

I am pleased to share Issue 9 of the Nutrition Research Update. Amongst other exciting developments in nutrition science, this issue features an article by [Dr. Marie Caudill](#) of Cornell University describing her recently published study, which shows the increased demand for choline during pregnancy and suggests that current recommendations for choline intake may be inadequate to support physiological needs during fetal growth and development.

ENC is also proud to share new evidence surrounding the changing landscape of the environmental impact and sustainability of egg production. Findings from the landmark study "[A Comparative Assessment of the Environmental Footprint of the U.S. Egg Industry in 1960 and 2010](#)" by Pelletier, Ibarburu and Xin from Iowa State University show that improvements in hen housing, manure management, hen lifespan, and feed content have led to healthier hens that are more productive while using far fewer resources. The current combined relative and absolute environmental footprint of egg farming and production has declined significantly since 1960 while continuing to provide high-quality nutrition for a growing population.

We hope the findings of the research presented here will continue to facilitate further research and development in health and nutrition. If any questions, concerns or comments arise regarding the content that appears in this edition of the Nutrition Research Update, please feel free to contact us at info@eggnutrition.org.

Regards,



Tia M. Rains, PhD
Senior Director of Nutrition Research and Communications
Egg Nutrition Center

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The Egg Nutrition Center (ENC) administers an annual research program with over \$2 million dollars provided by America's egg farmers through the USDA and the American Egg Board. Additional information is available at the ENC [website](#).



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Choline Tracer Study Conducted in Pregnant Women Demonstrates High Demand for Choline During this Reproductive State



By [Marie A. Caudill, PhD, RD](#)

Pregnancy-induced alterations in choline metabolism are evident throughout the last half of gestation with profound depletions in circulating choline-derived methyl donors (e.g., betaine) and significant increases in plasma phosphatidylcholine (PC) and choline (1). To better understand these metabolic alterations, my research group employed stable isotope methodology, whereby third trimester pregnant women consumed a choline tracer labeled with deuterium (a stable isotope of hydrogen) on its three methyl groups (see Figure) (2). This labeling strategy enabled the tracing of the intact choline molecule (i.e., d9-choline metabolites), as well as its methyl groups (d3-choline metabolites) (see Figure).

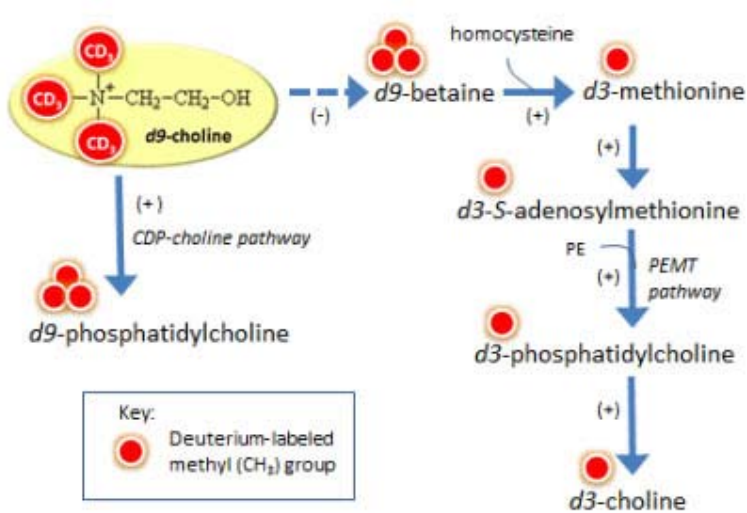


Figure. Diagram illustrating the metabolism of the choline tracer. Positive symbols indicate upregulation of the metabolic reaction by pregnancy. Negative symbols indicate downregulation of the metabolic reaction by pregnancy.

We found that pregnant (vs. nonpregnant) women used more choline to synthesize PC through the CDP-choline pathway. This greater partitioning of choline towards PC synthesis reduced its availability for betaine synthesis. Nonetheless, despite reduced betaine supply, pregnant (vs. nonpregnant) women used more of this choline derivative as a methyl donor, including for the production of a new PC molecule through the endogenous (denovo) phosphatidylethanolamine N-methyltransferase (PEMT) pathway. The use of choline-derived methyl groups to make choline through this endogenous pathway suggests that PEMT-PC may be especially important for fetal development. Indeed our tracer study revealed that PEMT-PC, but not PC generated by the CDP-choline pathway, was preferentially delivered to the fetus. We also found that pregnant (vs. nonpregnant) women degraded more of the PEMT-PC to choline, perhaps as a way to increase supply of free choline to the developing fetus. Neonates are born with circulating free choline concentrations that are 3-5 times higher than those in maternal blood (1). Finally, extra choline (approximately double the adequate intake [AI]) normalized the partitioning of choline between the CDP-choline pathway and the betaine synthesis pathway among pregnant women to the nonpregnant state.

