Choline: A Required Nutrient

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

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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
- ✓Choline during lactation
- ✓Make the case that choline is a required nutrient for ruminants as it is for other species

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A Brief History on Choline

Charles Herbert Best, a medical student with Frederick Banting at the University of Toronto during their discovery of insulin (1922) using pancreatectomized dogs observed they developed fatty liver.

Banting and Best (1922) J. Lab. Clin. Med. 7:464

Eventually in 1931-1993, Best and colleagues showed that lecithin and choline supplementation reversed the problem.

Hershey and Soskin (1931) Am. J. Physiol. 93:657–658

Best et al. (1933) J. Physiol. 79:94-102

https://insulin.library.utoronto.ca/

Derek Lindsay and Rex M. C. Dawson from 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 extensive ruminal degradation of choline, and conducted the initial experiments on supplementing different amounts of choline post-rumen to dairy cows

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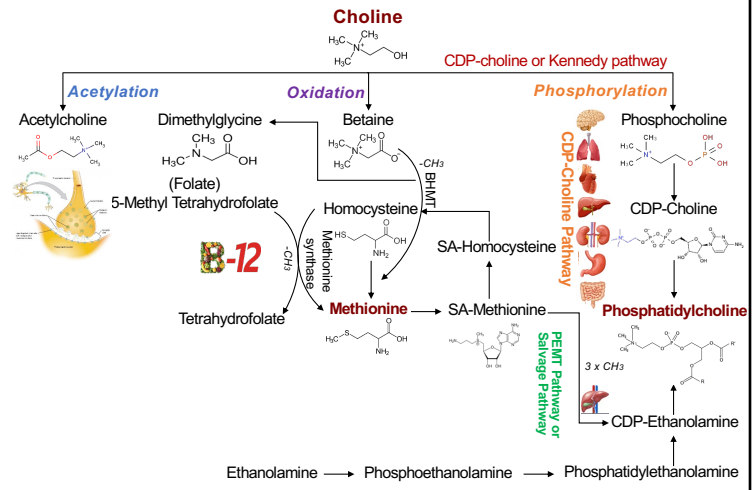
Pathways for Choline Metabolism in Tissues



Artegoitia et al. (2014) PLoS One 9:e103412; Zenobi et al. (2018) J. Dairy Sci. 101:5902-5923

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Choline – An Essential 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

- ✓ We do not know how much is absorbed from RPC products
- ✓ Lack of dose-response experiments demonstrating the optimum amount to feed

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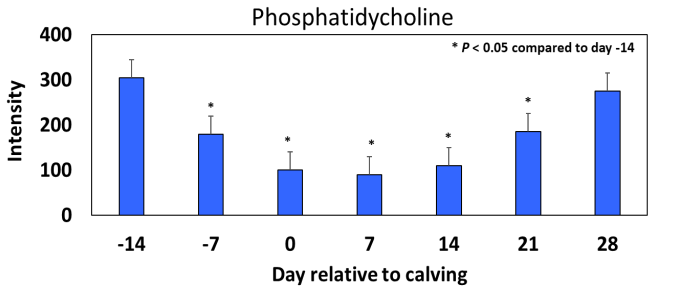
Phosphatidylcholine is Lowest Around Calving



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

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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

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

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

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

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Supplemental RPC and Hepatic Triacylglycerol

- ✓ 110 parous prepartum dry cows
- ✓ Weekly cohort of cows were blocked by BCS (4.02 ± 0.5) at 232 d of gestation and assigned randomly (22/treatment) to 1 of 5 treatments:
  - ✓ **CON** = 0 g of choline ion
  - ✓ **L12.9** = 12.9 g/d of choline ion in a rumen-protected choline form with low concentration (28.8% choline chloride)
  - ✓ **L25.8** = 25.8 g/d of choline ion in a rumen-protected choline form with low concentration (28.8% choline chloride)
  - ✓ **H12.9** = 12.9 g/d of choline ion in a rumen-protected choline form with high concentration (60% choline chloride)
  - ✓ **H25.8** = 25.8 g/d of choline ion in a rumen-protected choline form with high concentration (60% choline chloride)
- ✓ 5 d of ad libitum intake and 9 d of feed restriction at 42% of the NE_L required for maintenance and pregnancy

