Feedstuffs Reprint

Choline: A required nutrient for transition dairy cows

There is a strong case to be made for choline in transition dairy cow diets

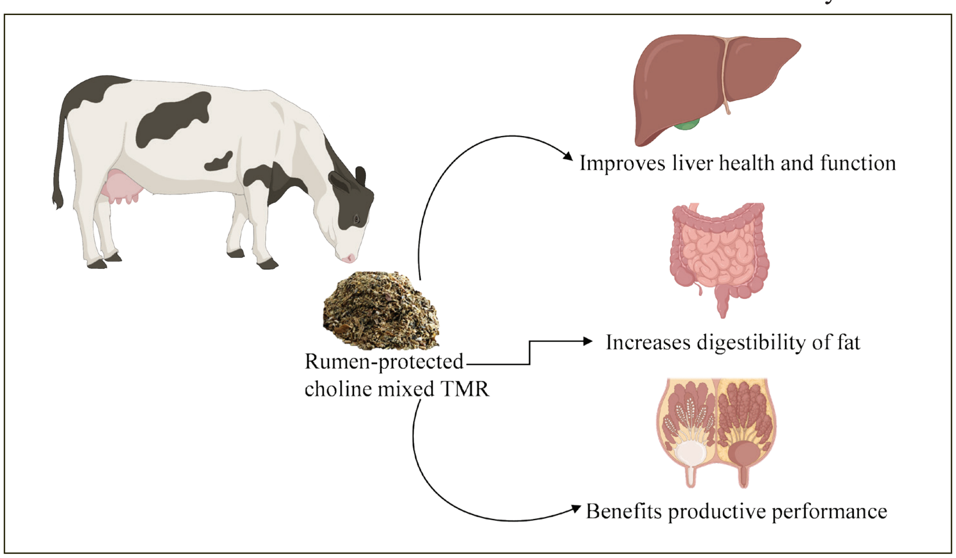
By **Usman Arshad** and **José E.P. Santos**

Dairy cows are incredible animals. If one thinks about abrupt changes, then think about what happens to a modern Holstein cow that, in a period of 3 to 4 weeks of lactation, she can go from 0 to as many as 50 kilograms of energy corrected milk per day. This remarkable production achieved today by many cows requires dynamic and integrated adaptations of numerous tissues to accommodate the shifts in nutrient partition with the onset of lactation. Work by Chris Reynolds at the University of Reading in England showed that hepatic blood flow doubles, from approximately 1,100 liters per hour to 2,220 liters per hour, in the first 3 weeks of lactation, concurrent with the equivalent doubling in oxygen consumption by the splanchnic tissues in the same period[1]. Such changes reflect the increase in dry matter intake and nutrient uptake by the gastrointestinal tract concurrent with the increased nutrient uptake by the gastrointestinal tract concurrent with the increased needs of glucose, amino acids, and fatty acids required for synthesis of milk by the mammary gland.

It is well known that dairy cows undergo a period of negative nutrient balance in the first 4 to 8 weeks of lactation, and this period is the phase of the lactation cycle in which cows are most susceptible to diseases. Approximately 30 to 35% of the postpartum cows will develop a clinical disease event in the first month or two of postpartum cows will develop a clinical disease event in the first month or two of lactation, and success during the transition period greatly influences the success of the remainder of the lactation of a cow. One of the issues that often affects dairy cows in early lactation is excessive fat tissue mobilization that can result in increased deposition of triacylglycerol in the liver, the so called hepatic lipidosis or fatty liver. Small increases in hepatic triacylglycerol are not necessarily associated with detrimental impacts with subsequent performance, but cows with moderate to excessive lipidosis have impaired production and health, with increased risk of premature culling. Approximately 40 to 45% of the postpartum dairy cows have moderate to severe hepatic lipidosis in the first 3 weeks of lactation.

Research from the University of Florida recently published in the Journal of Dairy Science sheds new light on some of the questions surrounding hepatic lipidosis and its impact on performance in dairy cows[2]. In that particular study, a cohort and its impact on performance in dairy cows[2]. In that particular study, a cohort of 329 cows were studied to understand the link between the content of hepatic of triacylglycerol in the first week postpartum and subsequent health, production, and survival. The findings of the study showed that when concentrations of triacylglycerol in hepatic tissue increased beyond 4 to 7%, then risk of diseases increased and productive performance decreased. beyond 4 to 7%, then risk of diseases increased and productive performance decreased. Although the study does not necessarily establish cause-effect, these associations suggest that identification of strategies to reduce the accumulation of triacylglycerol in hepatic tissue might prove beneficial for dairy cows.

