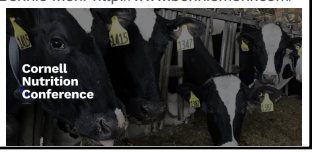
Choline: A Required Nutrient

José E. P. Santos, U. Arshad, J. Bollatti, and M. Zenobi

Department of Animal Sciences
University of Florida

Pictures by Bonnie Mohr http://www.bonniemohr.com/

UF UNIVERSITY of FLORIDA
Department of Animal Sciences



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Outline

- ✓A brief history on choline
- ✓Role of choline on intermediary metabolism
- ✓Choline for reduction of fatty liver in dairy cows
- ✓Effects of choline supplementation during the transition period on performance and health
- ✓BCS and responses to choline
- ✓Potential mechanisms
- ✓Make the case that choline is a required nutrient for ruminants as it is for other species

2

A Brief History on Choline

Derek Lindsay and Rex M. C. Dawson from the Agricultural Research Council in the Institute of Animal Physiology, Babraham, Cambridge, were the first to document that most choline in ruminants originated from *de novo* synthesis

Biochem. J. (1981) 196:499-504

Rich Erdman, from the University of Maryland, confirmed the findings by Dawson and Lindsay, of extensive ruminal degradation of choline, and conducted the initial experiments on supplementing different amounts of choline post-rumen to dairy cows

Sharma and Erdman (1989) J. Dairy Sci 72:2772-2776
Sharma and Erdman (1989) J. Nutr. 119:248-54

Multiple groups in the world (University of Milan, Purdue University, Cornell University, University of Illinois, University of Wisconsin, UC Davis, Wageningen University, University of Florida) conducted a series of experiments with RPC during the transition period in dairy cows demonstrating benefits to postpartum performance

3

Choline – An Required Nutrient

Choline is required for the structural integrity of cell membranes and neural tissue as a component of phospholipids and sphingolipids.

It plays a role in 1-C metabolism, cholinergic neurotransmission, transmembrane signaling, and lipid and cholesterol transport and metabolism.

0.5 g/day

0.6 g/day

0.1 g/day

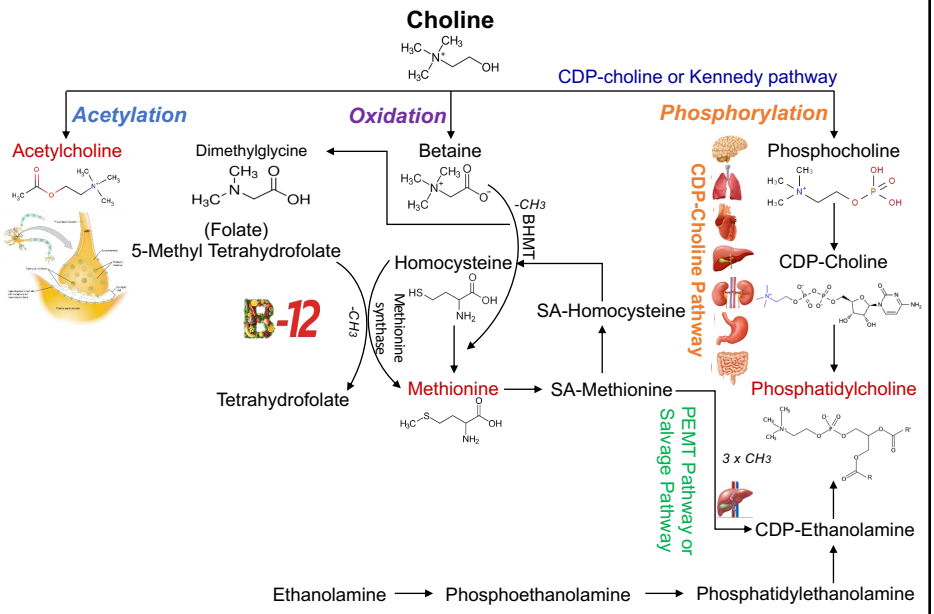
4 to 6 g/day

???

