leaning towards the left and becoming ensnared between the left abdominal wall and the rumen. This entrapment generates a hollow ping sound when tapped (percussion). The stretching of the abomasum leads to constriction at its entrance and exit, resulting in the accumulation of gas. This condition is more prevalent in high-yielding cows during the early stages of lactation, with a majority of cases arising within the initial weeks after calving (Doll *et al*., 2009). Although the precise cause of displaced abomasum remains uncertain, several factors, including the composition and physical structure of the diet, cow comfort and dairy cow management during the transition period, have been associated with the disorder's occurrence (Caixeta *et al*., 2018).

Nutrition significantly contributes to the risk of developing displaced abomasum (DA). An augmented negative energy balance and reduced feed intake during the prepartum period are commonly considered causes for increased DA risk in cows (Ingvartsen, 2006). Early lactation cattle fed diets rich in grains and featuring smaller particle sizes are more susceptible to DA (Goff, 2006). Feeding silage has been linked to a higher disease incidence compared to hay feeding, likely attributed to the finely chopped form of silage. This risk can be mitigated by providing a daily dose of straw (around a kilogram) to the cow (Ingvartsen, 2006). In the prepartum transition stage, increasing the amount of grass hay consumed each day can reduce the occurrence of displaced abomasum (Behluli *et al*., 2017). The abomasum's VFAs also have a tendency to lessen its motility. Low rumen absorption of VFAs during the transition period may exacerbate the effects of VFAs on motility, and hypocalcemia may also play a part (Shaver, 1997). Empty space appears for the abomasum to move due to reduced feed taking, insufficient filling and slow rumen contractions that prevent it from reaching the ventral abdominal wall. More fatty acids typically then manage to bypass ruminal absorption and arrive at the abomasum. These VFAs, in addition to accumulated gases and hypocalcemia, lessen the abomasum's ability to contract, which leads to atony (Goff and Horst, 1997). Therefore, insufficient rumen fills, insufficient feed consumption, decreased motility and weaker abomasal contractions all work together to cause the onset of DA.

Due to the fact that rumen papillae have a low capacity for absorption and rumen microbes are not well adapted to a high concentrate ration, the incidence of displaced abomasum also rises when a low concentrate ration is given during the dry period. As a result, the sudden increase in concentrates after parturition may cause animals to consume less roughage and possibly put them at risk for displaced abomasum (Ingvartsen, 2006). β-hydroxybutyric acid and aspartate aminotransferase activity in the blood may be used to predict the development of left-displaced abomasum (Geishauser *et al*., 1999).

Maintaining the forage-to-concentrate ratio of the diet given to the animal during late gestation and early lactation will help prevent it (Bacic *et al*., 2007). A total mixed ration that is easily sorted by cows may affect the ratio of forage to concentrate of total feed consumed by an individual cow and will contribute to displaced abomasum (Shaver, 1997). Grain intake (0.25 kg day^{-1}) after parturition should be gradually increased when a total mixed ration is not given until achieving peak grain intake (Bacic *et al*., 2007).

Hypomagnesaemia

Hypomagnesaemia (grass tetany) causes low magnesium and cerebrospinal fluid (CSF) levels in the blood, which activates neurons and induces continuous excitation of skeletal muscle, convulsions, cramps, paralysis and even death in grazing ruminants (Wu, 2018). In affected animals, a magnesium shortage typically coexists with a low blood calcium

concentration. Additionally, Mg^{2+} transmits nerve impulses and modifies the neuronal threshold. Magnesium shortage causes neuromuscular irritability, tetany and depression as well as reducing ATP synthesis. It primarily affects ruminant animals consuming Mg^{2+} deficient forages [e.g. oats, rye, wheat, etc]. Additionally, hypomagnesemia can happen when dietary intakes of potassium and NH^{4+} are high, which reduces the absorption of magnesium in the rumen and when dietary intakes of sodium are low, which impairs physiological processes (Martens and Schweigel, 2000). Grass tetany predominantly impacts grazing cattle, particularly those with higher milk production, during the late stages of gestation or early lactation, when their demand for Mg^{2+} significantly escalates. The prevalence of subclinical hypomagnesemia was observed to be greater in postpartum cows (9.96%) compared to pre-partum cows (8.49%) (Silva *et al*., 2020). Prolonged hypomagnesemia has been associated with alterations in lipid metabolism, low-grade inflammation, obesity, insulin resistance and hypertension (Pelczyñska *et al*., 2022).