One possibility to alleviate fatty liver is to increase the export of triacylglycerols from the hepatic tissue, which requires increased synthesis and assembly of very-low density lipoproteins (VLDL). Choline is a nutrient that was discovered in the 1850's and later it was shown to be required in the diets of mammals because of its role for the synthesis of



required in the diets of mammals because of its role for the synthesis of several compounds such as phospholipids, sphingolipids, and neurotransmitters. It turns out that synthesis and secretion of VLDL requires phospholipids, many of which are phosphatidylcholines. Serendipitously, in the process of discovery of insulin in the early 1920's by Canadian scientist Frederick Banting, the experimental model used included depancreatized dogs. These dogs developed hepatic lipidosis, an issue noted by one of Banting's students, Charles Best. Best, who became a world renown scientist, later showed that supplementing the diets of depancreatized dogs with phosphatidylcholine reduced the severity of lipidosis in the liver. These findings triggered the study of choline as a required nutrient in the human diet.

It has been shown that dairy cows affected by fatty liver display smaller concentrations of phosphatidylcholine in plasma than cows without fatty liver. Although phosphatidylcholine can be endogenously synthesized by tissues, it is likely that the demands of choline during the transition period are greater than the supply from dietary sources and from endogenous synthesis, particularly because endogenous synthesis requires methyl groups originated by compounds such as methionine, which can be in short supply at the onset of lactation.

As opposed to nonruminants that can acquire sufficient choline from dietary sources, the rumen microbes extensively degrade choline resulting in limited dietary supply, which establishes the need to supplement choline in a rumen-protected form. In spite of the well-established knowledge that choline is a required nutrient in diets of most mammals, the feeding guidelines of choline for the lactating or the dry dairy cow have not been established.

Choline plays important roles on hepatic lipid metabolism

A series of experiments at the University of Florida studied the role of choline on hepatic lipid metabolism. The experiments used a feed-restriction model to simulate the negative nutrient balance that dairy cows typically experience in the first weeks of lactation[3-6]. This model was originally used by Ric Grummer in Wisconsin who showed that rumen-protected choline (RPC) reduced the degree of hepatic accumulation of triacylglycerol in dry cows. In the Florida experiments, a total of 187 pregnant dry cows in late gestation received less than 40% of the energy needed for maintenance and pregnancy for a period of 9 days to induce fatty liver. Cows were fed diets with increasing amounts of choline ion, from 0 to 25.8 g/d, as RPC. During feed restriction, diets were supplemented with rumen-protected methionine to mimic the exact same metabolizable methionine intake of the dry cows when consuming 11 kg of dry matter daily.

Feeding RPC reduced the concentration of hepatic triacylglycerol by 31.7% and increased that of glycogen by 54.2%, and the effects on hepatic concentrations of triacylglycerol and glycogen were linear as the amount of choline ion fed increased. One of the novel aspects from one of the experiments was the fact that cows supplemented with 25.8 g/day of choline ion as RPC had increased hepatic secretion of triacylglycerol-rich lipoprotein[5], corroborating the findings from the non-ruminant literature that choline is important to support synthesis and secretion of VLDL needed to export lipids from the liver.

Feeding RPC during feed restriction altered the expression of several genes in the hepatic tissue involved in lipid metabolism and the observed changes suggest reduced hepatic lipogenesis and enhanced lipids export[4-6], which helps explain the reduction in hepatic lipidosis in cows fed RPC.

Supplementing rumen-protected choline enhances fat digestibility

Choline is a component of phosphatidylcholines, a group of phospholipids that are components of cell membranes and lipoproteins that are critical for absorption and transport of lipids. As cows approach parturition, dry matter intake typically decreases and gradually increases after calving. Work by Lance Baumgard at Iowa State University has shown that abrupt changes in dry matter intake perturb the architecture of the lining of the gastrointestinal tract that affects the integrity of the intestinal epithelium and influences nutrient absorption[7]. Indeed, feed restriction models have been used to induce perturbations in the intestinal tract that would mimic the spontaneous reduction in dry matter intake during the transition period. A recent experiment at the University of Florida investigated if supplementing RPC affects digestibility of fat in dairy cows[6]. For that, 33 prepartum Holstein cows were subjected to a feed restriction model in an attempt to disrupt the intestinal integrity. Cows were supplemented with either 0 or 25.8 g/day of choline ion for 9 days during feed restriction. On day 9, cows were left off feed and received a mixture of saturated fatty acids to determine the apparent digestibility of fat. Supra-mammary lymph was collected 6 hours after cows consumed the fatty acids. Feeding RPC increased fat digestibility and the concentrations of triacylglycerol in blood and lymph, which suggest that supplementing choline to cows in negative nutrient balance might improve intestinal fatty acid transport and absorption.

