# Transitioning to Success: The Intersection Between Peripartum Nutrition, Health, and Reproduction

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## Take Home Messages

- Manage body condition to avoid excessive body tissue loss in early lactation.
- Minimize the risk of diseases because disease suppresses appetite, causes inflammation and tissue damage, and alters nutrient partition, all of which compromise subsequent performance.
- Stimulate dry matter intake in early lactation by minimizing dietary and management factors that detain cows from eating more.
- Feed diets during the transition period that reduce the risk of diseases.
- Incorporate feed ingredients that have shown benefits to improved pregnancy per artificial insemination.

## Introduction

The success of a new lactation is largely determined by the events that take place during the last weeks of gestation and the first weeks of lactation. Extensive epidemiological studies clearly show that dairy cows are most susceptible to diseases in the first month or two of lactation. In part, this is simple to understand because the onset of lactation is linked with calving and increased susceptibility of the reproductive tract to problems such as retained placenta and metritis. Also, as lactation starts, the demands for nutrients increase substantially and cows have not been selected to display voracious appetite in the first weeks postpartum. Thus, cows quickly mobilize large amounts of body tissues, and body weight loss often surpasses 40 to 50 kg in the first month postpartum. Some of that weight loss is due to changes in gut fill, but tissue loss is represented primarily by adipose tissue. Cows carrying more body condition at calving are prone to increased tissue mobilization concurrently with reduced appetite. Managing body condition in the preceding lactation is key to minimizing losses in the subsequent lactation. A common denominator among all diseases that affect dairy cows is an inflammatory response. Inflammation is hypophagic (reduces feed intake) and alters nutrient partitioning toward fighting infection and combating inflammation and away from productive functions. The net result is reduced dry matter intake, increased risk of diseases, and compromised production, reproduction, and survival. Managing and feeding dairy cows to minimize the risk of diseases in early lactation is pivotal to the success in the remainder of that lactation. For instance, induction of mild inflammation of the reproductive tract disrupts ovarian and endometrial function, compromises oocyte quality and embryo development, and impairs the ability of the cow to establish and maintain pregnancy. The impacts of disease on fertility extend beyond the period of tissue damage and epidemiological studies show that pregnancy survival is compromised up to five months after the disease is diagnosed and treated. It is increasingly evident that minimizing disease incidence remains one of the foremost aspects of transition cow management.

## Time in the Transition Group and Risk of Diseases in Early Lactation

Diseases are common in early lactation and are often associated with bacterial infections or with tissue trauma induced by calving. Approximately 30 to 40% of dairy cows are diagnosed with a clinical disease event in the first three to eight weeks of lactation (Santos et al., 2010; Ribeiro et al., 2016), and 75% of the first clinical disease diagnosis typically happens in the first three weeks postpartum. Diseases in early lactation are more costly because they have the remainder of the lactation to disturb. A case of mastitis at 20 days postpartum is more costly than a similar case at 200 days postpartum.

Transition programs should be designed to reduce the risk of diseases, but cows need time to benefit from what is offered in the prepartum group. Epidemiological studies support the concept that cows should remain three to four weeks in the prepartum group. Vieira-Neto et al. (2021) showed a quadratic association between days in the prepartum group and subsequent risk of morbidity, production, and reproduction in dairy cows. Cows that spent three to four weeks in the prepartum group had the least risk of morbidity, produced the most milk, and had the greatest pregnancy rate.

## ▪ The Common Underlying Aspects of Diseases

It is easy to understand why cows that suffer from clinical disease have impaired production and reproduction, although the exact cellular mechanisms are not always understood. For instance, being pregnant during nutrient deprivation increases the risk of death in beef cows (Fordyce et al., 1990). Thus, it is not surprising that mechanisms are in place to control reproduction when the supply of nutrients is scarce, and one of the factors that alter nutrient intake and use of nutrients by tissues is disease.

