METABOLIC DISORDERS OF DAIRY CATTLE

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Summary

Dairy cattle metabolic disorders, which are diseases related to disturbance of one or more metabolic processes in the organism are discussed in this overview. The transition period which includes three weeks before and three weeks after parturition is very critical for dairy cows. This period of time is associated with multiple changes including hormonal changes, moving from non-lactating to lactating state as well as a major drop in feed intake and switching of the diet from a roughage-based diet (i.e. hay and grass) into a diet rich in rapidly fermentable carbohydrates (i.e. high-grain diets). One in two dairy cows in a herd is affected by one or multiple metabolic disorders. Although the etiology and pathogenesis of most metabolic disorders is not fully understood, different preventive and treatment strategies have been developed during the years. A more detailed and comprehensive treatise on cattle metabolic disorders can be obtained from several scientific review articles which have been listed and annotated in the bibliography section of this chapter.

1. Introduction

Metabolism is the sum of all physical, chemical, and metabolic processes occurring in a living cell or organism related to absorbance, breakdown or synthesis of necessary organic molecules in the body. Metabolic processes are associated with the release of a variety of metabolites that are either used as building blocks or degraded and excreted from the body as waste. During metabolism the cells, organs, systems or the whole organism extract energy from nutrients and use that for normal functioning of the body. Therefore, metabolism includes all metabolic processes that make life and normal

functioning of the organism possible. Dysfunction of any of the metabolic processes is associated with malfunctioning of separate parts or the whole organism. Disturbance of one or multiple metabolic processes, related to regulation of a certain metabolite in the body fluids, is known as metabolic disease or disorder.

In fact, during the years different synonymous terms have been used to describe metabolic disturbances in humans or animals such as metabolic diseases, metabolic disorders, or production diseases. The term metabolic disease has been used in human medicine to characterize an inherent defect in the metabolic constitution, whereas the term metabolic disorder has been used more to indicate the deficiency or excesses of one or more nutrients. Animal scientists and veterinarians use the term metabolic diseases or disorders interchangeably to indicate a group of diseases characterized by disturbance of one or more plasma metabolites such as ketone bodies, calcium, or non-esterified fatty acids. A production disease is a concept developed by Jack Payne and his team at Compton Research Institute during 1970s to indicate the breakdown of animals' capacity to meet the demands of high production couple with unsuitable feeding during modern husbandry. The term production disease is focused more on the human imposed nature (i.e. the human request for high milk production) of these diseases.

Metabolic disorders of cattle are a group of diseases that affect dairy cows immediately after parturition. There are several metabolic disorders identified in dairy cows during the first month after parturition and the most frequent ones are the following: (1) sub-acute and acute ruminal acidosis, (2) laminitis, (3) ketosis, (4) fatty liver, (5) left displaced abomasum (LDA), (6) milk fever, (7) downer cow, (8) retained placenta, (9) liver abscesses, (10) metritis, (11) mastitis, and (12) bloat. The reason that these diseases are called metabolic disorders is related to the fact that they are associated with the disturbance of one or more blood metabolites in sick cows. For example, ketosis is associated with enhanced ketone bodies (i.e. beta-hydroxybutyric acid - BHBA) in the blood; fatty liver is associated with enhanced nonesterified fatty acids (NEFA) and their accumulation in the liver; acidosis is associated with increased production of organic acids (e.g. acetic, propionic, and butyric acids) in the rumen and low rumen pH; and milk fever is associated with decreased blood calcium. There is not yet a blood metabolite identified for some of the metabolic disorders such as downer cow, LDA, metritis, mastitis, laminitis, retained placenta or bloat.

The most interesting observation with regards to the occurrence of metabolic disorders is that they are highly associated with each other. For example, cows affected by milk fever are more prone to mastitis, retained placenta, metritis, LDA, distocia, udder edema, and ketosis; cows affected by acidosis are more prone to laminitis, LDA, milk fever, mastitis, and fatty liver. Those animals affected by retained placenta are more prone to metritis, LDA, and ketosis. Ketosis and fatty liver are common findings in cows affected by milk fever, mastitis, laminitis, LDA, metritis, retained placenta and udder edema. Although these associations have been known for years by animal scientists, the reason behind these associations is not very well understood. One speculation is that there might be a common etiological factor that initiates the cascade of metabolic disorders. Therefore, scientists are searching to identify such a common causal agent of metabolic disorders; however, no such agent has been identified so far. Dr. Ametaj's team at the University of Alberta is intensively working to identify such a

common agent and preliminary results indicate that feeding high-grain diets might be the initial stimulus that disturbs multiple metabolic processes appearing as interrelated metabolic disorders.

