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# **RUMEN-STABLE CHOLINE'S ROLE IN TRANSITION COW LIVER METABOLISM AND PERFORMANCE**

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## **Introduction**

Choline is an essential nutrient that has long been supplemented to the diets of poultry and swine. Extensive degradation in the rumen has traditionally prevented its use in ruminant diets. Recently, rumen-stable technology has allowed supplementation of rumen-stable choline to the diets of dairy and beef cattle. A growing database of research confirms choline's role in improving the performance of transition dairy cows.

## **Background**

Choline (trimethyl, 2-hydroxy ethyl ammonium hydroxide) was first identified in 1849, and is often characterized as a B vitamin, although it doesn't fit the traditional characteristics of B vitamins (a co-factor in metabolic reactions). Choline has four basic areas of metabolic functions. One role is in the area of methyl donation, in which choline, with its three methyl groups, can serve to participate in transmethylation reactions. When choline is in the form of acetylcholine, it participates in transmission of nerve signals. Phospholipids derived from choline (phosphatidylcholine, phosphatidylethanolamine, sphingomyelin), are key parts of cell membranes and have other functional and structural roles. Finally, choline (phosphatidylcholine) plays a key role in lipid transport, being a key and often limiting nutrient for synthesis of lipoproteins.

Its roles as a nutrient began to evolve when it was determined to protect against fatty liver in the early 1930's. Growth responses to choline soon were identified. As a result, it has been a staple in monogastric nutrition for upwards of 60 years as nutrient requirements for poultry and swine were soon identified. Work with ruminant species was sporadic. In some of the earliest published research, Johnson et al., (5) demonstrated that pre-ruminant calves would develop choline deficiencies when fed synthetic diets. Similar to the work with monogastrics, these choline deficiencies resulted in fatty liver type symptoms. Studies with beef cattle were conducted in the early 1960's with inconsistent responses. However, it was research conducted in the late '70's (6) and throughout the '80's (e.g. 11) that has provided the key groundwork for our understanding of choline nutrition of ruminant animals.

## **The role for rumen-stable choline**

A series of studies by the lab of Dr. Richard Erdman at the University of Maryland did much to clarify choline as a nutrient for dairy cattle nutrition. Similar to the beef cattle research in the 1960's, the first attempts were to feed unprotected choline to lactating dairy cows. This led to marginal and inconsistent responses at best (e.g. 1). The breakthrough came in an experiment comparing feeding unprotected choline versus infusing choline post-ruminally in lactating dairy cows (11). In this experiment, similar to previous research, no response occurred to feeding

unprotected choline. However, the infusion of choline past the rumen increased milk yield by nearly 6 pounds per cow per day (Figure 1.).

Ruminal degradation of choline was found to be extensive, approaching 100% for choline chloride, the typical source of choline for feed supplementation (13). In one experiment (12), feeding up to 326 g/d of supplemental choline resulted in 2.6 g/d in post-ruminal choline flow. Work in sheep (6) also found low availability of supplemental choline to the animal, confirming the results that extensive ruminal degradation has on blocking supply of choline to ruminant animals.

It became apparent that in order to practically supplement cows with choline, rumen-stable choline would be required. Unfortunately, choline is an extremely hygroscopic nutrient, making it very difficult to effectively encapsulate. Eventually, effective rumen-stable prototypes were made, and of course, at least one is now commercially available.

In the first published experiment with rumen-stable choline supplementation to dairy cows (4), graded levels of rumen-stable choline were added to the diets of early lactation cows from weeks 1 to 20 of lactation. Significant improvements in milk yield resulted from choline supplementation, from 4 to 6 pounds per cow per day depending on level of choline supplementation. This confirmed that the production responses from the earlier post-ruminal infusion trials could be applied for broader periods of time with an effective rumen-stable choline product.

#### **The role for rumen-stable choline in transition cows – liver metabolism improvements translates into performance improvements**

Because of choline's role in fat transport from the liver, a logical role for choline supplementation in transition cow diets emerged. When cows are in negative energy balance and are losing body condition stores, the mobilized fat enters the blood stream in the form of NEFA (non-esterified fatty acids). The liver will extract a great deal of this NEFA from the blood. Upon being taken up by the liver, the NEFA have four primary fates (Figure 2). They can be oxidized to carbon dioxide, oxidized to ketone bodies, stored in the liver as triglycerides, or incorporated as part of very-low density lipoproteins (VLDL) and exported out of the liver for utilization by other tissues. Choline aids in the synthesis of VLDL. In transition cows, this leads to increases in fat export from the liver, reducing fat buildup in the liver and, indirectly, the amount of NEFA used for ketone production.