Arshad et al. (2023) J. Dairy Sci. 106: https://doi.org/10.3168/jds.2023-23270

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Hepatic Tissue Composition According to Treatments During Feed Restriction

Item	Treatment					SE
	CON	L12.9	L25.8	H12.9	H25.8	

Effect $P < 0.05$: *choline; ‡concentration; †amount; §interaction

Arshad et al. (2023) J. Dairy Sci. 106: https://doi.org/10.3168/jds.2023-23270

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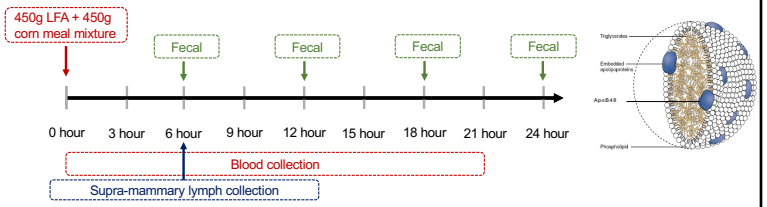
Experimental Design - Fat Dosing on Day 9

Day 9 of the experiment



✓Fecal samples collected and analyzed for iNDF and fat

✓Supra-mammary lymph analyzed

- ✓Triacyglycerol
- ✓Free fatty acids
- ✓B-hydroxybutyric acids
- ✓Glucose
- ✓Metabolome

Arshad et al. (2023) J. Anim. Physiol. Anim. Nutr. in review

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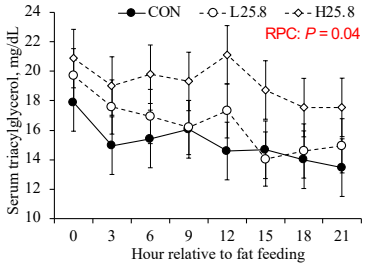
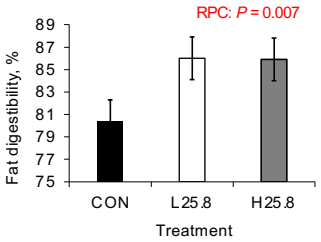
Effect of RPC on Serum and Lymph Composition After Fat Feeding





Item	CON	L25.8	H25.8	SE	RPC	Source
Lymph metabolites						
Choline, n*M*/g of protein	479	789	867	141	0.03	0.66
Triacylglycerol, mg/dL	11.4	15.7	15.9	3.4	0.08	0.98

Arshad et al. (2023) J. Anim. Physiol. Anim. Nutr. in review

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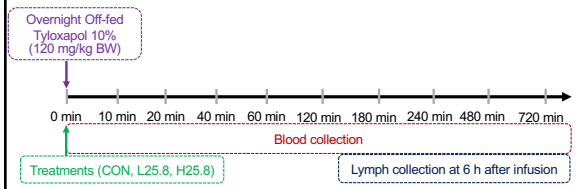
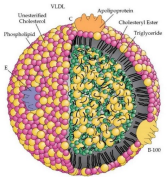
Experimental Design - Tyloxapol Infusion on Day 14





- ✓Blood collected and serum assayed for concentrations of triacylglycerol after tyloxapol infusion
- ✓Lymph sampled for
  - ✓Free fatty acids
  - ✓β-hydroxybutyrate
  - ✓Glucose
  - ✓Triacylglycerol

Arshad et al. (2023) J. Dairy Sci.106: accepted

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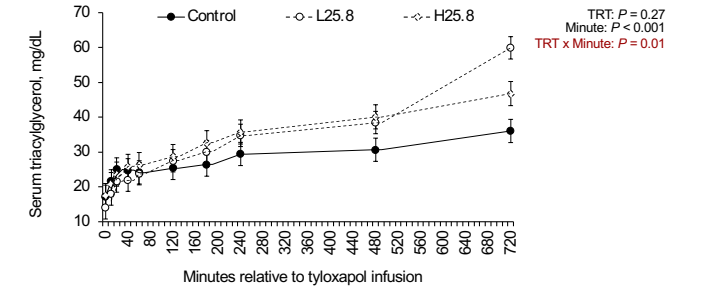
Effect of RPC on Hepatic Secretion of TAG-Rich Lipoprotein