In all species studied, a consequence of disease is suppression of appetite. The exact reason why intake is depressed is not fully understood, but it might be linked with control of nutrients needed for pathogens to thrive during infection or a method to limit nutrients needed for the inflammatory response typically associated with activation of the immune system by trauma or infection (Brown and Bradford, 2021). In addition, diseases often alter how nutrients are used, and the change in partition of nutrients affects the supply of substrate for milk synthesis. For instance, an acute activation of the immune system by lipopolysaccharides or LPS results in hypoglycemia (Kvidera et al., 2017). Replenishing the plasma glucose pool by infusing glucose intravenously was suggested to be a method to quantify the glucose needs for activation of the immune system. Under that scenario, the authors showed that acute activation of the immune system by LPS required almost 1 kg of glucose infused intravenously to maintain plasma glucose concentrations like those of cows treated with sterile saline (Kvidera et al., 2017).

Beef steers subjected to endotracheal bacterial challenge showed a major shift in nutrient use by the splanchnic tissues (Burciaga-Robles, 2009). The authors infused either saline or a solution containing *Mannheimia haemolytica*, a bacterium often associated with bovine respiratory disease. Beef steers were surgically multi-catheterized with catheters placed in the portal vein, hepatic vein, and mesenteric vein and artery to study nutrient flux across the portal-drained viscera and liver after bacterial-induced inflammation of the lungs. They showed that inducing inflammation largely increased the use of nutrients by the liver. Use of essential and non-essential amino acids by the liver increased substantially when steers received the bacterial inoculum. Such effects would increase the calculated nutrient needs for maintenance of the animal.

In dairy cows, inducing mild endometrial inflammation at 37 days postpartum reduced dry matter intake and milk yield and compromised pregnancy rate for the remainder of the lactation (Husnain et al., 2023a). Induced endometrial inflammation at 26 days postpartum impaired conceptus development in lactating cows receiving insemination and a similar treatment to dairy heifers receiving embryos reduced conceptus quality after embryo transfer (Husnain et al., 2023b). Obviously, when cows develop diseases, often they also have fever, and hyperthermia is a known disruptor of pregnancy in cattle. Furthermore, diseases damage tissue and alter their function, which affects numerous aspects of reproduction in dairy cows (Ribeiro et al., 2016). Collectively, the combined effects of disease on tissue integrity and function, release of pro-inflammatory molecules, altered nutrient partitioning, hyperthermia, and exacerbation of negative nutrient balance work in conjunction affecting subsequent production and reproduction in dairy cows.

## ▪ Manage Body Condition and Stimulate Dry Matter Intake

The degree of fatness of cows at dry off or when entering the prepartum group is one of the factors that influence tissue loss in early lactation. Cows with increased body condition in the dry period are those more likely to have extensive lipomobilization in early lactation. It is a simple concept that carries intricate cellular mechanisms. To lose body fat, a cow must carry body fat. Large epidemiological studies have clearly shown that over-conditioned cows are less likely to maintain dry matter intake prepartum, more likely to experience extensive loss of body condition, and more likely to develop postpartum diseases (Roche et al., 2013).

Over-conditioned cows have less appetite and consume less dry matter per unit of body weight than cows in moderate to low body condition. One possibility is that lipomobilization, which is more extensive in over-conditioned cows, induces satiety by increasing hepatic signals that suppress appetite (Allen and Bradford, 2012). Those effects might be more marked in cows fed diets with excess of rumen-fermentable energy in early lactation (Allen and Bradford, 2012). Obviously, cows that mobilize more body tissue are less likely to resume postpartum ovulation before the end of the voluntary waiting period and they also have reduced pregnancy per artificial insemination (AI) and increased risk of pregnancy loss (Santos et al., 2010). Thus, managing body condition in the preceding lactation, by proper feeding according to production, grouping of cows, and having cows become pregnant at the proper time postpartum, will have consequences to the success of the subsequent lactation, in particular reproduction (Fricke et al., 2022).

## ▪ Feed Diets to Transition Cows that Reduce the Risk of Diseases

An important goal of transition cow diets is to reduce the risk of diseases. Meeting the energy needs and avoiding body fat gain in prepartum cows is one of the components of prepartum diets (Drackley and Cardoso, 2014). Supplying sufficient forage neutral detergent fiber (NDF), particularly from sources that maintain physical effectiveness in stimulating cud chewing and rumen fill, reduces the risk of displaced abomasum in early lactation.