In ruminants, choline requirements remain unknown because of degradation of choline in the rumen (we do not know how much choline is available for absorption) and lack of dose-response experiments demonstrating the optimum amount to feed

4

Pathways for Choline Metabolism in Tissues



Adapted: Artegoitia et al. (2014) PLoS ONE 9:e103412

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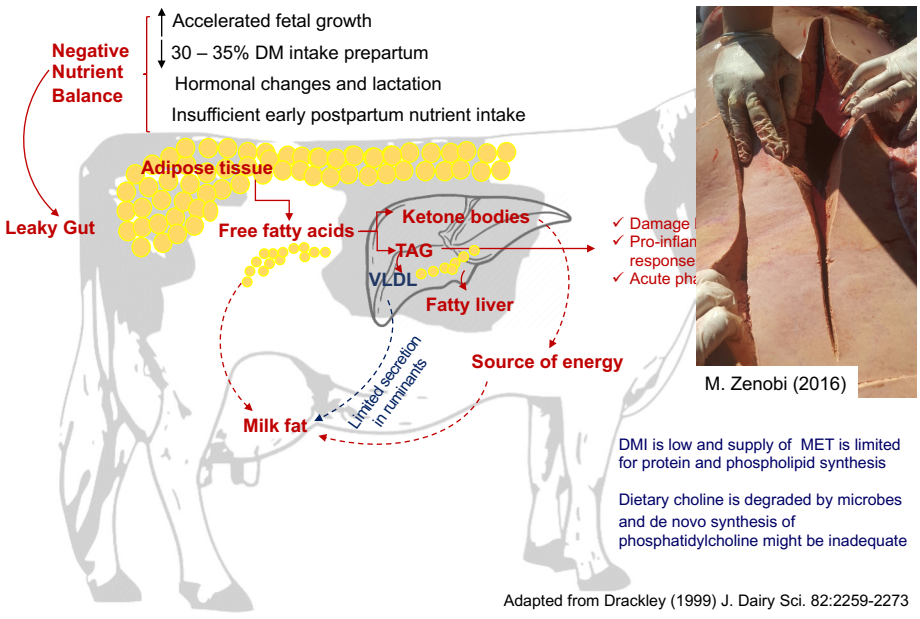
Intermediary Metabolism During the Transition Period



Adapted from Drackley (1999) J. Dairy Sci. 82:2259-2273

6

Prevalence of Fatty Liver in Dairy Cows Reported in the Literature

Study	Prevalence of fatty liver, %	
	Moderate (5 to 10% TAG)	Severe (> 10% TAG)
Reid (1980)	48	15
Reid (1980)	33	5
Jorritsma et al. (2000)	45	NR
Jorritsma et al. (2000)	40	14
Gerloff et al (1986)	20	15
Herd (1991)	>24	24
Lima et al. (2013)	28	17

49.5% of the early lactation cows develop at least moderate fatty liver (>5% TAG)

Adapted from Bobe et al. (2004) J. Dairy Sci. 87:3105–3124

7

Hepatic Triacylglycerol and Incidence of Diseases and Survival

Item	Hepatic triacylglycerol, % wet-basis			*P*-value	
	2.5	5.0	7.5	Linear	Quadratic
Clinical diseases, %					
Retained placenta	9.3 ± 2.7	11.9 ± 3.2	15.1 ± 4.7	0.12	---
Metritis	12.5 ± 3.4	18.2 ± 4.5	25.7 ± 6.8	0.01	---
Puerperal metritis	6.7 ± 2.3	10.2 ± 3.4	13.5 ± 5.4	0.07	---
Mastitis	14.2 ± 3.2	16.9 ± 3.3	19.9 ± 4.5	0.15	---
Morbidity	36.2 ± 5.0	41.3 ± 5.4	46.7 ± 6.9	0.10	---
Multiple diseases	8.7 ± 2.9	13.7 ± 4.1	21.1 ± 6.6	0.01	---
Left the herd by 300 DIM, %	8.9 ± 1.9	11.0 ± 1.8	13.7 ± 2.8	0.10	---
Subclinical diseases, %					
Hyperketonemia	15.2 ± 3.1	24.7 ± 3.8	37.5 ± 5.6	< 0.01	---
Hypocalcemia	30.3 ± 6.5	40.8 ± 7.1	52.4 ± 8.1	< 0.01	---

Arshad and Santos (2022) J. Dairy Sci. 105:5393-5409

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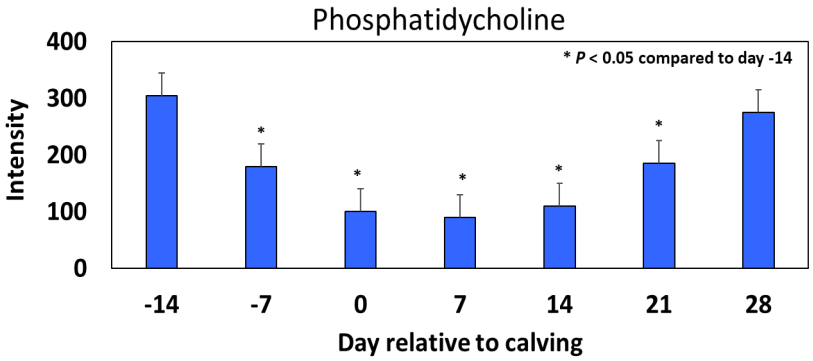
Phosphatidylcholine is Lowest Around Calving