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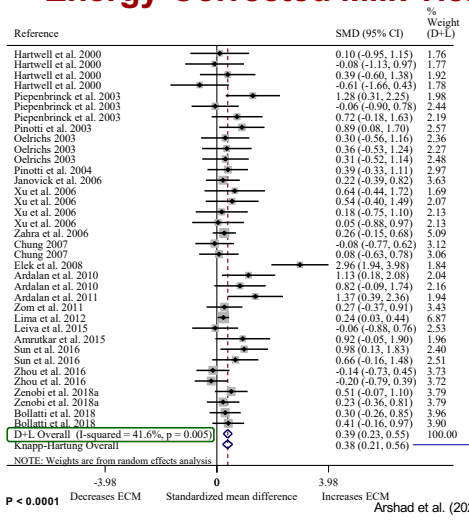
Energy-Corrected Milk Yield



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

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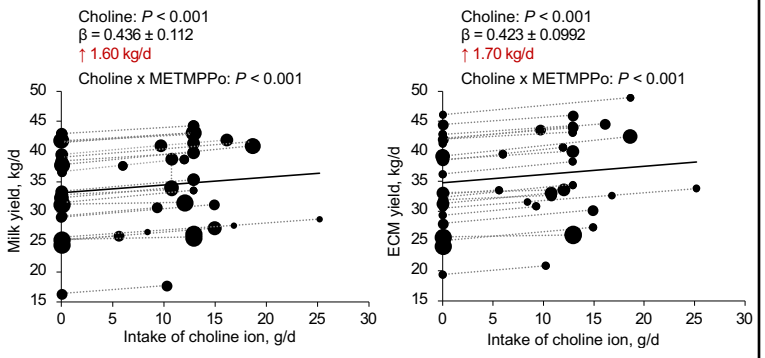
Yields of Milk and Energy-Corrected Milk



* 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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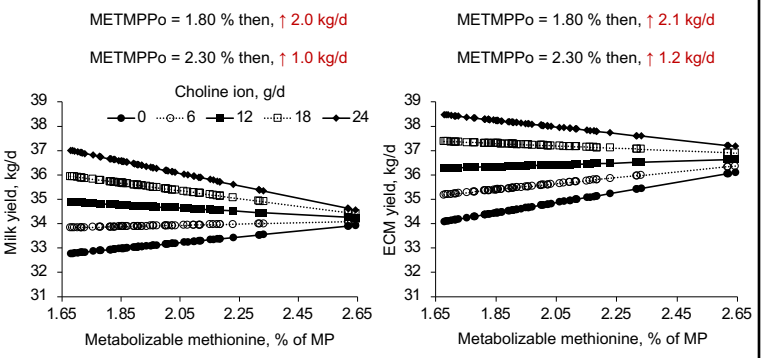
Interactions Between Supplemental Choline and Postpartum Dietary Methionine



* 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

Item	Means (Exp.),[2] n	Treatment[1] 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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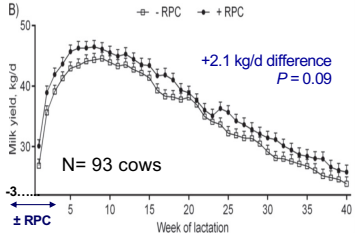
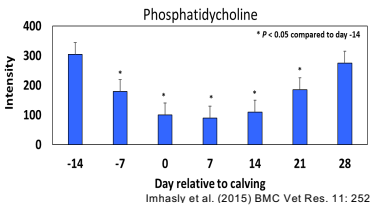
Effects From RPC Continued After Supplementation Ceased

