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Nutritional management of the transition dairy cow for optimal health and production

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Abstract

Feeding and management during the transition period i.e. three weeks immediately before and three weeks after calving, has a significant influence on milk production and fertility. Therefore, time and money spent during transition should be considered as valuable investments for improving farm profitability. Poor feeding and management during the transition period can result in a host of problems around calving such as dystocia, retained placenta, milk fever (hypocalcaemia), grass staggers or hypomagnesaemia, rapid weight loss and ketosis. Most health disorders occur during this time. Feed intake tends to decline as calving approaches, and does not peak until about 10 to 12 weeks after calving. This is the opposite of cow requirements as nutrient demands increase rapidly in the last two months of pregnancy, and cows achieve peak milk yields about six to eight weeks after calving. When cows dip into a negative energy balance, non-esterified fatty acid (NEFA) and beta hydroxy butyrate (BHBA) levels in the blood increase. This is due to large amounts of body fat being utilized as an energy source to support colostrum or milk production., results is ketosis. Nutrition and management programs during this phase directly affect the incidence of post-calving disorders, milk production and reproduction in the subsequent lactation.

Introduction

The transition period in dairy cows is defined as the last three weeks before parturition to three weeks after parturition (Grummer, 1995). It is characterized by tremendous metabolic and endocrine adjustments that the cows must experience from late gestation to early lactation (Drackley et al., 2001). Perhaps the most important physiological change occurring during this period is the decrease in dry matter intake (DMI) around parturition and the sudden increase in nutrients that cows need for milk production (Drackley, 1999). One week before calving, DMI has been shown to decline, with a drop of approximately 30% occurring in the 24 hours before calving (Huzzey et al., 2007). DMI has been shown to drop by 19% on the day after calving, relative to the day of calving when cows are routinely switched to a high energy diet to support lactation needs (Huzzey et al., 2007). As a result, postpartum intakes are usually less than energy requirements (Bell, 1995) leads ton egative energy balance. In response to negative energy balance, cows mobilize stored triglycerides in the adipose tissue in an attempt to meet energy demands for maintenance and milk production. As a result of these remarkable changes, most of the infectious diseases and metabolic disorders occur during this time (Goff and Horst, 1997; Drackley, 1999). Milk fever, ketosis, retained foetal membranes (RFM), metritis and displacement of the abomasum (DA) primarily affect cows within the first two weeks of lactation (Drackley, 1999).

Physical and metabolic stresses of pregnancy, calving and lactation contribute to the decrease in host resistance during the periparturient period (Mallard et al., 1998). During two weeks before and after parturition the T-cells populations exhibit a significant decline, which contribute to the immune-

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suppression in dairy cows at calving (Kimura et al., 1999). This immunosuppression during the periparturient period leads to increased susceptibility to mastitis and other infectious diseases (Mallard et al., 1998).

Metabolic Changes during the Transition Period

In transition cow after calving, an excessive incidence of metabolic and infectious disorders, cyclic feed intakes, and excessive loss of body condition after calving (Drackley, 1998). Poor reproductive success also may be linked back to problems in the transition period (Ferguson, 2001). As calving approaches, concentrations of progesterone in blood decrease and those of estrogen remain high or actually increase (Grummer, 1995). High circulating estrogen is believed to be one major factor that contributes to decreased dry matter intake (DMI) around calving (Grummer, 1993). During the last weeks of pregnancy, nutrient demands by the fetal calf and placenta are at their greatest (Bell, 1995), yet DMI may be decreased by 10 to 30% compared with intake during the early dry period. After calving, the initiation of milk synthesis and rapidly increasing milk production greatly increases demand for glucose for milk lactose synthesis, at a time when feed intake has not reached its maximum. Because much of the dietary carbohydrate is fermented in the rumen, little glucose is absorbed directly from the digestive tract. Consequently, dairy cows rely almost exclusively on gluconeogenesis from propionate in the liver to meet their glucose requirements. Limited feed intake during the early postpartal period means that supply of propionate for glucose synthesis also is limited. Amino acids from the diet or from breakdown of skeletal muscle as well as glycerol from mobilized body fat contribute to glucose synthesis.