2. Main Metabolic Disorders of Dairy Cattle

2.1. Ruminal Acidosis

2.1.1. Definition and Pathogenesis

Subacute and acute rumen acidosis (i.e. SARA and ARA) are very prevalent disorders of dairy herds. Two groups of cows at special risk for acidosis are early lactation cows and cows with high intake of grain in their diets. Acute acidosis is characterized by specific symptoms, which, if caught in time, can be treated directly; however, symptoms of subclinical acidosis are not very well defined. Often, subclinical acidosis is wrongly identified with poor forage quality or poor bunk management. Because of the chronicity and unidentified signs subclinical acidosis inflicts major economic losses to dairy herds. The most typical clinical manifestation of subclinical acidosis is reduced or inconsistent feed intake. Other associated signs include decreased milk production, lowered fat content in the milk, poor body condition score, high culling rate, diarrhea, and laminitis. Subclinical acidosis occurs very often even in well managed and in high producing dairy herds.

On the other hand, acute acidosis results in very sick cows: physiological functions may be significantly impaired and death may occur. Acute acidosis is characterized by a significant decrease in ruminal pH ($\leq$ 5.0), enhanced concentrations of volatile fatty acids (VFA) and lactate in the rumen as well as a large decrease in the number of protozoa. Acidosis is most prevalent following intake of large amounts of grain or other rapidly fermented carbohydrates. Excessive intake of readily fermented starch often occurs immediately after calving when cows are first being adapted to a high-grain diet. For optimum ruminal fermentation and fiber digestion, ruminal pH should range between 6.0 and 6.4, although, even in healthy cows, ruminal pH will fluctuate below this level for short periods during the day.

Under normal conditions, bacteria in the rumen ferment the starch contained in cereal grains into weak organic acids such as VFA as well as glucose and lactic acid. Under normal feeding conditions, VFA are readily absorbed by papillae on the rumen wall. Once absorbed, VFA enter the cow's bloodstream and can be used for milk production. However, under acidic conditions VFA accumulate in the rumen and contribute to acidosis. On the other hand, rapid release of glucose in the rumen has the following deleterious effects: (1) growth of rumen bacteria that are involved in digestion of starch such as *Streptococcus bovis*, (2) growth of Gram-negative bacteria (e.g. *Escherichia coli*) which release toxic compounds such as endotoxin, and (3) rumen osmolality and accumulation of organic acids (i.e. VFA) in the rumen. Rumen bacteria such as *Streptococcus bovis* and *Lactobacillus species* produce lactic acid which lowers rumen pH further (that is, increases acidity). Low rumen pH inhibits the activity of bacteria which utilize lactic acid such as *Megasphera elsdenii* and encourages the rapid growth of bacteria which produce lactic acid (i.e., *Streptococcus bovis* and *Lactobacillus*). At

very low pH, the enzymatic activity and fermentation stops. Furthermore, presence of high concentration of lactic acid damages rumen wall and the acid rapidly enters the bloodstream and upsets the acid-base balance of the cow. Cows at this point will be suffering severe acidosis and are likely to die.

Symptoms of ruminal acidosis include low milk fat content, low appetite and feed intake, diarrhea, accelerated respiration, salivation, depression, lethargy, lameness, and possibly death. To identify herds with presence of subclinical acidosis milk fat test is commonly used. Bulk fat test is not accurate to identify individual sick cows. Therefore, individual milk fat testing is recommended. In fact, the best diagnostic test for subclinical acidosis is measurement of ruminal pH. Stomach tubing or rumenocentesis (collection of rumen fluid with a syringe by a percutaneous method) have been used to collect samples of ruminal fluid for determination of pH.

2.1.2. Treatment

It is important to treat the sick cow as soon as possible. Selection of treatment for acidosis depends on the severity of the clinical symptoms. Producers need to consult a veterinary specialist for the most appropriate treatment. However, the following can be used as a guide until the veterinarian is contacted. If some cows show mild signs of acidosis such as diarrhea, they should be fed a diet with smaller proportion of grain or increased amount of roughage. Cows with more severe signs such as severe diarrhea, off feed, and in a depressed state should be removed from the grain diet and fed roughage only. Cows should be given orally about 120 g of sodium bicarbonate and an electrolyte replacer dissolved in four to five liters of water. This treatment should be repeated three times per day if possible and the cows need to be encouraged to walk around. One should keep in mind that cows having very severe signs of acidosis such as lying down and being unable to stand are unlikely to respond to this type of treatment. A veterinarian should be consulted immediately.