To mitigate the risk of hypomagnesemia, susceptible animals should avoid grazing on lush, immature forages that are low in Mg^{2+} but rich in potassium (K) content. Alongside enhancements in pasture management, addressing hypomagnesemia through dietary measures involves the inclusion of Mg^{2+}, NaCl and Ca supplements. This can be accomplished by providing approximately 85-110 g of mineral mixes containing 12% - 15% MgO on a daily basis. In urgent cases, cows affected by hypomagnesemia can receive intravenous administration of 2 - 3 g of Mg^{2+}, in the form of either $MgSO_4$ or magnesium and calcium gluconate, as part of therapy (Wu, 2020).

Conclusion

The metabolic illness causes a heavy loss in dairy animals. It is essential to identify, treat and prevent diseases using safer and eco-friendly approaches. Nutritional measures should begin before parturition in order to prevent metabolic abnormalities in the periparturient period. However, the study of nutrigenomics necessitates an understanding of nutrition and genetics levels towards the effect of nutrients on various metabolic diseases, which can bring a strong base and understanding of this topic. Omics technologies in order to research the intricate interaction between genetic and environmental relevant to metabolic health are needed to expand future studies to prevent metabolic disorders.

Conflict of interest: Authors have no competing interests to declare.

Author's contributions: PMN: Conceptualization and wrote the manuscript; MSS, ATFR, SAK: Helped in data collection; PC: Helped in editing the manuscript; VM, GM: Conceptualization and final editing of the manuscript. All authors read and approved the manuscript.

ACKNOWLEDGMENTS

We thank the Director of the National Dairy Research Institute, Karnal, Haryana, India for providing facilities to prepare this review article.

REFERENCES

Abdela N, 2016. Sub-acute ruminal acidosis (SARA) and its consequence in dairy cattle: A review of past and recent research at global prospective. Achiev Life Sci, 10(2): 187-196, doi: 10.1016/j.als.2016.11.006

Adams AE, Lombard JE, Fossler CP, Román-Muñiz IN and Kopral C, 2017. Associations between housing and management practices and the prevalence of lameness, hock lesions and thin cows on US dairy operations. J Dairy Sci, 100(3): 2119-2136, doi: 10.3168/jds.2016-11517

Aiello SE, Moses MA and Allen DG, 2016. The Merck Veterinary Manual. Merck and Company, Incorporated, pp 3325

Ametaj BN, 2010. In: Metabolic Disorders of Dairy Cattle. Hudson R., Nielsen O., Bellamy J., Stephen C., editors. UNESCO- EOLSS Publishers, Paris. Veterinary science, pp 56-73

Antanaitis R, Džermeikaitė K, Krištolaitytė J, Stankevičius R, Daunoras G *et al*., 2024. Changes in parameters registered by innovative technologies in cows with subclinical acidosis. Animals, 14: 1883, doi: 10.3390/ani14131883

Bacic G, Karadjole T, Macesic N and Karadjole M, 2007. A brief review of etiology and nutritional prevention of metabolic disorders in dairy cattle. Vet Arhiv, 77(6): 567-577

Bakshi MPS, Wadhwa M and Makkar HP, 2017. Feeding of high-yielding bovines during transition phase. CABI Rev, 12: 1-8, doi: 10.1079/PAVSNNR201712006

Behluli B, Musliu A, Sherifi K, Youngs CR and Rexhepi A, 2017. Risk factors for occurrence of displaced abomasum and their relation to nutritional management of Holstein dairy cattle. Vet Arhiv, 87(4): 419-430, doi: 10.24099/vet.arhiv.160216

Bertoni G, Trevisi ERM, Han X and Bionaz M, 2008. Effects of inflammatory conditions on liver activity in puerperium period and consequences for performance in dairy cows.

J Dairy Sci, 91(9): 3300-3310, doi: 10.3168/jds.2008-0995

Besheer GE, Ahmed E, Samy M, Asmaa G, Rokaia FR *et al*., 2023. Association between biochemical parameters and ultrasonographic measurement for the assessment of hepatic lipidosis in dairy cows. Italian J Anim Sci, 22(1): 136-147, doi: 10.1080/1828051X.2023.2170284

Bobe G, Young JW and Beitz DC, 2004. Invited review: Pathology, etiology, prevention and treatment of fatty liver in dairy cows. J Dairy Sci, 87(10): 3105-3124, doi: 0.3168/jds.s0022-0302(04)73446-3