Dairy cows are highly susceptible to developing fatty liver in the first weeks of lactation. Excessive accumulation of hepatic triacylglycerol (fat) is linked with suppressed health and production performance in dairy cows (Arshad and Santos, 2022). Prepartum over-conditioned cows are more likely to develop fatty liver in early lactation. Thus, managing body condition and feeding diets that limit lipomobilization reduce fatty liver. Furthermore, certain dietary nutrients can affect fatty liver in cows under negative nutrient balance (Arshad et al., 2023). Choline is supplemented to diets of transition cows because of its benefits to production and health (Arshad et al., 2020). Feeding rumen-protected choline reduced hepatic triacylglycerol accumulation by stimulating hepatic lipoprotein secretion prepartum. When fed during the entire transition period, rumen-protected choline reduces the risk of some diseases and increases yields of energy-corrected milk.

Similar to preventing lipid-related disorders, prevention of mineral related disorders is one of the cornerstones of transition cow diets. Hypocalcemia is a common problem in early postpartum parous dairy cows. Cows with clinical hypocalcemia, also known as milk fever, have numerous problems, and those with persistent subclinical hypocalcemia have reduced dry matter intake, impaired immune response, and increased risk of uterine diseases. One method to reduce hypocalcemia is to alter the mineral composition of the prepartum diet by limiting the intake of sodium, potassium, and phosphorus, and increasing the intake of chloride and magnesium. Such diets affect the acid-base status of prepartum cows, reduce prepartum blood phosphate, and increase the supply of magnesium, which make cows less susceptible to both clinical and subclinical hypocalcemia (Santos et al., 2019). Feeding acidogenic diets prepartum not only reduced the risk of hypocalcemia, but also those of retained placenta and metritis. Parous cows fed acidogenic diets prepartum had increased yields of milk and fat-corrected milk in the subsequent lactation (Santos et al., 2019).

## ▪ Meet the Nutrient Needs of the Cow

Prepartum diets should meet the nutrient needs of the prepartum cow. Intake of the prepartum group should be measured daily and diets formulated according to the observed intake at the farm. The recent NASEM Dairy Cattle (2021) suggests that cows require 100 kcal of net energy for lactation per kg of metabolic body weight for their maintenance. An additional 4 to 5 Mcal/day are needed to support fetal growth in the last three weeks of gestation. Thus, a typical prepartum Holstein cow requires approximately 13 to 14 Mcal for maintenance plus another 4 to 5 Mcal for pregnancy. Diets should be formulated to supply approximately 18 to 19 Mcal/day for a large frame Holstein cow.

Protein supply is also important and nulliparous (lactation 0 prepartum) and parous cows (lactation > 0 prepartum) have different needs for metabolizable protein (Husnain and Santos, 2019). Nulliparous cows have lesser intake prepartum than parous cows (NASEM Dairy Cattle, 2021; Husnain and Santos, 2019), which results in reduced supply of metabolizable amino acids for a given diet. Thus, the same diet fed to a nulliparous and to a parous cows will result in distinct metabolizable amino acid supply because of the differences in dry matter intake. Nulliparous cows have increased needs for growth and accretion of lean tissue (NASEM Dairy Cattle, 2021). Very likely, nulliparous cows also have greater needs of nutrients, including amino acids, for developing the mammary tissue compared with parous cows. Altogether, these differences justify the distinct needs for metabolizable protein between nulliparous and parous cows. Husnain and Santos (2019) showed that parous cows did not benefit from metabolizable protein beyond 800 to 900 g/day, whereas nulliparous showed a linear response in fat-corrected milk when the metabolizable protein prepartum increased up to 1,100 g/day. The impacts of protein supply prepartum and health on the subsequent lactation remain unknown at this time.

## ▪ Forage Quality Remains Critically Important

Limiting adipose tissue gain and maintaining rumen fill prepartum have been important components of diet formulation during the dry period. Overfeeding energy in the form of highly digestible carbohydrates results in weight gain, mostly body fat, and is linked with increased depression of dry matter intake in the last days of gestation (Drackley and Cardoso, 2014). Cows that suffer from a marked reduction in dry matter intake in the last week of gestation are more likely to eat less in early lactation and to develop ketosis and displaced abomasum, with consequences for other diseases. Supplying sufficient forage NDF is important to maintain rumen fill, to ensure rumination, and to dilute the digestible energy density of the diet. A common method has been the incorporation of straw or less digestible forages into prepartum diets (Drackley and Cardoso, 2014). Such diets have been successfully implemented, particularly in herds with high risk of having cows developing displaced abomasum. Nevertheless, cows do not require ‘straw’ in their diets but benefit from forage NDF.