Imhasly et al. (2015) BMC Vet Res. 11: 252

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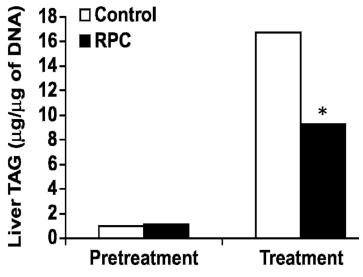
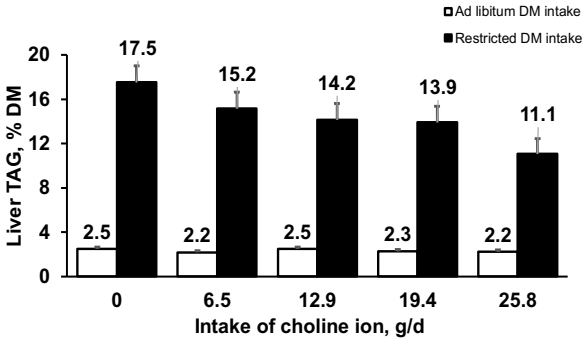
Lipotropic Effects of Choline in Dry Cows

Effect of Choline



Cooke et al. (2007) J. Dairy Sci. 90:2413-2418

Dose of Choline



Zenobi et al. (2018) J. Dairy Sci. 90:5902-5923

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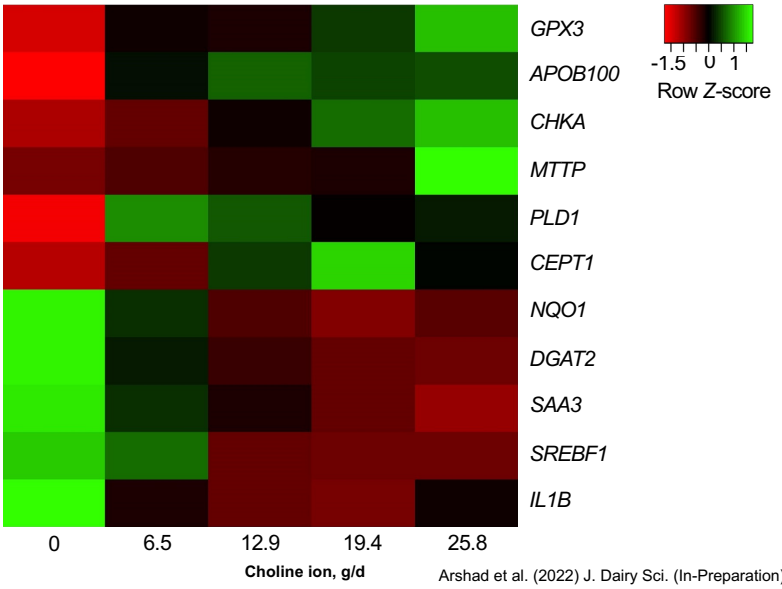
Effect of Choline on mRNA Expression of Genes During Feed Restriction



Arshad et al. (2022) J. Dairy Sci. (In-Preparation)

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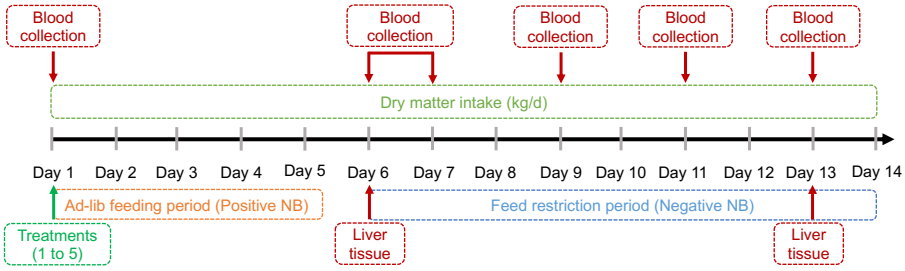
Experimental Design

- ✓ Randomized complete block design
- ✓ Dry pregnant Holstein cows (n = 110)
- ✓ 232 ± 3.9 days of gestation
- ✓ Blocked by BCS (4.02 ± 0.50)



- ✓ **CON** = 0 g of choline ion
- ✓ **L12.9** = 12.9 g/d of choline ion as RPC form with a low concentration (28.8% choline chloride)
- ✓ **L25.8** = 25.8 g/d of choline ion as RPC form with a low concentration (28.8% choline chloride)
- ✓ **H12.9** = 12.9 g/d of choline ion as RPC form with a high concentration (60% choline chloride)
- ✓ **H25.8** = 25.8 g/d of choline ion as RPC form with a high concentration (60% choline chloride)