Boosman R, Nemeth F and Gruys E, 1991. Bovine laminitis: clinical aspects, pathology and pathogenesis with reference to acute equine laminitis. Vet Quart, 13(3): 163-171, doi: 10.1080/01652176.1991.9694302

Bramley E, Lean IJ, Fulkerson WJ, Stevenson MA, Rabiee AR *et al*., 2008. The definition of acidosis in dairy herds predominantly fed on pasture and concentrates. J Dairy Sci, 91(1): 308-32, doi: 10.3168/jds.2006-601

Caixeta LS and Omontese BO, 2021. Monitoring and improving the metabolic health of dairy cows during the transition period. Animals, 11(2): 352, doi: 10.3390/ani11020352

Caixeta LS, Herman JA, Johnson GW and McArt JA, 2018. Herd-level monitoring and prevention of displaced abomasum in dairy cattle. Vet Clin Food Anim Pract, 34(1): 83-99, doi: 10.1016/j.cvfa.2017.10.002

Caixeta LS, Ospina PA, Capel MB and Nydam DV, 2017. Association between subclinical hypocalcemia in the first 3 days of lactation and reproductive performance of dairy cows. Theriogenology, 94: 1-7, doi: 10.1016/j.theriogenology.2017.01.039

Cardoso FC, Kalscheur KF and Drackley JK, 2020. Symposium review: Nutrition strategies for improved health, production and fertility during the transition period. J Dairy Sci, 103(6): 5684-5693, doi: 10.3168/jds.2019-17271

Christakos S, 2012. Mechanism of action of 1, 25-dihydroxyvitamin D3 on intestinal calcium absorption. Rev Endocr Metab Disord, 13(1): 39-44

Cook NB, Nordlund KV and Oetzel GR, 2004. Environmental influences on claw horn lesions associated with laminitis and subacute ruminal acidosis in dairy cows. J Dairy Sci, 87: E36-E46, doi: 10.3168/jds.S0022-0302(04)70059-4

Credille BC and Fubini S, 2022. Left Displacement of the Abomasum. In Comparative Veterinary Anatomy. Academic Press, pp 1063-1068

Crnkic C and Hodzic A, 2012. Nutrition and health of dairy animals. In Milk Production- An Up-To-Date Overview of Animal Nutrition, Management and Health. Intech Open, doi: 10.5772/50804

DeGaris PJ and Lean IJ, 2008. Milk fever in dairy cows: A review of pathophysiology and control principles. Vet J, 176(1): 58-69, doi: 10.1016/j.tvjl.2007.12.029

Ding J, Li S, Jiang L, Li Y, Zhang X *et al*., 2020. Laminar inflammation responses in the oligofructose overload induced model of bovine laminitis. Front Vet Sci, 7: 351, doi: 10.3389/fvets.2020.00351

Doll KM, Sickinger T and Seeger, 2009. New aspects in the pathogenesis of abomasal displacement. Vet J, 181: 90-96, doi: 10.1016/j.tvjl.2008.01.013

Duffield T, 2000. Subclinical ketosis in lactating dairy cattle. Vet Clin North Am Food Pract, 16(2): 231-253, doi: 10.1016/s0749-0720(15)30103-1

Elmhadi ME, Ali DK, Khogali MK and Wang H, 2022. Subacute ruminal acidosis in dairy herds: microbiological and nutritional causes, consequences and prevention strategies. Anim Nutr, 10: 148-155, doi: 10.1016/j.aninu.2021.12.008

Geishauser T, Leslie K and Duffield T, 1999. Prevention and prediction of displaced abomasum in dairy cows. In: American Association of Bovine Practitioners. Proceedings of the Annual Conference, pp 203-207, doi: 10.21423/bovine-vol34no1p51-55

Goff J, 2006. Major advances in our understanding of nutritional influences on bovine health. J Dairy Sci, 89(4): 1292-1301, doi: 10.3168/jds.S0022-0302(06)72197-X

Goff JP and Horst RL, 1997. Physiological changes at parturition and their relationship to metabolic disorders. J Dairy Sci, 80(7): 1260-1268, doi: 10.3168/jds.s0022-0302(97)76055-7

Goff JP, 2014. Calcium and magnesium disorders. Vet Clin North Am Food Pract, 30(2): 359-381, doi: 10.1016/j.cvfa.2014.04.003

Goff JP, Hohman A and Timms LL, 2020. Effect of subclinical and clinical hypocalcemia and dietary cation-anion difference on rumination activity in periparturient dairy cows. J Dairy Sci, 103(3): 2591-2601, doi: 10.3168/jds.2019-17581