2.1.3. Prevention

There are two commonly used management practices for prevention of ruminal acidosis: (1) increasing the proportion of roughage in the diet, and (2) decreasing the intake of starch (i.e. cereal grains such as corn, wheat, or barley). The reason for increasing the amount of roughage, in the form of hay or forages, is that it lowers the frequency of eating as well as the size of a meal. In addition, by increasing the proportion of roughage in the diet the time of chewing and the amount of saliva produced will be increased. Moreover, feeding roughage has two other beneficial effects: (1) the size of grain particles entering the rumen decrease and thereby increases its rate of fermentation, and (2) the time of mastication increases and thereby the amount of buffers from saliva which neutralizes and dilutes ruminal acids increases. Another efficient way to lower the starch content of the diet is by substituting the starch-extracted concentrates (e.g. distilling or brewing co-products and middlings) for cereal grains. The total feed intake also can be restricted by using a feeding scheme with limited maximum intake. Feeding direct-fed microbials or probiotics that utilize glucose or lactate prevents their accumulation and the lowering of rumen pH.

2.2. Laminitis

2.2.1. Definition and Pathogenesis

Laminitis is an inflammatory, non-infectious condition of the foot. The causative agents of laminitis are multiple and interrelated and they have not been fully explained. Feeding diets rich in highly fermentable carbohydrates that induce an acidotic state has been identified as one of the key factors in pathogenesis of laminitis. Digestive disorders such as acidosis, changes in the gastrointestinal bacterial flora, and translocation of endotoxin into the bloodstream predisposes cows to laminitis. Gram-negative-related infectious diseases such as mastitis, metritis, and foot rot also contribute indirectly to the etiology of the disease by providing large sources of endotoxin. Several environmental factors including hard surfaces, poor bedding, and lack of or excessive exercise have been blamed for the disease. Other contributing factors, such as body weight and feet and leg structure exacerbate the foot damage that is associated with laminitis.

Development of laminitis has been suggested to go through four consecutive stages: (1) transferring of endotoxin from gastrointestinal tract into the systemic circulation and damage of blood vessels, (2) lowering of the availability of nutrients and oxygen to the foot tissue, (3) breakdown and degeneration of the foot tissue, and (4) separation of bone and soft tissue with bleeding and bruises signs and development of inflammation (i.e. laminitis).

There are three main forms of laminitis recognized as acute, subacute, and chronic laminitis. During acute laminitis, although the cow is systemically ill and inflammation of the corium is evident, very few clinical signs are observed. However, local sign such as pain, swelling of the foot tissue and temperatures slightly greater than normal above the corium band are obvious. Conversely, subacute laminitis is more of a less apparent form of the disease. The most notable signs are softer horn, yellow coloration of the sole and bleeding stains in the solar area. On the other hand, chronic laminitis is associated with several typical changes to the hoof area. For example, the growth pattern of the keratinized horn is disrupted and the shape of the digit is altered into a more elongated, flattened, and broadened one. Moreover, grooves and ridges on the dorsal wall become more prominent, giving a rippled appearance to the foot. Other important signs include ulcerations on the solar area, double soles with yellowish coloration, destruction of the small blood vessels, separation between the dermal and epidermal junction, and finally internal foot destruction. If the disease process has progressed to this irreversible point no medication can return the foot to its original normal structure.

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Bibliographical sketch

Dr. Burim N. Ametaj is an Associate Professor of Animal Physiology at Department of Agricultural, Food and Nutritional Sciences, University of Alberta, Edmonton, Canada. He holds a veterinary degree and two PhDs related to metabolic diseases of cattle and nutritional immunology, respectively. His present research activity is focused on the study of the relationship between nutritional malpractices and immune responses and their contribution in development of production diseases in dairy and beef cattle. Dr. Ametaj's research activity includes studying the role of high grain diets on the etiology and pathogenesis of production diseases in ruminant animals as well as development of novel techniques for their prevention. He is using systems biology approach to study disease processes in cattle.