Effects of a Plant-Based diet with whole eggs or egg substitute on parameters of metabolic syndrome, plasma choline and TMAO

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ABSTRACT

Plant-based (PB) diets typically result in lowering of total and LDL cholesterol. Eggs could complement the PB diet by increasing HDL cholesterol and by increasing plasma antioxidants and choline in individuals with metabolic syndrome (MetS). **Methods:** In this randomized controlled cross-over intervention, we recruited 29 participants (49.3 ± 8 y) with MetS who followed a PB diet for 13 wk. A registered dietitian advised all subjects on food selection and followed them through the whole intervention to ensure compliance. Participants underwent a 2-wk washout with no eggs or spinach (sources of dietary choline) and were randomly allocated to consume spinach (70g) with either 2 eggs (EGG) or the equivalent amount of egg substitute (SUB) for breakfast for 4 wk. After a 3-week washout, they were allocated to the alternate breakfast. We hypothesized that whole egg intake (EGG) would increase plasma choline and plasma carotenoids and result in better improvement in parameters of metabolic syndrome. Twenty-four participants (13 women/11 men) finished the intervention. Plasma lipids, glucose, anthropometrics, liver enzymes, insulin, plasma choline and TMAO, were assessed at baseline and the end of each intervention. **Results**: Compared to the SUB breakfast, we observed a significant decrease in body weight ($P < 0.02$) and a significant increase in HDL cholesterol ($P < 0.025$) following the EGG breakfast. There were no differences in plasma LDL, triglycerides, glucose, insulin, or blood pressure. The number of large HDL particles measured by NMR was higher after EGG ($P < 0.01$). Plasma choline was higher in both treatments ($P < 0.01$) compared to baseline (8.3±2.1 nmol/mL). However, choline values were higher in EGG (10.54 ± 2.8 nmol/L) compared to SUB (9.47 ± 2.7 mmol/L) $P < 0.025$. Plasma lutein was increased by both breakfasts compared t baseline ($P < 0.01$) while plasma zeaxanthin was only increased in eggs ($P< 0.01$). **Conclusion:** These results indicate that consuming a plant-based diet in combination with whole eggs results in increases in plasma HDL cholesterol, choline and zeaxanthin, therefore increasing the benefits for patients with metabolic syndrome.

HYPOTHESES AND AIMS

Central hypothesis: The intake of 2 eggs per day in combination with a plant-based diet will significantly increase plasma choline, lutein and zeaxanthin when compared to a plant-based diet without whole eggs without increases in plasma TMAO.

A second hypothesis is that intake of 2 eggs per day will result in increase of HDL cholesterol as well as concentrations of large HDL, which will correlated with the observed increases in lutein and zeaxanthin.

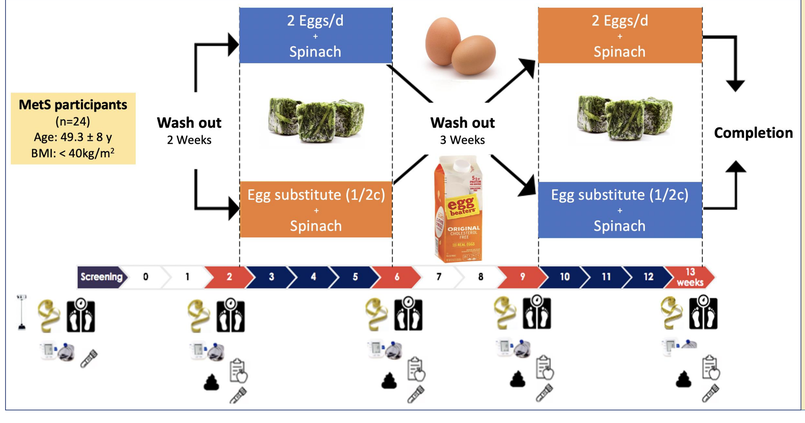
The 3 major **aims** are: To compare the inclusion of 2 eggs/d with a plant-based diet to the same diet with egg substitute on:

AIM 1: Parameters of the Metabolic syndrome

AIM 2: Plasma concentrations of choline, lutein and zeaxanthin as well as TMAO

AIM 3: Large HDL and correlations with plasma carotenoids

EXPERIMENTAL DESIGN



MATERIALS AND METHODS

Study Population

Metabolic Syndrome Participants (3/5 of NCEP-ATP III criteria)

N= 24

Waist circumference	Blood pressure	HDL-C	Triglycerides	Fasting blood glucose
≥ 102 cm for men or ≥ 88 cm for women	≥ 130/85 or Sys ≥ 130 or Dia ≥85	< 40 mg/dL for men or < 50 mg/dl for women	≥ 150 mg/dL	≥ 100 mg/dL