The higher production of PC through both synthetic pathways highlights the substantial demand for this phospholipid during late pregnancy. PC is required for the production of very low density lipoproteins, the synthesis of which accelerates during normal pregnancy to provide lipids for membrane formation, cell division and fetal growth (3, 4). The selective partitioning of PC generated by the endogenous PEMT pathway denotes a unique requirement for PEMT-PC by the developing fetus, which may be due to its enrichment with docosahexaenoic acid (DHA) (5 - 7). Importantly, both choline and DHA play a prominent role in the development of the central nervous system (8). Finally, the greater use of betaine, coupled with its reduced production from choline, contribute to the profound reduction in plasma betaine during pregnancy. Greater consumption of choline in the last trimester of pregnancy mitigated some of these aberrations, indicating pregnant women may benefit from choline intakes that exceed current recommendations. A higher maternal choline intake during pregnancy has been shown to beneficially influence offspring cognition (9, 10) and response to stress (11), as well as placental functioning (12, 13).

Most women in the U.S. consume less than the current AI of 450 mg choline/d (14, 15). Eggs, beef, fish, poultry, cruciferous vegetables and legumes can be added to the maternal diet to increase the intake of this essential bioactive micronutrient (16). However, some women may require supplements to meet dietary recommendations. At present, choline is absent from most prenatal vitamins, but is commercially available as choline bitartrate, or as phosphatidylcholine, which may be used to provide extra choline during this critical period of human development.

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Amassing evidence for heightened satiety from protein-containing breakfasts

Studies demonstrating protein's ability to increase satiety more than other macronutrients have been amassing in the scientific literature, a notable and important trend in a nation where almost 70% of adults are overweight or obese (1). Particularly when consumed at breakfast, research indicates that a meal containing >15-20 g protein imparts greater feelings of fullness and reductions in energy intake at a subsequent meal compared to an equivalent amount of carbohydrate or fat, facilitating weight loss and weight loss maintenance when sustained over extended periods of time (2 - 4).

The satiating properties of a number of different protein sources have been tested under acute conditions. Several acute and longer-term trials have evaluated eggs specifically given their wide consumer acceptance as a breakfast food. In particular, [Dr. Nikhil Dhurandhar](#) from the Pennington Biomedical Research Center, Baton Rouge, Louisiana, has conducted a series of studies suggesting a distinct satiating property of eggs that may promote body weight management (5 - 7). The earliest of these was an acute study comparing postprandial satiety and cravings, and subsequent energy intake following consumption of either an egg-containing breakfast (18 g protein) or an isocaloric bagel-based breakfast (14 g protein) in overweight and obese participants. Results indicated greater satiety and significantly less energy intake consumed (by 400 calories) throughout the day and up to 36 hours following the egg-based breakfast versus the bagel (5).

Augmenting this preliminary evidence on satiety, Dr. Dhurandhar's research group evaluated the effects of an egg-based breakfast as part of an 8-week energy-restricted weight loss regimen. The group of participants that consumed 2 scrambled eggs each day at breakfast (17 g protein) experienced 65% greater weight loss than the group consuming the bagel breakfast of equal calories (14 g protein) and volume (6). Further, waist circumference and body fat were decreased to a greater degree in those consuming eggs at breakfast. In addition, participants who ate eggs for breakfast reported feeling more energetic than those who ate bagel breakfasts.

In their most recent study, Dr. Dhurandhar and colleagues compared the acute effects of isocaloric breakfasts providing an equivalent level of protein (20 g) derived from either eggs or wheat (cereal plus a slice of bread). This study evaluated the influence of higher protein quality of eggs versus that of wheat on postprandial hunger and fullness, a change from prior studies that differed in protein quantity. Results showed that despite the matching quantity of protein, the egg-based breakfast increased some, but albeit, not all indicators of satiety. In particular, the egg-based breakfast favorably influenced the satiety hormones, PYY and ghrelin, revealing a potential mechanism whereby eggs may influence appetite (7). This study suggests that protein quality, in addition to the amount of protein consumed, may be an important determinant of protein-induced satiety. More research is necessary to solidify these preliminary findings and ascertain the longer-term effects on weight loss and weight maintenance.

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- [Carbohydrate feeding and impact on global metabolomics in relation to insulin sensitivity in men with metabolic syndrome \(1\)](#)

In this study, researchers sought a better understanding of the metabolic effects of differential macronutrient distribution in the diet. Serum global metabolomic analysis was performed in men with metabolic syndrome, concurrent with dietary manipulations over time. Participants were fed isocaloric and isonitrogenous diets that incrementally increased in carbohydrate (CHO) and decreased in fat content for three weeks. Results showed that insulin resistance decreased from baseline to low CHO intake, but increased following moderate and high CHO intake and appeared to be linked to several specific metabolic markers. Authors indicated that the study's results may help explain the mechanisms behind dietary CHO content and insulin resistance.

- [Dietary cholesterol and heart health: a systematic review and meta-analysis \(2\)](#)

A growing body of evidence suggests that previously declared correlations between dietary cholesterol consumption and heart disease may be unfounded. This meta-analysis systematically reviewed the literature from the past 35 years in order to elucidate this ambiguous and unconfirmed relationship. Close examination of 39 studies showed no association between dietary cholesterol and ischemic heart disease deaths, ischemic stroke or hemorrhagic stroke. An analysis of randomized controlled trials showed that dietary cholesterol produced small increases in total plasma cholesterol, LDL- and HDL-cholesterol, however all studies fed subjects dietary cholesterol at levels two to five times current intakes. The authors concluded that more research was needed to fill evidence gaps.