Typically, transition dairy cows enter negative energy balance in the week prior to calving and continue in negative energy balance for up to six to eight weeks into lactation (Figure 3). As a result, cows typically go from low levels of fat in the liver three weeks before calving, to a 3 to 4 fold increase in liver triglyceride content by the day of calving (2). This high level of liver triglyceride continues until at least three to four weeks into lactation (Figure 4). Research has shown that accumulation of fat in the liver can lead to significant reductions in the glucose synthetic rate by liver cells (3). Thus, cows with fat build up in the liver at calving may have a liver that makes less glucose, resulting in lower milk yields and increased oxidation of fatty acids to ketones, making the animal more prone to subclinical and clinical ketosis.

Recent research by Cornell researchers (8), measured the effect of rumen-stable choline on liver metabolism in transition dairy cows. They supplemented the cows' diets with 0, 45, 60 or 75 g/d of rumen-stable choline (Reashure® Choline, Balchem Corporation) from -21 to 60 days in milk. There was a significant linear reduction in the rate of fat storage in the liver at calving and in early lactation. Correspondingly, there was a significant linear increase in the amount of glycogen (stored glucose) in the liver at the same time points. Thus, the ratio of glycogen to stored triglyceride in the liver increased with the level of choline supplementation (Figure 5). Furthermore, there also was a trend for a linear increase in the rate of gluconeogenesis. Research has shown that a decreased ratio of stored triglyceride to glycogen in the liver reduces the risk for clinical ketosis (7). There was a trend for choline supplementation to improve fat corrected milk yield by approximately six pounds per cow per day.

Field studies have examined the milk yield responses to rumen-stable choline supplementation in early lactation (10). Significant improvements in milk yield were reported in the first 30 to 50 days of lactation. Ranges in responses were from 3 to 9 pounds per cow per day across field trial sites, with the average nearing 6 pounds per cow per day (Figure 6).

More recently, studies were conducted in Mexico, in which rumen-stable choline was tested in well managed, high yielding herds following typical transition cow management practices. In three studies, rumen-stable choline supplementation increased milk yield on average 3.5 kg/d over the first 21 days of lactation (Figure 7). Additionally, in one study, there was a 35% reduction in retained placenta and a 24% reduction in ketosis in the cows supplemented with rumen stable choline.

In a controlled, side by side experiment in Washington State, in a herd averaging 12,300 liters/cow/year, rumen-stable choline's impact on metabolism and intake in the transition period was recorded as well as subsequent reproductive performance. In this experiment (Table 1), rumen-stable choline increased prepartum glucose concentrations, and decreased concentrations of ketones (BHBA – beta-hydroxy-butyric acid) and NEFA both pre and postcalving. Also, the only 4% of the rumen-stable choline supplemented cows were measured to have subclinical ketosis in early lactation, whereas 28% of the control cows were found to be subclinically ketotic. Dry matter intake was higher for rumen-stable choline supplemented cows pre and postcalving. Furthermore, the group of cows supplemented with rumen-stable choline had more pregnancies, higher pregnancy rates, fewer services per conception and fewer days open than the control group. The changes with reproduction are reflective of the improvements in metabolism noted throughout the transition time period.

## **Summary**

Choline is an important nutrient that has long been known to have important metabolic functions. Current rumen-stable technology allows ruminant animals to be effectively supplemented with choline, whereas it was previously not possible. Whether infusing choline past the rumen or supplying cows with choline through an effective rumen-stable choline product, consistent sizable increases in milk yield have been measured. The biology of choline clearly matches some of the unique metabolic challenges faced by transition cows. Recent research supports using rumen-stable choline in transition cow diets to reduce fat storage in the liver, reducing the

risk for ketosis and potentially improving energy supply to support milk yield. Rumen-stable choline holds much promise to improve liver metabolism and milk yield in transition and early lactation dairy cows.

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Figure 1. Dietary unprotected versus abomasally infused choline effects on milk yield.

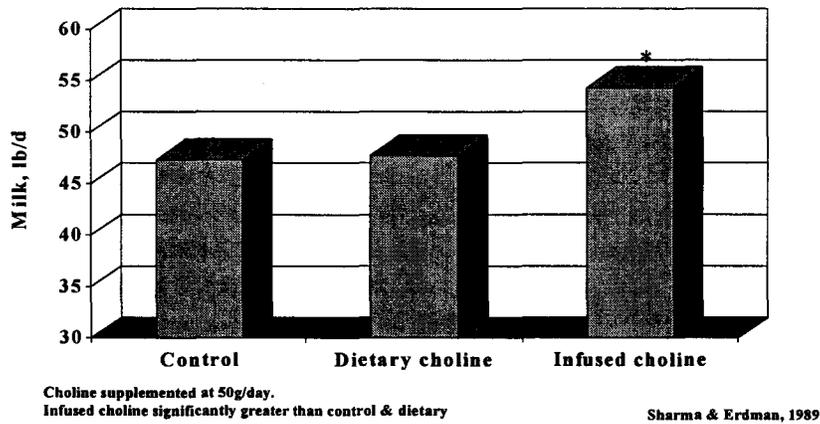


Figure 2. Overview of liver fat metabolism in dairy cows.