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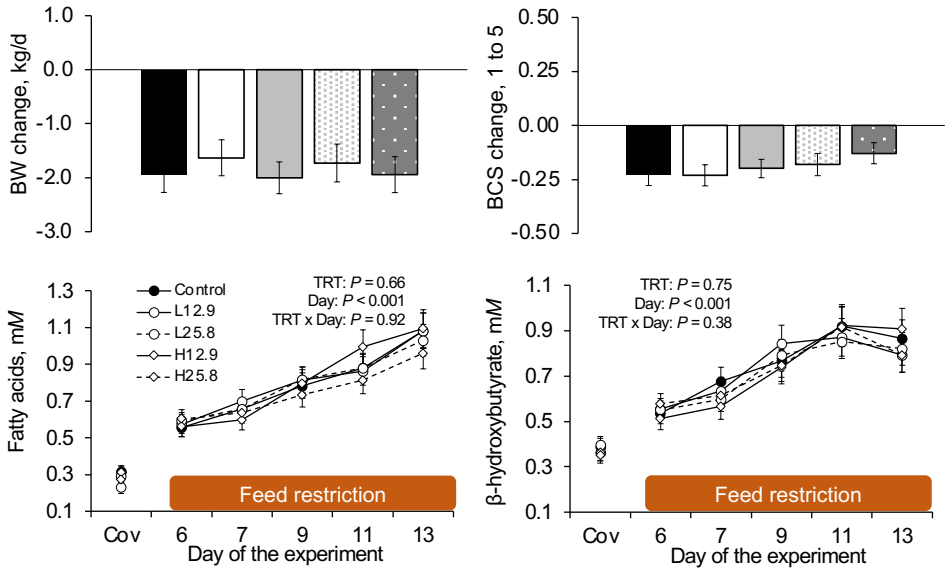
Effect of Source and Amount of RPC on Lipomobilization



Arshad et al. (2020) J. Dairy Sci. (Suppl. 1) Abstr. 103

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Intake and Hepatic Composition

	Treatment						*P*-value			
Item	CON	L12.9	L25.8	H12.9	H25.8	SEM	RPC	Source	Amount	S x A

Arshad et al. (2020) J. Dairy Sci. (Suppl. 1) Abstr. 103

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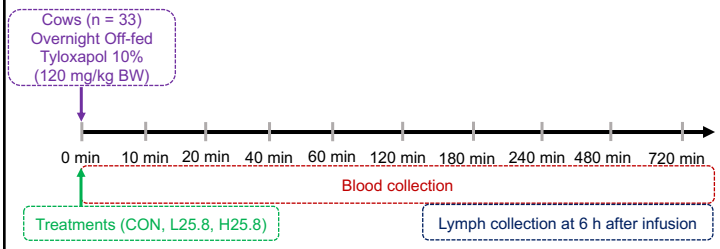
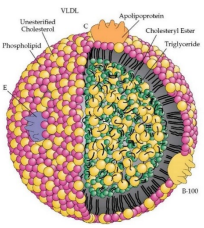
Experimental Design Day 14 – Secretion Rate of Triglyceride-Rich Lipoprotein

✓ Rumen-protected choline reduces hepatic triacylglycerol content by increasing triglyceride-rich lipoprotein secretion rate in cows induced to develop fatty liver





✓Blood was assayed to determine concentrations of serum triacylglycerol after tyloxapol infusion

✓Lymphatic fluid was collected from CON, L25.8, and H25.8 treatments to quantify

✓Free fatty acids; β-hydroxybutyrate; glucose; triacylglycerol; and total cholesterol

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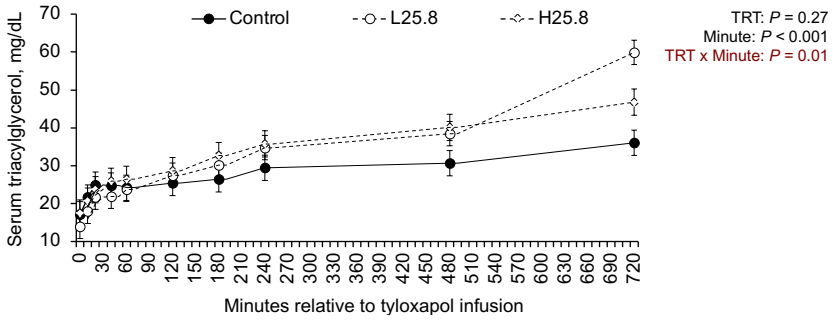
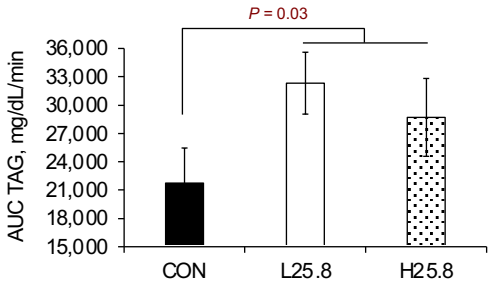
Effect of RPC on Hepatic Secretion of Triglyceride-Rich Lipoprotein