- [Consumption of an egg-based breakfast reduces hunger and increases postprandial energy metabolism in normal weight and overweight school-aged children \(3\)](#)

In this study, researchers compared egg (protein)-based breakfasts to isocaloric CHO-based breakfasts and the resulting thermic effect of food, glycemic control, and hunger levels in school-aged children. Blood glucose levels were not significantly different following consumption of the two different breakfasts, but after consuming egg breakfasts, participants felt less hungry and ate an average of approximately 100 fewer calories at the subsequent ad libitum buffet lunch. Additionally, higher thermic effect of food tended to occur following the egg breakfast as compared to CHO breakfast. Authors of the study concluded from these results that protein-based breakfasts may have positive effects on subsequent energy metabolism.

- [One egg a day does not increase the risk for cardiovascular disease in diabetic patients \(4\)](#)

This crossover study assessed the plasma lipoprotein lipid concentrations of 15 female and 7 male diabetic patients following consumption of either an egg breakfast (one egg per day) or oatmeal breakfast each for five weeks. Male participants experienced no significant changes in plasma lipid measurements. In female participants, the consumption of one egg per day decreased plasma triglycerides and increased LDL-cholesterol, but did not alter HDL-cholesterol. Despite the increase in females' serum LDL-cholesterol, levels remained below recommended serum concentrations for patients at risk for heart disease. Consumption of one egg per day, therefore, was determined not to negatively impact already existing dyslipidemias in diabetic patients.

- [Consumption of 12 eggs per week for 1 year increases serum zeaxanthin concentrations but not other major carotenoids, tocopherols, and retinol in humans \(5\)](#)

To understand the effects of an egg-rich diet on serum levels of carotenoids, 45 adults were placed into either the intervention group who consumed 12 eggs per week for 12 months, or a control group consuming no eggs for 12 months. Results showed that the group consuming eggs had a significant increase in serum zeaxanthin concentrations and a notable, although not significant, increase in serum lutein after 1 year. However, no significant changes were observed in other serum carotenoids, retinol or alpha- or gamma-tocopherol concentrations. The findings of this study thus suggest that egg yolk consumption increases concentrations of only select carotenoids.

- [Whole egg protein markedly increases blood vitamin D concentrations in male Sprague-Dawley rats \(6\)](#)

As a means of exploring the links between diet, diabetes and cardiovascular disease in more detail, researchers in this study examined the differential effects of control, egg white protein and whole egg diets in rats. In particular, researchers measured circulating 25(OH)D and the relative activity of a regulatory enzyme for methyl group metabolism, both of which are disrupted in a diabetic state. While there appeared to be no difference in vitamin D concentrations between the control and egg white diet groups, the whole egg diet elicited a 4-fold increase in circulating vitamin D. In addition, the regulatory enzyme in question was more active in both egg diet groups than the control. These results suggest that whole egg consumption may help to alleviate physiologic diabetic dysfunctions by elevating circulating vitamin D and by increasing methyl group metabolic activity.

- [Effect of a very low carbohydrate diet followed by incremental increases in carbohydrate on respiratory exchange ratio \(7\)](#)

This study aimed to examine the effects of incremental increases in dietary carbohydrate intake on fat oxidation. Post-absorptive respiratory exchange ratio (RER) across a broad range of dietary carbohydrate and fat levels was measured in 16 adults with metabolic syndrome. After an initial 3-wk run-in low-carbohydrate diet, participants were fed six sequential moderately hypocaloric diets for 3 weeks each, which progressively increased carbohydrate with simultaneous decreases in fat. Results showed that resting RER was lowest after the diet with the lowest amount of carbohydrate and increased in a linear manner as carbohydrate increased, indicating that very low carbohydrate diets may accelerate fat oxidation and incremental increases in carbohydrate track linearly with decreased fat oxidation.

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Congratulations to **Ashley Binns**, PhD student collaborating with Dr. Jamie I. Baum at the **University of Arkansas- Fayetteville**, and winner of the 2014 abstract competition conducted by the Energy and Macronutrient Metabolism Research Interest Section of the American Society for Nutrition. Ashley submitted the winning abstract titled '**Consumption of an egg-based breakfast reduces hunger and increases postprandial energy metabolism in normal weight and overweight school-aged children**', featuring her ENC-funded work on the potential of a protein-based breakfast to modulate postprandial energy metabolism in overweight children.




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Look for ENC at these upcoming health professional events:

National Nurse Practitioner Symposium
July 10-13, 2014, Keystone, CO

Presentation by Mitch Kanter, PhD, Executive Director of the Egg Nutrition Center, and board-certified family nurse practitioner, Dixie L. Harms, DNP, ARNP, FNP-C, BC-ADM, FAANP



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