Grossi S, Rossi L, Dell'Anno M, Biffani S and Sgoifo Rossi CA, 2021. Effects of heated drinking water on the growth performance and rumen functionality of fattening Charolaise beef cattle in winter. Animals, 11(8): 2218, doi: 10.3390%2Fani11082218

Guliñski P, 2021. Ketone bodies- causes and effects of their increased presence in cows' body fluids: A review. Vet World, 14(6), 1492, doi: 10.14202%2Fvetworld.2021.1492-1503

Haass CL and Eness PG, 1984. Bovine fatty liver syndrome. Iowa State Uni Vet, 46(2): 7

Hernandez-Castellano LE, Hernandez LL and Bruckmaier RM, 2020. Review: Endocrine pathways to regulate calcium homeostasis around parturition and the prevention of hypocalcemia in periparturient dairy cows. Animals, 14: 330-338, doi: 10.1017/s1751731119001605

Ingvartsen KL, 2006. Feeding-and management-related diseases in the transition cow: physiological adaptations around calving and strategies to reduce feeding-related diseases. Anim Feed Sci Technol, 126(3-4): 175-213, doi: 10.1007/s11154-011-9197-x

Jaramillo-López E, Itza-Ortiz MF, Peraza-Mercado G and Carrera-Chávez JM, 2017. Ruminal acidosis: strategies for its control. Austral J Vet Sci, 49(3): 139-148, doi: 10.4067/S0719-81322017000300139

Kim S and Cho YI, 2019. Analysis of total mixed ration (TMR) nutrition and metabolic diseases in Korean dairy

farm. Korean J Vet Serv, 42(2): 67-71, doi: 0.7853/kjvs.2019.42.2.67

Lacasse P, Vanacker N, Ollier S and Ster C, 2018. Innovative dairy cow management to improve resistance to metabolic and infectious diseases during the transition period. Res Vet Sci, 116: 40-46, doi: 10.1016/j.rvsc.2017.06.020

Langova L, Novotna I, Nemcova P, Machacek M, Havlicek Z *et al*., 2020. Impact of nutrients on the hoof health in cattle. Animals, 10: 1824, doi: 10.3390/ani10101824

Lee M, Jeong S, Seo J and Seo S, 2019. Changes in the ruminal fermentation and bacterial community structure by a sudden change to a high-concentrate diet in Korean domestic ruminants. Asian-Australas J Anim Sci, 32(1): 92, doi: 10.5713%2Fajas.18.0262

Li H, Liu J, Zhu W and Mao S, 2017. Intraruminal infusion of oligofructose alters ruminal microbiota and induces acute laminitis in sheep. J Anim Sci, 95(12): 5407-5419, doi: 10.2527/jas2017.1860

Ma Y, Wang C, Elmhadi M, Zhang H, Han Y *et al*., 2021. Thiamine ameliorates metabolic disorders induced by a long-term high-concentrate diet and promotes rumen epithelial development in goats. J Dairy Sci, 104(11): 11522-11536, doi: 10.3168/jds.2021-20425

Mallette LE, 1989. Regulation of blood calcium in humans. Endocrinol Metab Clin N Am, 18(3): 601-610, doi: 10.1016/S0889-8529(18)30355-4

Mandebvu P, Ballard CS, Sniffen CJ, Tsang DS, Valdez F *et al*., 2003. Effect of feeding an energy supplement prepartum and postpartum on milk yield and composition and incidence of ketosis in dairy cows. Anim Feed Sci Technol, 105(1-4): 81-93, doi: 10.1016/S0377-8401(03)00058-0

Mann S, Yepes FAL, Behling-Kelly E and McArt JAA, 2017. The effect of different treatments for early-lactation hyperketonemia on blood β-hydroxybutyrate, plasma on esterified fatty acids, glucose, insulin and glucagon in dairy cattle. J Dairy Sci, 100: 6470-6482, doi: 10.3168/jds.2016-12532

Martens H and Schweigel M, 2000. Pathophysiology of grass tetany and other hypomagnesemias: implications for clinical management. Vet Clin N Am, 16(2): 339-368, doi: 10.1016/s0749-0720(15)30109-2

Martinez N, Risco CA, Lima FS, Bisinotto RS and Greco LF, 2012. Evaluation of peripartal calcium status, energetic profile and neutrophil function in dairy cows at low or high risk of developing uterine disease. J Dairy Sci, 95(12): 7158-7172, doi: 10.3168/jds.2012-5812

