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Fat Mobilization & New Ideas about Health Risks in Transition Cows

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Introduction

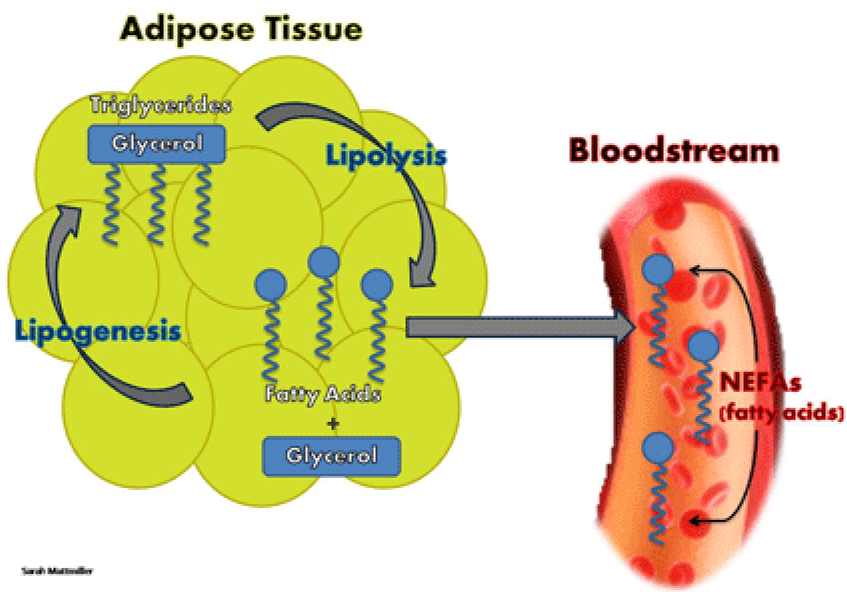
Calving and the onset of lactation lead to a sudden increase in the energy requirements of the dairy cow. This time also is characterized by a drop in feed intake, therefore lowering the amount of energy provided by feed. The imbalance between the energy that the cow consumes and the energy needed for production demands is termed negative energy balance (NEB). Cows adapt to NEB periods by moving body fat reserves through a process known as lipid mobilization. Although this is a normal adjustment common among mammals, lipid mobilization is exacerbated in the dairy cow with the genetic drive for high milk production.

Research in humans has linked elevation of blood lipids to metabolic diseases such as type-2 diabetes, metabolic syndrome, and to inflammatory diseases such as cardiac, hypertension, asthma, and Alzheimer's disease. In cattle, increases in blood lipid content are known to induce metabolic diseases (fatty liver, ketosis) and predispose dairy cows to inflammatory-based diseases (mastitis, metritis, and lameness) affecting animal welfare and profitability. A better understanding of how elevated blood lipids may affect dairy cow immunity during the transition period may lead to innovative approaches to control increased disease susceptibility.

What Is Lipid Mobilization?

Adipose (or fat) functions as the body's energy store and is a very dynamic tissue. For example, adipose tissue is constantly storing and releasing energy for bodily functions. The main molecules used as an energy currency are known as triglycerides; these are composed of three fatty acid molecules and a glycerol "backbone". When energy is required, fatty acids are released into the bloodstream by cleaving off the glycerol backbone, a process called lipolysis. In contrast, lipogenesis is a process that stores energy by reuniting fatty acids to a glycerol molecule. The resulting triglyceride is a stable molecule that is more suitable for storage. Around calving and during periods of NEB, the rate of lipolysis (breakdown) is greater than the rate of lipogenesis (synthesis and storage), resulting in more fatty acids released into the bloodstream.

Figure 1: Fat mobilization process. Lipolysis releases fatty acids from triglyceride molecules in adipose tissue into the bloodstream. Lipogenesis assembles triglycerides from fatty acids and glycerol.



Ketosis: a Consequence of Lipid Mobilization

The direct outcome of lipid mobilization is the rise in the concentrations of fatty acids in blood. These fatty acids are named non-esterified fatty acids (NEFA), because they are transported in blood unattached to glycerol. The NEFA are converted to more available energy substrates once the liver transforms them into ketone bodies. The most common ketone body in dairy cows is beta hydroxybutyrate (BHB). This ketone body is used by muscle and nervous tissue as an energy substrate, but in excess causes clinical problems, for example, ketosis. Traditionally, NEFA and BHB were used to assess the degree of NEB and lipid mobilization. They also can be used to evaluate the performance of transition cow nutrition programs.

Both NEFA and BHB are measured in micromolar per liter of blood (Table 1). Late lactation cows usually have NEFA values less than 200 µM, and concentrations begin to rise as cows approach calving reaching the highest values of 800 to 1200 µM during the first week of lactation. Values return to less than 300 µM by 30 days in milk. Similarly, BHB concentrations increase as calving approaches and start to decrease after 30 days in milk (DIM).

Table 1: NEFA and BHB measurements.