Stone et al. (2012) tested the hypothesis that improving forage NDF digestibility during the last three weeks of gestation and first three weeks of lactation affects production performance of dairy cows. The authors fed Holstein cows prepartum diets containing approximately 72% forage and replaced conventional whole plant corn silage with whole plant silage made from brown mid-rib corn (BMR). Corn silage made up approximately 47% of the prepartum diet. Postpartum, for the first three weeks of lactation, cows were fed diets with one of the two corn silages, and they represented approximately 40% of the diet DM. After three weeks postpartum, all cows were fed the conventional whole plant corn silage. Prepartum and the first three-week postpartum diets contained, respectively, 44 and 33% total NDF, and 39 and 26% forage NDF. Thus, these transition cow diets had adequate to high content of forage NDF (NASEM Dairy, 2021). As expected, the BMR corn silage reduced the dietary lignin content and increased 30-hour *in vitro* NDF digestibility. Cows fed the BMR corn silage ate 1.1 kg/day more dry matter in the last two weeks of gestation (14.3 vs. 13.2 kg/day) and 2 kg/day more during the first three weeks of lactation (20.1 vs. 18.1 kg/day). Once all cows were fed the same corn silage from four to 15 weeks of lactation, intake no longer differed. A very important aspect of the experiment was that cows fed the BMR corn silage during the transition period not only produced more 3.5% fat-corrected milk during the first three weeks postpartum (42.9 vs. 38.8 kg/d), but the increase in fat-corrected milk persisted beyond the period of treatments. Cows fed the BMR silage produced an additional 2.7 kg/d (49.4 vs. 46.7 kg/d) from four to 15 weeks postpartum, when they were fed the same diet as those in the conventional corn silage group. Perhaps part of this extended increase in production was caused by the stimulation in dry matter intake during the transition period and part by the tendency to reduce disease events observed in the experiment (Stone et al., 2012).

## Supplement Nutrients and Feed Ingredients that Benefit Reproduction

Experiments designed to evaluate effects on reproduction typically require hundreds of cows per treatment. This is a difficult task when the intervention is applied to the diet and cows should be fed the treatments individually. Most experiments involving nutrition and reproduction suffer from a common limitation — insufficient power to test the effect on pregnancy per AI or maintenance of pregnancy in cows. Oftentimes, results are extrapolated from small experiments or never replicated in subsequent experiments. The science of the effects of nutrition on reproduction in dairy cows remains infantile largely because of the inability to conduct properly powered experiments. Nevertheless, one group of nutrients that has consistently been shown to improve reproduction in dairy cows is fatty acids.

Increasing dietary fatty acids from the traditional 2.5 to 3% of the diet dry matter to 4 to 4.5%, by adding supplemental fat sources, improves pregnancy per AI and reduces days open (Rodney et al., 2015). The benefits to reproduction are observed concurrent with improved production performance because cows supplemented with fatty acids produce more milk than non-supplemented cows (Rodney et al., 2015). The mechanisms for improved reproduction are multiple, with effects on follicle development and progesterone secretion by the corpus luteum, improvements in fertilization and embryo quality, changes in endometrial function, and increased maintenance of pregnancy (Santos et al., 2008). A common misunderstanding is that the benefits to reproduction from supplemental fatty acids in early lactation are caused by improvements in energy balance. Feeding supplemental fats seldom affects energy balance in early lactation and the benefits to reproduction are observed regardless of changes in body weight or energy balance (Santos et al., 2008; Rodney et al., 2015). Nonetheless, the effects on reproduction vary with the type of fatty acid fed and usually unsaturated fatty acids tend to be more beneficial to reproduction. Thus, providing moderate amounts of supplemental fatty acids to increase the total dietary content up to 4.5 to 5% of the diet dry matter should be part of the early lactation diet to promote not only production performance, but also reproduction.