Martín-Tereso J and Martens H, 2014. Calcium and magnesium physiology and nutrition in relation to the prevention of milk fever and tetany (dietary management of macrominerals in preventing disease). Vet Clin N Am, 30(3): 643-670, doi: 10.1016/j.cvfa.2014.07.007

Mitchell KE and Rossow HA, 2020. Effects of a glucose precursor supplement fed to Holstein and Jersey cows during the transition period on ketosis prevalence and milk production. EC Vet Sci, 5: 1-13

Monteiro HF and Faciola AP, 2020. Ruminal acidosis, bacterial changes and lipopolysaccharides. J Ani Sci, 98(8): 248, doi: 10.1093/jas/skaa248

Neubauer V, Humer E, Kröger I, Braid T and Wagner M, 2018. Differences between pH of indwelling sensors and the pH of fluid and solid phase in the rumen of dairy cows fed varying concentrate levels. J Anim Physiol Anim Nutr, 102(1): 343-349, doi: 10.1111/jpn.12675

Oh J, Harper MT, Melgar A, Räisänen S, Chen X *et al*., 2021. Dietary supplementation with rumen-protected capsicum during the transition period improves the metabolic status of dairy cows. J Dairy Sci, 104(11): 11609-11620, doi: 10.3168/jds.2020-19892

Overton TR and Waldron MR, 2004. Nutritional management of transition dairy cows: strategies to optimize metabolic health. J Dairy Sci, 87: E105-E119, doi: 10.3168/jds.S0022-0302(04)70066-1

Pascottini OB and LeBlanc SJ, 2020. Modulation of immune function in the bovine uterus peripartum. Theriogenology, 150: 193-200, doi: 10.1016/j.theriogenology.2020.01.042

Pelczyñska M, Moszak M and Bogdañski P, 2022. The role of magnesium in the pathogenesis of metabolic disorders. Nutrients, 14(9): 1714, doi: 10.3390/nu14091714

Pickett MM, Piepenbrink MS and Overton TR, 2003. Effects of propylene glycol or fat drench on plasma metabolites, liver composition and production of dairy cows during the periparturient period. J Dairy Sci, 86(6): 2113-2121, doi: 10.3168/jds.s0022-0302(03)73801-6

Pirestani A and Aghakhani M, 2018. The effects of rumen-protected choline and l-carnitine supplementation in the transition period on reproduction, production and some metabolic diseases of dairy cattle. J App Ani Res, 46(1): 435-440, doi: 10.1080/09712119.2017.1332632

Pizoni C, Barbosa AA, Cardoso KB, Velasquez B, Freitas KC *et al*., 2022. Effects of short term acidogenic diet feeding on metabolic parameters of dairy cows with induced subclinical hypocalcemia. Res Soc Dev, 11(4): e48211427081-e48211427081, doi: 10.33448/rsd-v11i4.27081

Pryce JE, Gaddis KP, Koeck A, Bastin C, Abdelsayed M *et al*., 2016. Invited review: Opportunities for genetic improvement of metabolic diseases. J Dairy Sci, 99(9): 6855-6873, doi: 10.3168/jds.2016-10854

Radostits OM, Blood DC, Gay CC, Hinchiff KW and Handerson JA, 2000. Veterinary Medicine, 9th edn. Bailliere and Tindall Publication, Ltd. London, pp 1450-1452

Rivas RMO, Gutierrez-Oviedo FA, Komori GH, Beihling VV, Marins TN *et al*., 2021. Effect of supplementation of a mixture of gluconeogenic precursors during the transition period on performance, blood metabolites and insulin concentrations and hepatic gene expression of dairy cows. Anim Feed Sci Technol, 272: 114791, doi: 10.1016/j.anifeedsci.2020.114791

Roberts T, Chapinal N, LeBlanc SJ, Kelton DF, Dubuc J *et al*., 2012. Metabolic parameters in transition cows as indicators for early-lactation culling risk. J Dairy Sci, 95(6): 3057-3063, doi: 10.3168/jds.2011-4937

Roche JR, Bell AW, Overton TR and Loor JJ, 2013. Nutritional management of the transition cow in the 21st century– A paradigm shift in thinking. Anim Prod Sci,

53(9): 1000-1023, doi: 10.1071/AN12293

Ross AB, Godin JP, Minehira K and Kirwan JP, 2013. Increasing whole grain intake as part of prevention and treatment of nonalcoholic fatty liver disease. Int J Endocrinol, doi: 10.1155/2013/585876