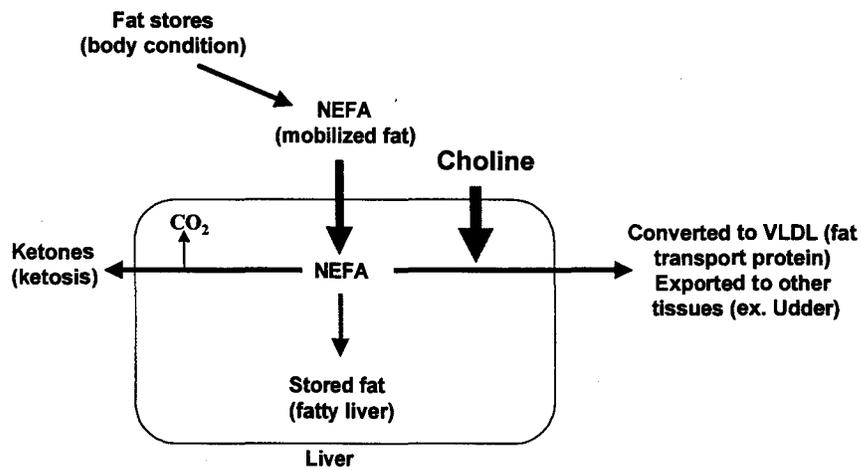


Figure 3. Typical energy balance of transition dairy cows.

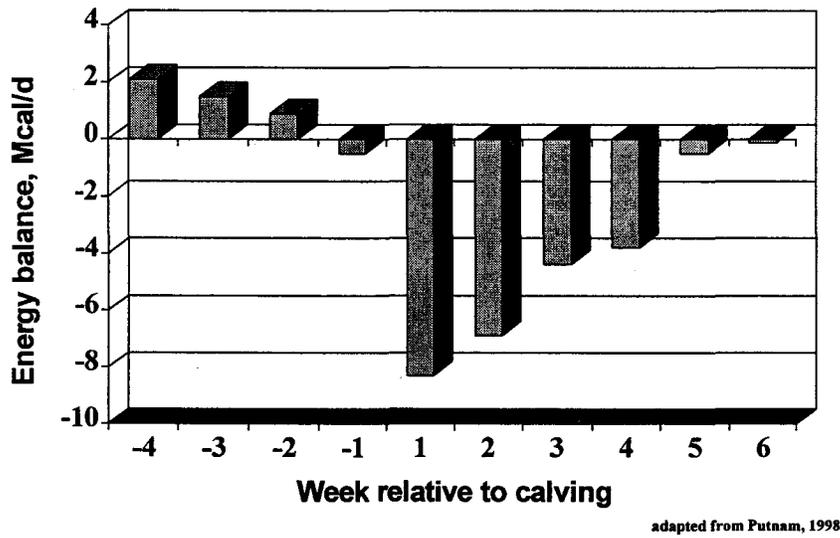


Figure 4. Changes in liver triglyceride concentrations during the transition period.