## Conclusions

Transition cow programs should be designed to accommodate the numerous needs of the pregnant cow. Providing proper cow comfort is a must. Cows should spend sufficient time in the prepartum group to benefit from what is provided to them at that time, which should include a diet that meets the nutrient needs of the cow and reduces the risk of diseases. Managing body condition in the preceding lactation remains pivotal for the success of the subsequent lactation. Lipomobilization is an adaptive mechanism to meet the energy needs when intake is insufficient, but when excessive weight and tissue loss occurs, health and reproduction are compromised. Inflammation is a common denominator of almost all diseases that affect dairy cows and, although important to contain the disease process, the inflammatory response depresses appetite, alters nutrient partition, and often causes damage to tissues that have negative consequences to production and reproduction.

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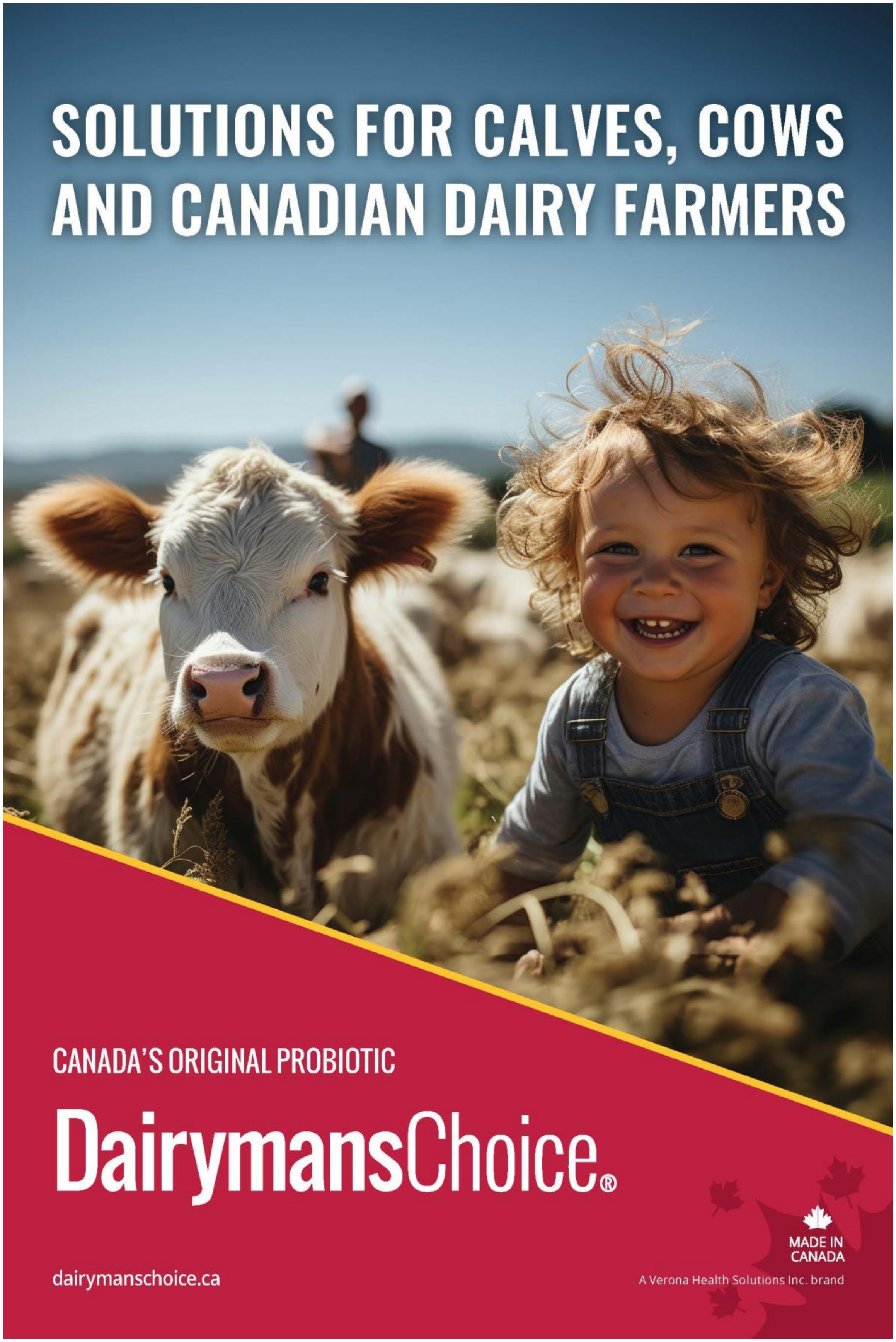
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