Safari M, Ghasemi E, Alikhani M and Ansari-Mahyari S, 2018. Supplementation effects of pomegranate by-products on oxidative status, metabolic profile and performance in transition dairy cows. J Dairy Sci, 101(12): 11297-11309, doi: 10.3168/jds.2018-14506

Safdar AHA, 2015. Fundamental research in relation to minimizing adverse effects on metabolic disorders. Bio Forum, 7(1): 1156-1163

Santos MM, Bregadioli GC, Santos LG, Curti JM, Duarte CA *et al*., 2020. Treatment of acute rumen lactic acidosis with intravenous hypertonic sodium chloride or bicarbonate solutions followed by intraruminal water. Res Vet Sci, 128: 24-34, doi: 10.1016/j.rvsc.2019.10.009

Shaver RD, 1997. Nutritional risk factors in the etiology of left displaced abomasum in dairy cows: A review. J Dairy Sci, 80(10): 2449-2453, doi: 10.3168/jds.s0022-0302(97)76197-6

Silva DCD, Fernandes BD, Lima JMDS, Silva BAD, Rodrigues GP *et al*., 2020. Subclinical hypomagnesemia: prevalence and causes in dairy cows in the semiarid region of the state of Paraíba, Brazil. Rev Bras Saúde Prod Anim, 21: 2020, doi: 10.1590/S1519-99402121132020

Socha MT, Tomlinson DJ, Johnson AB and Shugal LM, 2002. Proceedings of the 12th International Symposium on Lameness in Ruminants, Orlando, pp 62-69

Stone WC, 2004. Nutritional approaches to minimize subacute ruminal acidosis and laminitis in dairy cattle. J Dairy Sci, 87: E13-E26, doi: 10.3168/jds.S0022-0302(04)70057-0

Sun X, Wang Y, Wang E, Zhang S, Wang Q *et al*., 2021. Effects of saccharomyces cerevisiae culture on ruminal fermentation, blood metabolism and performance of high-yield dairy cows. Animals, 11(8): 2401, doi: 10.3390%2Fani11082401

Sundrum A, 2015. Metabolic disorders in the transition period indicate that the dairy cows' ability to adapt is overstressed. Animals, 5(4): 978-1020, doi: 10.3390/ani5040395

Thilsing-Hansen T, Jørgensen RJ and Østergaard S, 2002. Milk fever control principles: A review. Acta Vet Scand, 43(1): 1-19, doi: 10.1186/1751-0147-43-1

Wen K, Zhao MM, Liu L, Khogali MK, Geng TY *et al*., 2021. Thiamine modulates intestinal morphological structure and microbiota under subacute ruminal acidosis induced by a high-concentrate diet in Saanen goats. Animals, 15(10): 100370, doi: 10.1016/j.animal.2021.100370

Wisnieski L, Norby B, Pierce SJ, Becker T, Gandy JC *et al*., 2019. Predictive models for early lactation diseases in transition dairy cattle at dry-off. Prevent Vet Med, 163: 68-78, doi: 10.1016/j.prevetmed.2018.12.014

Wu G, 2018. Principles of animal nutrition. Boca Raton: CRC Press, doi: 10.1201/9781315120065

Wu G, 2020. Management of metabolic disorders (including metabolic diseases) in ruminant and nonruminant animals. In Animal Agriculture Bazer, Academic Press, Cambridge, MA, USA, pp 471-491, doi: 10.1016/B978-0-12-817052-6.00027-6

Xia G, Sun J, Fan Y, Zhao F, Ahmed G *et al*., 2020. B-sitosterol attenuates high grain diet-induced inflammatory stress and modifies rumen fermentation and microbiota in sheep. Animals, 10(1): 171, doi: 10.3390%2Fani10010171

Zachut M, Šperanda M, de Almeida AM, Gabai G, Mobasheri A *et al*., 2020. Biomarkers of fitness and welfare in dairy cattle: healthy productivity. J Dairy Res, 87(1): 4-13, doi: 10.1017/s0022029920000084

Zhang F, Nan X, Wang H, Zhao Y, Guo Y *et al*., 2020. Effects of propylene glycol on negative energy balance of postpartum dairy cows. Animals, 10(9): 1526, doi: 10.3390%2Fani10091526

Received- 13.12.2023, Accepted- 03.08.2024, Published- 20.08.2024 (Online), 01.12.2024 (Print)
Section Editor: Dr. A. K. Patra, Associate Editor