Supplementing rumen-protected choline benefits productive performance and health

Although extensive literature on choline exists supporting its role on numerous cellular mechanisms, a common question asked is if its role on synthesis of phospholipids, the effects on the liver, or on nutrient transport might translate in improvements in health and productive performance. Experiments in which the treatment is applied to the diet and cows have to be fed individually often have the limitation of sample size to be able to investigate the effects of dietary interventions on health and reproduction. One approach to overcome this limitation and to interrogate the external validity of interventions is to use meta-analytical methods to integrate findings from the published literature from multiple experiments. In 2020, we performed a systematic review of the published literature and conducted a meta-analysis on the effects of supplemental RPC during the transition period[8]. We identified 20 publications including 21 experiments and 1,313 transition cows that were randomly assigned to receive either 0 g/day of choline ion or some amount of choline ion as RPC starting prepartum. Supplementing RPC during the transition period increased energy-corrected milk yield by 2.2 kg/day and tended to reduce the risk of retained placenta and mastitis compared to non-supplemented cows. Interestingly, the changes in yields of energy-corrected milk and milk components observed increased linearly as the amount of choline ion supplemented increased up to 25.2 g/day. Because responses were linear, the optimum amount of choline ion to be supplemented to transition cows remained undetermined. The meta-analysis also showed that response to choline was influenced by the supply of metabolizable methionine in the postpartum diet. Such finding was expected given the biochemical interplay between choline and methionine in the body and their role on the 1-carbon metabolism and synthesis of phosphatidylcholines. Nevertheless, even when the lactating diet supplied metabolizable methionine at 2.60% of the metabolizable protein, supplementing RPC increased the yield of energy-corrected milk. One observation from the meta-analysis was the scarcity of literature to understand the role of supplemental choline in nulliparous cows. They typically represent approximately 30 to 35% of cows in the prepartum pen on most dairy farms. It is expected that nulliparous cows also benefit from supplementation of choline during the transition period; however, this is an area that remains mostly unexplored today.

Responses to rumen-protected choline are observed independent of body condition of cows

Because choline plays a role on hepatic lipid metabolism and reduces the risk of fatty liver, it is not uncommon for nutritionists and veterinarians to suggest that RPC should be supplemented only to overconditioned prepartum cows, those at greatest risk to develop hepatic steatosis. In order to interrogate this suggestion, we went back to data from two randomized experiments in which prepartum cows were assigned to receive either 0 or 12.9 g/day of choline ion as RPC starting at around 255 days of gestation until 21 days postpartum[9]. The goal was to understand if response to RPC was dependent on the body condition of cows when they entered the prepartum group. A total of 215 pregnant parous Holstein cows were enrolled in both experiments and cows had a mean body condition of 3.51, ranging from 2.69 to 4.25, which was evaluated twice for each cow before treatments started. We found that, irrespective of body condition score prepartum, supplementing transition diets with 12.9 g/day of choline as RPC increased yields of milk by 1.8 kg/ day, fat by 0.08 kg/day, true protein by 0.04 kg/day, energy-corrected milk by 1.9 kg/day, and 3.5% fat-corrected milk by 2.1 kg/day. Cows supplemented with RPC were more efficient in converting feed into energy-corrected milk irrespective if they were under or overconditioned prepartum. The data from this study showed that response to RPC is observed in cows regardless of their degree of fatness when supplementations starts prepartum.

Responses to rumen-protected choline are extended beyond the period of supplementation

Work at the University of Florida and a recent experiment by Barry Bradford at Michigan State University showed that cows fed RPC during the transition period have increased milk production during the period of supplementation that carries over for several weeks past-supplementation ends[10-12]. In one experiment, cows were fed RPC starting in the close up group until 21 days postpartum and milk yield increased by 2.1 kg/day up to 40 weeks in lactation. In a second experiment, the increase in milk yield of 2.0 kg/day extended for 25 weeks in lactation. This is not surprising as several dietary interventions implemented during transition period that benefit animal health and metabolism also increase production beyond the period of intervention, although the exact mechanism of this carry-over effect remains to be elucidated.

Substantial progress has been made on our understanding of choline as a nutrient for dairy cows. The advent of rumen-protected products containing choline chloride has allowed researchers to investigate some aspects of the mode of action of choline on intermediary lipid metabolism in dairy cows and to answer important questions relative to the role choline plays on hepatic health and productive performance during the transition period. Although the exact amount of choline required to optimize production and health in dairy cows remains unclear, the available data unequivocally show that feeding choline ion up to 25 g/day as RPC during the transition period promotes not only lipotropic effects on the hepatic tissue, but also improves productive performance and health, making a strong case for choline as a required nutrient in the diet of transition dairy cows ■

Usman Arshad and José E.P. Santos are with the Department of Animal Sciences, University of Florida. References available online.

SCIENTISTS SAY

Choline is a Required Nutrient for Every Cow

Zenobi et al. 2018
Arshad et al. 2020
Bollatti et al. 2020
Potts et al. 2020
Holdorf et al. 2023
Swartz et al. 2023

Milk Production

Zenobi et al. 2018
Arshad et al. 2020
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Healthy Transition

Lima et al. 2012
Zenobi et al. 2018
Arshad et al. 2020
Arshad et al. 2022
Poindexter et al. 2023

Calf Health & Growth

Zenobi et al. 2018
Zenobi et al. 2022
Holdorf et al. 2023

Improved Colostrum Quantity

Zenobi et al. 2018
Bollatti et al. 2020
Swartz et al. 2022
Holdorf et al. 2023

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