Negative energy balance results in a high ratio of growth hormone to insulin in blood of cows, which promotes mobilization of long chain fatty acids from adipose tissue (body fat). Fatty acids released from adipose tissue circulate as non-esterified fatty acids (NEFA), which is a major source of energy to the cow during this period. The concentration of NEFA in blood reflects the degree of adipose tissue mobilization (Pullen et al., 1989), therefore greater the extent of negative energy balance, the more NEFA are released from body fat and the higher the concentration of NEFA in blood. The liver of cows takes up NEFA from the blood that flows through it. As the concentration of NEFA in blood increases around calving or in early lactation, more NEFA are taken up by the liver (Emery et al., 1992). Once taken up by the liver, NEFA can be completely oxidized to carbon dioxide to provide energy for the liver or partially oxidized to produce ketone bodies that are released into the blood and serve as fuels for other tissues, or reconverted to storage fat (triglycerides).

Feed intake and carbohydrate status of the cow are important in determining the extent of body fat mobilization, fatty liver, and ketone body production in the liver. The sudden start of milk synthesis in the udder results in a tremendous demand for calcium. As a result, blood calcium concentrations can drop precipitously at calving, leading to milk fever. Smaller decreases in blood calcium, called sub-clinical hypocalcemia. Hypocalcemia also leads to increased secretion of cortisol, which is believed to be a factor in increased incidence of retained placenta (Goff, 1999).

Metabolic acidosis caused by a negative dietary cation-anion difference (DCAD) favors mobilization of calcium from bone, whereas high dietary potassium concentrations and positive DCAD suppress this process (Horst et al., 1997).

Function of the immune system is depressed during the transition period (Mallard et al., 1998). Decreased ability of the immune system to respond to infectious challenges likely is responsible for the high incidence of environmental mastitis around calving, as well as the high incidence of metritis. Reasons for the decreased immune function are not well understood. Vitamins A and E as well as a number of the trace minerals (selenium, copper, zinc) play a role in enhancing immune function. Recent evidence suggests that negative energy balance may be a major contributing factor (Goff, 1999).

Glucose and Lipid Metabolism During Transition Period

Glucose and amino acids are the major fuel supply of the developing fetus in ruminants. Glucose and amino acids are also needed by the mammary gland for lactose and milk protein synthesis, respectively (Herdt, 2000). Ruminants are not entirely dependent on dietary glucose; as a result they are in a constant stage of gluconeogenesis (Herdt, 2002). The liver serves as a linchpin in adaptation to the maintenance of body fuel supplies and consequently it is the key regulator of glucose supply to the tissues (Herdt, 2000). The major gluconeogenic precursor in ruminants is propionic acid produced in the rumen. Hepatic propionate metabolism is modulated during the transition period. As an example, hepatic blood flow in cows increases 84% from 11 d prepartum to 11 d postpartum (Reynolds et al., 2000). Amino acids, lactate and glycerol are secondary substrates for gluconeogenesis in ruminants (Herdt, 2002).

Excessive lipid mobilization from adipose tissue is linked with greater incidences of peri-parturient health problems like fatty livers may occur in ketotic cows nearly a half-century ago (Saarinen and Shaw, 1950). Fat mobilization syndrome may occurs in early lactation, in which cows mobilized body lipids from adipose tissue and deposited lipids in the liver, muscle, and other tissues. The elevated NEFA concentrations during the last 7 d before calving were associated with greater incidences of ketosis, displaced abomasum and retained fetal membranes but not of milk fever. Metabolism of NEFA by the liver is a critical component of understanding the biology of the transition cow. Extreme rates of lipid mobilization lead to increased uptake of NEFA by liver and increased triglyceride accumulation (Figure 1). If this lipid infiltration becomes severe, the syndrome of hepatic lipidosis or fatty liver may result, which can lead to prolonged recovery for other disorders, increased incidence of health problems, and development of "downer cows" that may die. Increased lipid accumulation and decreased glycogen in the liver were associated with an increased susceptibility to induction of ketosis.