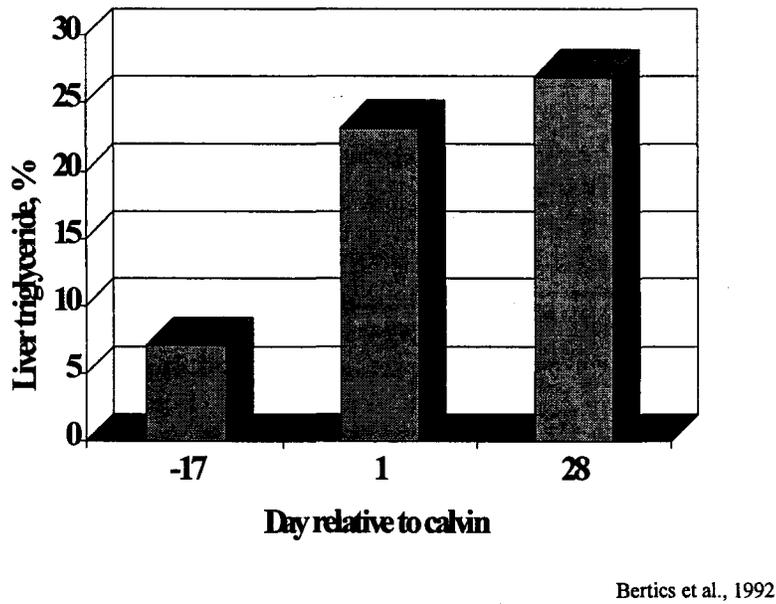
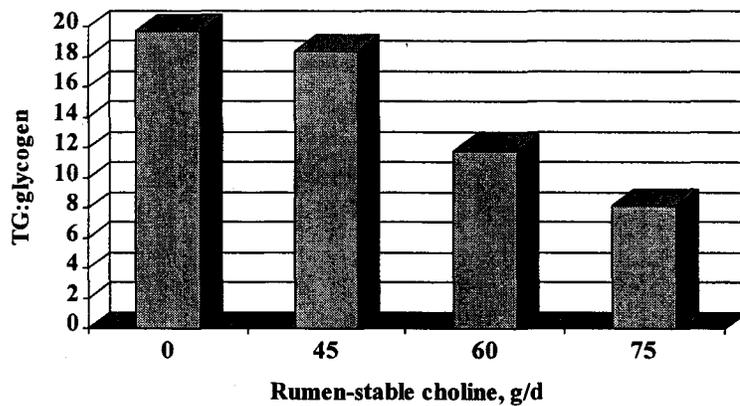
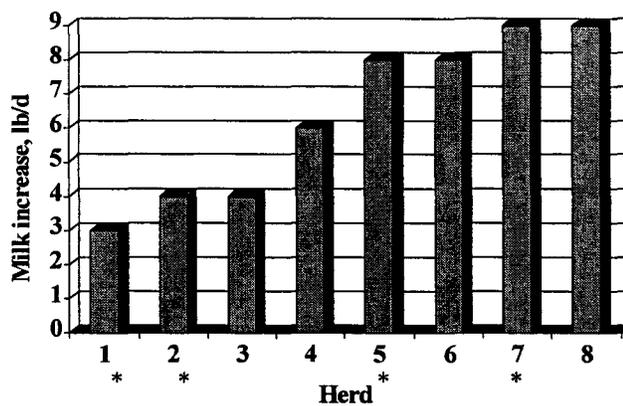


Figure 5. Changes in liver stored triglyceride to glycogen ratio in transition dairy cows supplemented with rumen-stable choline.



Adapted from Overton and Piepenbrink, 2000

Figure 6. Milk yield increases in early lactation with rumen-stable choline supplementation.



\* Siciliano-Jones and Putnam, 2000

Figure 7. Early lactation milk yield responses to rumen-stable choline supplementation in Mexican dairy farms.

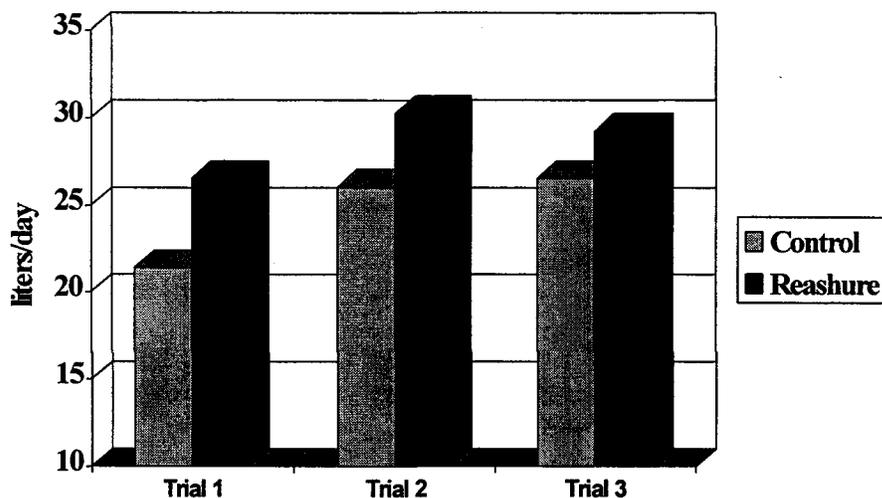


Table 1. Response of transition and early lactation dairy cows to rumen-stable choline supplementation during the transition period.

Item	Control	Rumen-stable choline
Number of cows	71	70
Prepartum		
Plasma glucose, mg/dl	58.4	63.1
Plasma NEFA, meq/L	.178	.086
Plasma BHBA, mg/dl	7.7	4.7
DMI, kg/d	12.5	14.2
Postpartum		
Plasma glucose, mg/dl	46.4	48.2
Plasma NEFA, meq/L	.509	.365
Plasma BHBA, mg/dl	9.2	8.1
DMI, kg/d	13.2	14.8
Subclinical ketosis rate, %	28%	4%
Reproduction		
Total pregnancies	35	40
Pregnancy rate, %	12%	16%
Conception rate, %	20%	27%
Services/conception	4.7	3.6
Days open	231	205