Arshad et al. (2022) J. Dairy Sci. (Suppl. 1) Abstr. 1098

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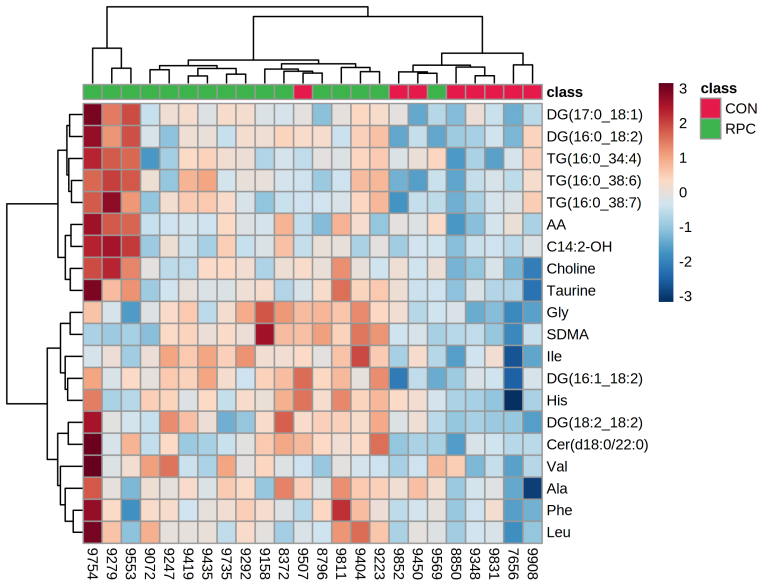
Effect of RPC on Lymph Metabolome After Fat Feeding



Arshad et al. (2022) J. Dairy Sci. (*In-Preparation*)

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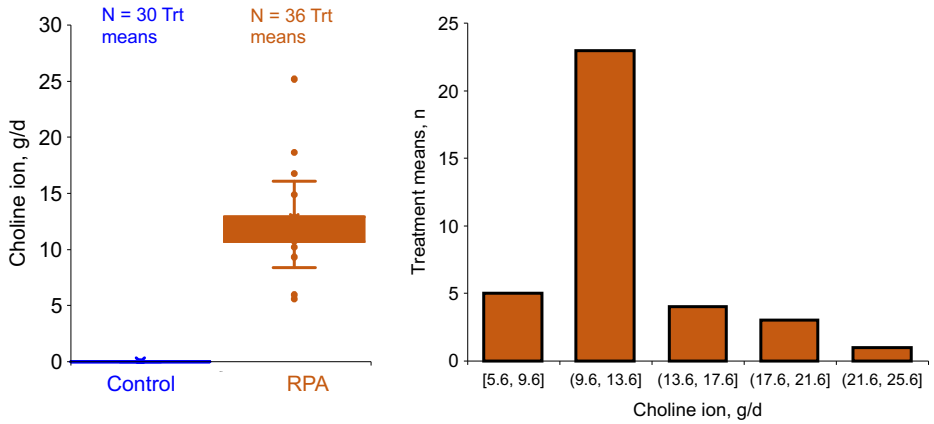
Amounts of Choline Ion Fed as RPC to Transition Cows Pre- and Postpartum



Arshad et al. (2020) J. Dairy Sci. 103:282–300

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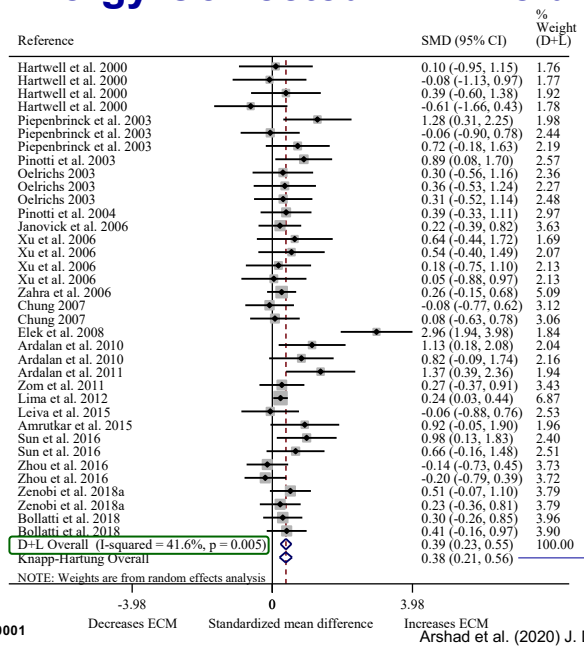
Energy-Corrected Milk Yield