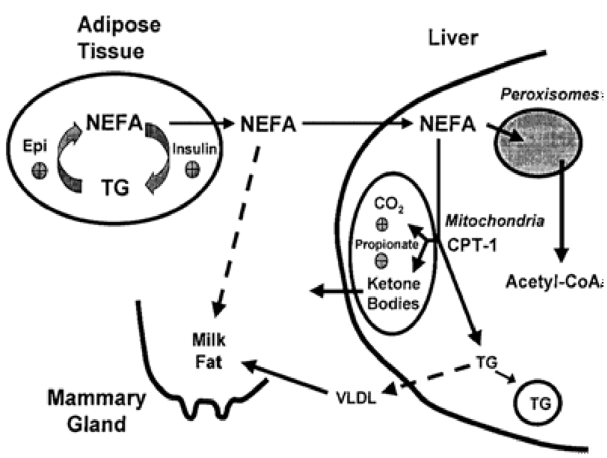

Fig. 1: Schematic representation of relationships among lipid metabolism in adipose tissue, liver, and mammary gland

Animal Management during Transition Period

Nutritional Management

To maximize productivity and ensure successful reproduction, rations fed during this time need to be nutrient dense and often contain more expensive ingredients. Therefore, a poor nutritional program during the transition period increases feed costs per unit of milk produced and decreases income through lost milk production, decreased reproductive efficiency, and increased incidences of metabolic disorders. Interest in nutrition and management of dairy cows during the transition period has increased dramatically during the last decade as researchers and field nutritionists have recognized the importance of this critical six week period (Drackley, 1999).

Nutritional transition management consisting of three distinct phases for the cow: Phase 1 is the far-off dry period. This phase has relatively simple nutritional requirements but should not be ignored. Phase 2 is the close-up period, when many of the metabolic changes for lactation actually occur. Phase 3 is the fresh cow, which completes the transition into full lactation. The new National Research Council (NRC) publication Nutrient Requirements of Dairy Cattle (NRC, 2001) has incorporated much new information regarding the transition period, and has made recommendations for nutritional management of transition cows during these three phases. The general concept of ration changes during the transition is that nutrient density is increased gradually from that fed to far-off dry cows to the higher nutrient density required for fresh cows. Because DMI of close-up cows declines by 10 to 30% during the last 7 to 14 days before calving, nutrient density must be increased to compensate.

The balance between structural carbohydrates (fiber) and nonstructural carbohydrates (grains or concentrate by-product feeds) in diets fed before and after calving is probably the most important dietary factor for transition success. Adequate fiber of sufficient particle size is needed to maintain rumen function, prevent acidosis and displaced abomasum, and achieve high DMI. On the other hand, excessive neutral detergent fiber (NDF) content may limit intake. Sufficient non-fiber carbohydrates must be present to provide adequate energy in the form of propionic acid for glucose synthesis and to suppress synthesis of ketone bodies. Another benefit of additional grains in the pre-partum diet is to adapt the ruminal tissues and the rumen microbial population to the type of diet that will be fed after calving (Goff and Horst, 1997). Grain feeding increases length of the rumen papillae in comparison to feeding only poorly digestible roughages (Dirksen et al., 1985). To prevent periparturient diseases five areas are for concern maximizing dry matter intake, stimulating rumen papillae development, minimizing negative energy and protein balance, maintaining protein homeostasis, minimizing immune dysfunction. It is in the best interest of dairy farmers to reduce disease during the transition period for both their economic survival and for the welfare of their cows. A key challenge for veterinarians is to educate dairy producers to devote adequate resources in terms of labor, facilities and management to implement a structured transition cow program. One approach is to build an economic basis for this approach. It is generally accepted that a good dry cow program will result in an additional 1,000 to 2,000 lbs of milk in the next lactation. At least a portion of this production response is due to a decrease in post-calving disorders.

To prevent periparturient diseases and increase the potential for successful reproduction, there are five critical control points during transition period that need to be addressed.