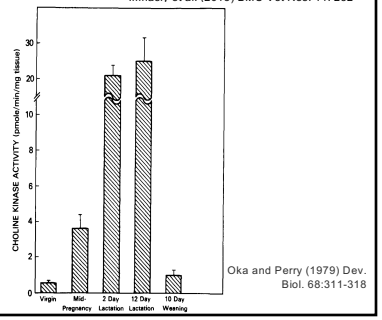


Zenobi et al. (2018) J. Dairy Sci. 101:1088–1110

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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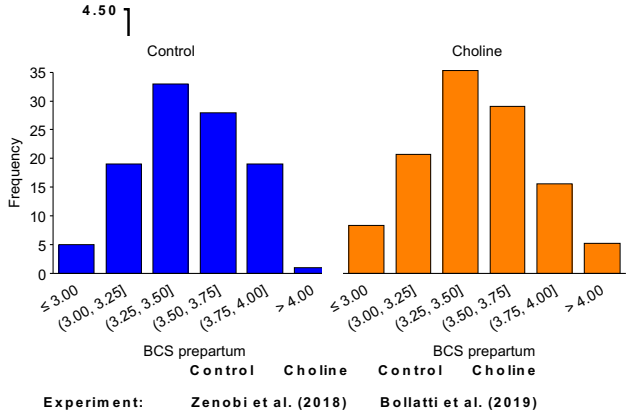
Distribution of Prepartum BCS According to Treatments



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

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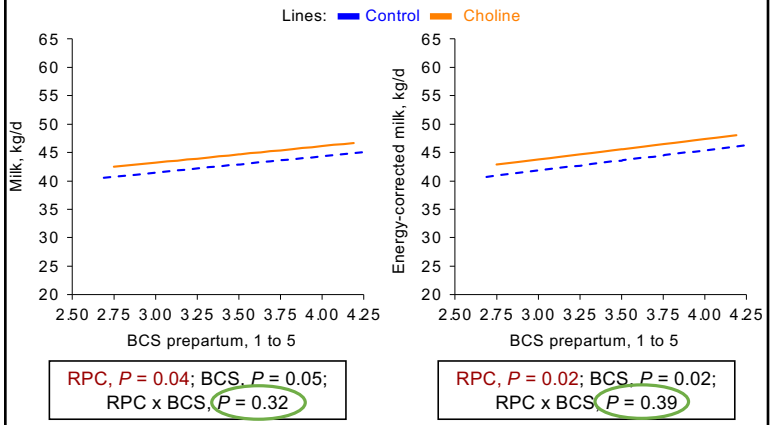
Effect of RPC During Transition on Yields of Milk and ECM According to BCS Prepartum



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

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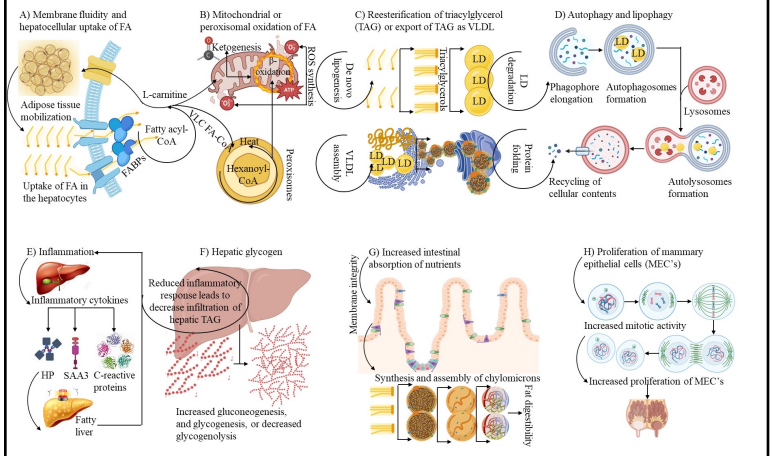
Proposed Mechanisms by which RPC Affects Metabolism in Dairy Cows



Arshad and Santos (2023) J. Dairy Sci.106: submitted

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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
  - ✓ Other non-classical mechanisms (reduced inflammatory response, mammary cell proliferation, etc)

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