SMD = 0 z = 4.18 P < 0.0001

Arshad et al. (2020) J. Dairy Sci. 103:282–300

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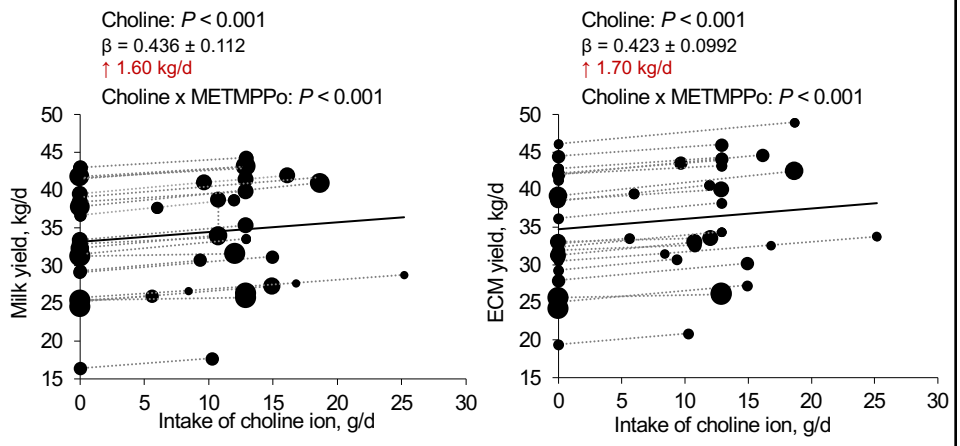
Yields of Milk and Energy-Corrected Milk



* Estimated response when cows are supplemented with 12.9 g of choline ion

Arshad et al. (2020) J. Dairy Sci. 103:282–300

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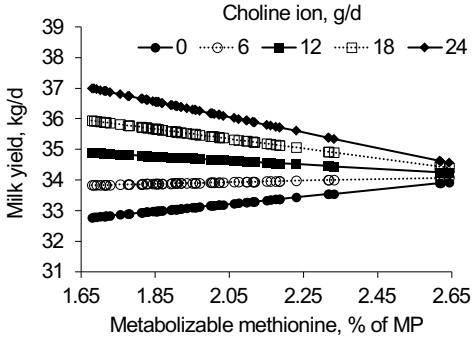
Interactions Between Supplemental Choline and Postpartum Dietary Methionine

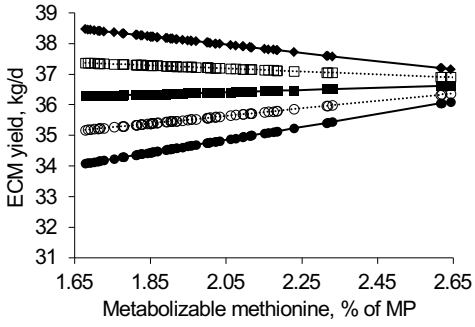
METMPPo = 1.80 % then, ↑ 2.0 kg/d

METMPPo = 2.30 % then, ↑ 1.0 kg/d



METMPPo = 1.80 % then, ↑ 2.1 kg/d

METMPPo = 2.30 % then, ↑ 1.2 kg/d



* Estimated response when cows are supplemented with 12.9 g of choline ion

Arshad et al. (2020) J. Dairy Sci. 103:282–300

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Effect of Choline on Health in Dairy Cows

		Treatment[1]		
Item	Means (Exp.),[2] n	Control	Choline	*P*-value
Retained placenta	38 (11)	10.6 ± 2.9	7.5 ± 2.2	0.06
Metritis	28 (09)	11.7 ± 2.2	8.7 ± 1.8	0.19
Mastitis	34 (11)	14.8 ± 3.0	11.7 ± 2.5	0.09
Milk fever	38 (11)	2.5 ± 1.5	1.5 ± 0.9	0.23
Displaced abomasum	38 (11)	6.0 ± 1.7	5.2 ± 1.5	0.67
Ketosis	36 (10)	12.0 ± 3.0	12.1 ± 3.0	0.96
Disease cases/cow	40 (12)	0.55 ± 0.1	0.48 ± 0.1	0.23

[1] Treatment as a categorical variable in the statistical models (not supplemented vs. supplemented) because most experiments that reported disease incidence supplemented choline ion at 12.9 g/d.