- *Maximizing Dry Matter Intake*

Cows that experienced periparturient disease have shown that there was a greater decline in dry matter intake. Restricting DMI in the dry period allows cows to increase DMI immediately postpartum, resulting in higher energy balances, and decreased body fat mobilization, evident by lower NEFA (non-esterified fatty acid) and BHBA (beta hydroxyl butyrate) concentrations (Dann et al., 2006).

The National Research Council (2001) reported the following prediction equations for DMI during the last 21 days of gestation:

Heifers: DMI (% of BW) = $1.71 - 0.69\, e^{0.35t}$

Cows: DMI (% of BW) = $1.97 - 0.75\, e^{0.16t}$

Where: "t" = days of pregnancy minus 280.

Increasing dietary NFC (non-fibre carbohydrates) or decreasing NDF (neutral detergent fibre) during the transition period stimulates DMI. When energy density of the diet increased from 1.3 to 1.54 Mcal ENI/kg DM and crude protein increased from 13 to 16% at about 3 weeks prior to calving, DMI increased in 30% (Emery, 1993).

- *Stimulating Rumen Papillae Development*

Rumen papillae helps to maintain acid-base balance in the rumen by absorbing volatile fatty acids and especially lactate, generated by microbial fermentation. Growth of these papillae is influenced by the presence of fermentation products, primarily propionate and butyrate and not acetate. Higher fibre diets predominately produce acetate during fermentation, which results in a reduction in papillae length. Adding fermentable non-structural carbohydrates to the late gestation diet can have positive effects by initiating rumen papillae growth and allowing rumen organisms to adapt to the starch substrate.

- *Minimizing Negative Energy and Protein Balance*

Excessive energy intake leads to 'fat cow syndrome'. Feeding gluconeogenic precursors such as propylene glycol has also shown positive effects on energy status of the late pregnant cow. Prepartum protein depletion adversely affects periparturient metabolic status, resulting in a greater incidence of ketosis and fat cow syndrome. Energy balance of a transition cow is determined by subtracting energy requirements for maintenance and gestation from energy intake. During the transition period, feed intake is decreasing at a time when energy requirements are increasing due to growth of the conceptus. Increasing the energy and protein density up to 1.6 Mcal of NEI/kg and 16% CP in diets during the last month before parturition improves nutrient balance of cattle prepartum and decreases hepatic lipid content at parturition.

- *Maintaining Calcium Homeostasis*

The onset of lactation causes a severe and rapid drain on blood calcium required to produce milk. If this blood calcium is not replaced as rapidly as it is reduced via bone calcium release (resorption) or intestinal absorption of calcium, cows will become hypocalcaemia with some developing clinical milk fever. Reducing DCAD (dietary cation-anion difference) to negative values has been shown by many authors to prevent this rapid decline in blood calcium at calving.

- *Minimizing Immune Dysfunction*

The immune system of the cow has been shown to decline in response to the transition period, possibly as a result of increased cortisol secretion associated with stress of late gestation and calving. Neutrophils are a type of white blood cell involved in the first line of defence against infection (Frandson et al., 2006). It has been reported that the function of neutrophils is impaired in transition dairy cows leading to a state of immune-suppression. Elevated blood NEFA concentrations before calving have been linked with uterine disorders and impaired neutrophil function (Hammon et al., 2006). Micro minerals and vitamins supplementation recover from immune function problem.

Conclusions

The transition period is a critical determinant of both productivity and profitability in a dairy herd. Nutrition and management programs during this phase directly affect the incidence of post-calving disorders, milk production and reproduction in the subsequent lactation. The transition period imposes a number of abrupt changes on the cow. The cessation and initiation of lactation is one example. Rapid changes in both hormonal and metabolic systems must occur. All of these tend to increase the level of stress in the cow during this period. The stress response mechanism in ruminants is a complex, multifaceted system. Nutrition and management alterations provide an opportunity to minimize the effects of stress. Attention to keeping cows as comfortable as possible during the transition likely is as important as the nutritional management program.

Future Prospects

To obtain maximum profits, nutritionists and veterinarians should work together with dairy producers to design practical strategies to help cows make smooth transitions, so that cows produce to their potential during early lactation.

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