Metabolite	Late Lactation	1 week before calving	1 week after calving	30 DIM
NEFA (µM)	<200 µM/L	300 µM/L	800-1200 µM/L	<300 µM/L
BHB	500 µM/L	800 µM/L	1100 µM/L	900 µM/L

Elevated Blood Lipid Can Mean More Problems

Although NEFA and BHB values measure the degree of lipid mobilization, these tests do not describe other changes that occur in blood lipids during the transition period. For example, there are alterations in the fatty acid composition of blood NEFA. These changes also may have consequences on cow health. Research at MSU's College of Veterinary Medicine recently established some compositional changes in blood NEFA during the transition period. The main alteration is an increase in the concentrations of palmitic and stearic acids. In humans, these two saturated fatty acids are known to damage bodily functions, including energy utilization and immune response that could increase dairy cow's susceptibility to disease.

Fatty Acids and Inflammation

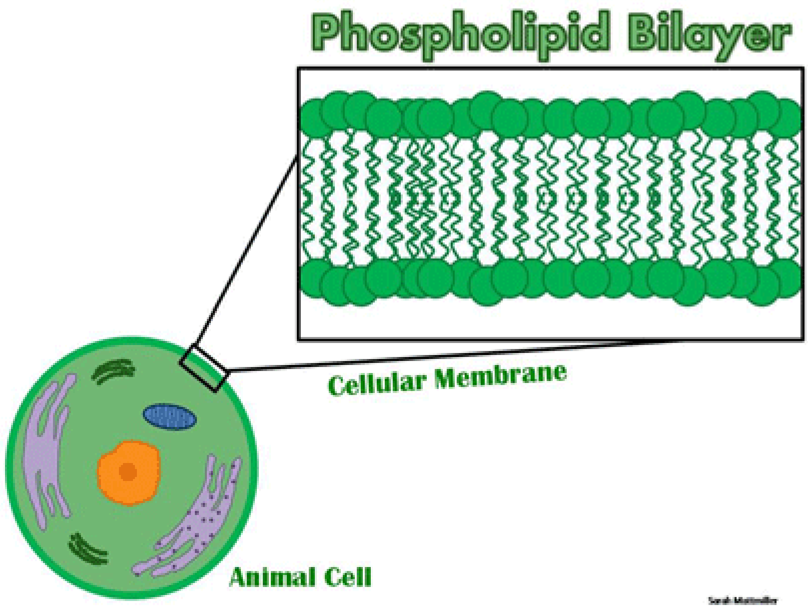
Studies in human medicine demonstrated that high concentrations of NEFA induce low-grade inflammation and affect immune function. Similarly, during the transition period when blood NEFA increase severely, dairy cows experience immune dysfunction that enhances their susceptibility to disease. At the same time, saturated fatty acids such as palmitic acid increase in concentration within the blood NEFA. This fatty acid is capable of activating white blood cells at high concentrations.

As saturated fatty acids increase in blood NEFA, other fatty acids such as mono- and polyunsaturated fatty acids decrease. Some of these fatty acids include arachidonic acid (an Omega-6 fatty acid), eicosapentanoic acid EPA, and docosahexanoic DHA (both omega-3 fatty acids). These fatty acids are essential for immune function because their products affect different steps of the inflammatory process. Reduction in the availability of these necessary fatty acids may promote immune dysfunction in dairy cows.

NEFA Effect on Immune Function

Changes in the concentration and composition of plasma NEFA directly affect white blood cell function. A first way of altering immune function is by changing the composition of the cellular membrane of blood cells. In animal cells, this membrane is composed of phospholipids. These molecules are formed by different kinds of fatty acids including saturated, monounsaturated and polyunsaturated. Fatty acids together with some proteins form a bilayer that surrounds and protects the cells. The fatty acid composition of the cellular membrane is directly affected by the composition of lipids in blood especially NEFA. Therefore any change in the content of blood NEFA will be reflected directly in the phospholipid membrane of white blood cells.

Figure 2: Fatty acids are the main components of the phospholipid bilayer that is known as the cellular membrane in animal cells.



Fatty acids from the cellular membrane are involved in the inflammatory process as they are transformed into lipid mediators. Some examples of lipid mediators are prostaglandins and prostacyclins. These fatty acid-derived molecules can cause damage by inducing changes in blood vessels and altering white blood cell function.

A second way of altering immune function is by altering the internal communication of white blood cells. Saturated fatty acids directly affect cell behavior, making a cell more likely to promote rather than fight inflammation. Therefore, changing the composition of fatty acids within the cellular membrane of white blood cells may be an effective way of altering how a cow responds to infectious and metabolic diseases during the transition period.

Regulating Lipomobilization in the Transition Period

Lipomobilization is related directly to energy balance. Minimizing dry matter intake depression during the transition period will decrease the need for mobilizing fat reserves. Providing adequate housing, minimizing abrupt management changes around calving, and targeting a diet that fulfills energy requirements without dry matter intake depression will reduce excessive mobilization of fats after calving. It is important also to prevent excessive fat deposition during the previous lactation and early dry period, because over-conditioned dairy cows will mobilize fat at a faster rate than properly conditioned animals.

Future Implications

The importance of lipid metabolism to the incidence of human diseases is well established and as a result, this has led to a significant amount of research in this field. In the near future, the dairy industry may be able to use some of the new technologies and treatments developed for human health.

Novel nutritional interventions including supplementation of specific fatty acids during times of increased nutritional requirements and new drugs that will reduce and control lipid mobilization (therefore decreasing its damage), are a couple of examples of what dairy producers may have available in the near future. However, lipidomics (lipid science) is still in its infancy and considerably more information is needed to fully understand how modulation of lipid metabolism can affect dairy cow health.

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