The mean (± SD) amounts of supplemental choline for experiments reporting data on health and hepatic composition were 13.3 ± 2.6 and 13.3 ± 2.1 g/d.

[2] Number of treatment means (experiments) that contributed data for statistical analyses.

Arshad et al. (2020) J. Dairy Sci. 103:282–300

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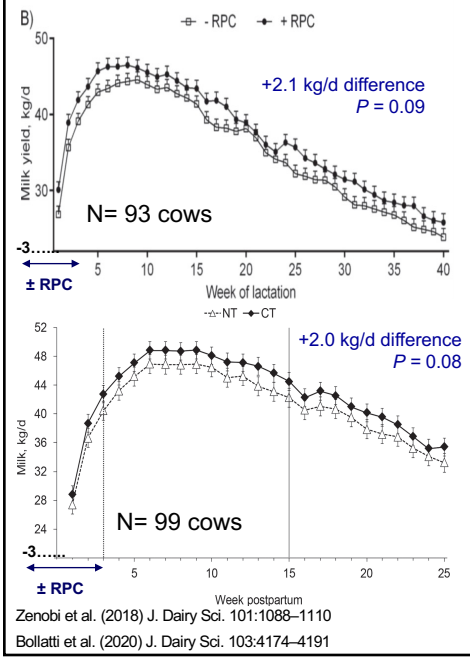
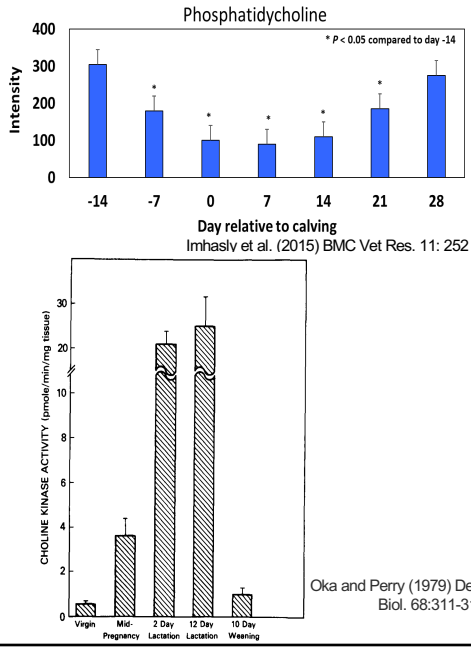
Effects From RPC Continued After Supplementation Ceased



Zenobi et al. (2018) J. Dairy Sci. 101:1088–1110

Bollatti et al. (2020) J. Dairy Sci. 103:4174–4191



Imhasly et al. (2015) BMC Vet Res. 11: 252

Oka and Perry (1979) Dev. Biol. 68:311-318

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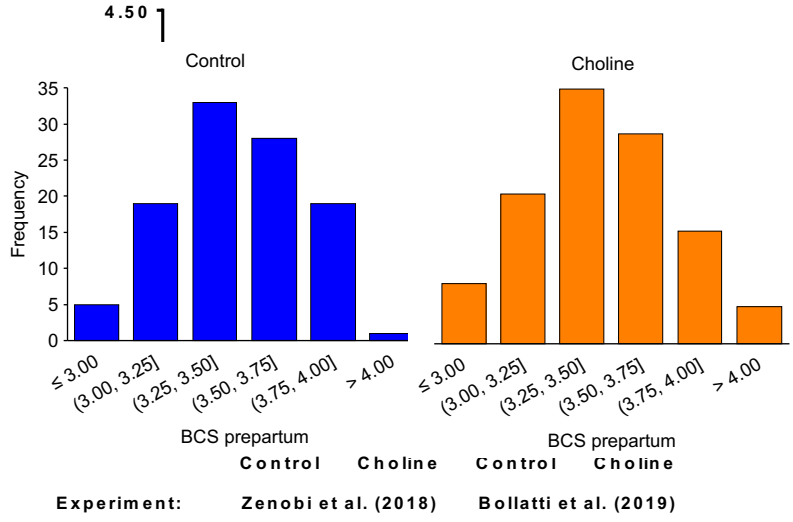
Distribution of Prepartum BCS According to Treatments



Bollatti et al. (2020) J. Dairy Sci. 103:2272–2286

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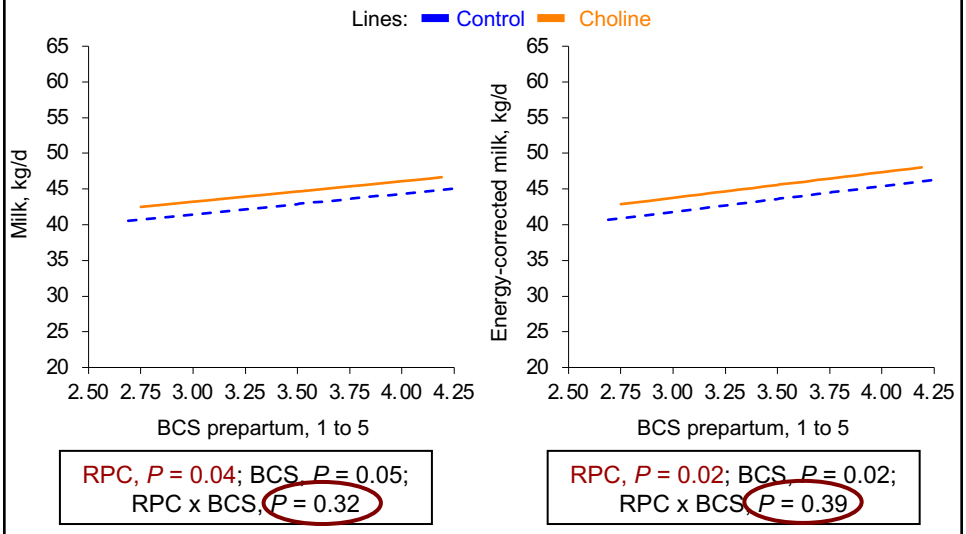
Effect of RPC During Transition on Yields of Milk and ECM According to BCS Prepartum



RPC, $P = 0.04$; BCS, $P = 0.05$; RPC x BCS, $P = 0.32$

RPC, $P = 0.02$; BCS, $P = 0.02$; RPC x BCS, $P = 0.39$

Bollatti et al. (2020) J. Dairy Sci. 103:2272–2286

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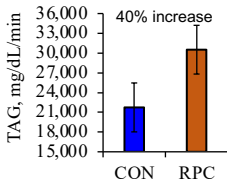
Potential Mechanisms for Improved Production and Health

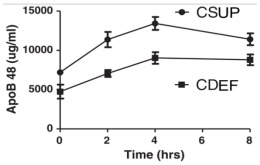
Increased VLDL Secretion



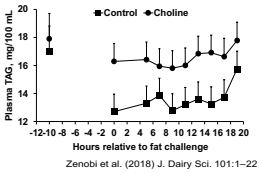
Arshad et al. (2021) J. Dairy Sci.

Fatty acid absorption and transport

Chylomicron Assembly

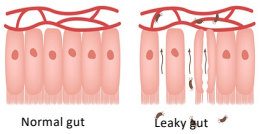


Da Silva et al. (2015) J. Nut. Bio. 26:1077-1083



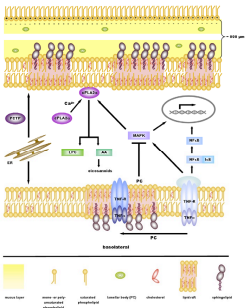
Zenobi et al. (2018) J. Dairy Sci. 101:1–22

Gastrointestinal lining integrity



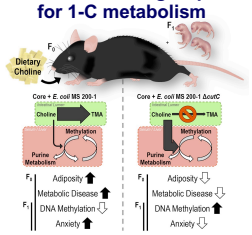
PC is critical for epitelial cell integrity

Anti-inflammatory actions



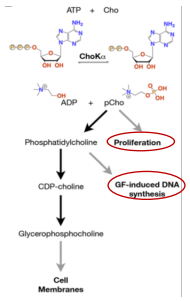
Schneider et al. (2010) Int. J. Mol. Sci. 11:4149-4164

Source of CH_3 groups for 1-C metabolism



Romano et al. (2017) Cell Host & Microbe 22:279–290

Cell proliferation



Kall et al. (2019) Sci. Rep. 9:17121

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Conclusions

- ✓ Unquestionable that choline fits the criteria of a required nutrient for dairy cattle
  - ✓ Supplementation reduces TAG infiltration into the hepatic tissue
  - ✓ Increases DM intake and yields of milk, ECM, fat and protein
  - ✓ Tends to reduce the incidence of retained placenta and mastitis
- ✓ The responses to RPC are influenced by the supply of metabolizable methionine
- ✓ The benefits of RPC are observed regardless of BCS of cows, and they extend beyond the period of supplementation
- ✓ Mechanisms that justify improved productive performance
  - ✓ Increased nutrient intake
  - ✓ Improved health (reduced hepatic lipidosis and clinical diseases)
  - ✓ Other non-classical mechanisms (improved nutriente transport, reduced inflammatory response, mammary cell proliferation, etc)

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