Samples

Diet Assessment	Fasting blood samples
3 day-diet records at baseline and after whole egg or egg substitute	Fasting blood collected from antecubital vein at baseline and at the end of each intervention, centrifuges at 2000 x g for 20 minutes, and plasma collected and stored at -80°C for analyses

Assays

Dietary analysis	Plasma biomarkers
Evaluated using NDSR software (University of Minnesota NDSR Nutrition Data System for Research)	• Plasma lipids (total cholesterol, triglycerides, HDL-c), glucose, CRP and liver enzymes (ALT & AST) were measured using a **Cobas c-111** analyzer • Plasma Insulin was measured using ELISA immunoassay **(R&D systems).** • Plasma choline and TMAO evaluated using LC-MS/MS • Lipoprotein particle size was measured by NMR • Plasma Lutein and Zeaxanthin measured using Reverse phase High-Performance liquid Chromatography

Statistics were performed in SPSS version 20. Data are represented as mean ± SD in all figures; $p< 0.05$ was considered significant

RESULTS

- **Eggs increased dietary choline to meet the DRI requirement, as well as Vitamin D, selenium, and MUFA and decreased carbohydrate intake.**
- **Lutein/zeaxanthin, W-3 fatty acids were increased by both dietary interventions compared to baseline**

Daily dietary intake

Dietary Component	Baseline	EGG	SUB
Energy (Kcal)	1677 ± 573^a	1798 ± 579^a	1699 ± 512^a
Total Fat (%)	35.6 ± 6.5^a	40.9 ± 7.2^b	35.4 ± 6.4^a
Total CHO (%)	49.6 ± 4.7^a	43.7 ± 7.7^b	47.1 ± 7.9^{ab}
Total Protein (%)	13.3 ± 3.0^a	14.8 ± 2.9^b	15.4 ± 2.8^b
SFA (g)	21.8 ± 2.8^a	29.2 ± 1.3^b	24.2 ± 11.2^{ab}
MUFA (g)	23.5 ± 9.3^a	28.6 ± 10.9^b	23.4 ± 9.1^a
Cholesterol (mg)	102 ± 86^a	438 ± 135^b	143 ± 115^a
W-3 fatty acids (g)	1.6 ± 0.7^a	2.0 ± 0.9^b	2.0 ± 0.7^b
Added sugars (g)	45.7 ± 36.2^b	32.4 ± 30.0^a	32.0 ± 21.2^a
Beta-Carotene (µg)	4084 ± 2890^a	6357 ± 2527^b	7684 ± 3387^b
Lutein + Zeaxanthin (µg)	3151 ± 4382^a	9190 ± 1527^b	9179 ± 2188^b
Choline (mg)	200.7 ± 82.9^a	436.0 ± 96.9^b	226.7 ± 109.4^a
Vitamin A (µg)	1207 ± 538^a	1643 ± 493^b	1748 ± 640^b
Vitamin D (µg)	3.3 ± 2.3^a	5.4 ± 2.3^c	4.3 ± 1.7^b
Selenium (µg)	78.6 ± 38.9^a	106.6 ± 29.4^b	101.0 ± 29.3^b

Values in the same row with different superscripts are significantly different at $p < 0.025$

Anthropometric and plasma biomarkers

Parameters	Baseline	EGG	SUB
Body weight (Kg)	99.4 ± 19.6^b	98.5 ± 19.2^a	99.6 ± 20.1^b
BMI (kg/m^2)	34.3 ± 4.8^b	33.8 ± 4.6^a	34.7 ± 4.6^b
WC (cm)	112.5 ± 11.9	113.4 ± 13.3	113.3 ± 12.7
Diastolic BP (mm Hg)	86.6 ± 5.6	86.2 ± 8.4	86.7 ± 6.6
Systolic BP (mm Hg)	183.0 ± 27.6	185.3 ± 29.0	179.1 ± 24.6
HDL cholesterol (mg/dL)	42.1 ± 10.3^b	43.3 ± 10.7^a	41.5 ± 10.1^b
Triglycerides (mg/dL)	155 ± 68	149 ± 58	156 ± 66
LDL cholesterol (mg/dL)	109.9 ± 26.6	112.3 ± 25.9	108.1 ± 19.8
LDL/HDL ratio	2.75 ± 0.88	2.72 ± 0.77	2.72 ± 0.73
Glucose (mg/dL)	103 ± 12	93 ± 11	92 ± 9
CRP (mg/dl)	0.25 ± 0.24	0.40 ± 0.57	0.27 ± 0.26

Values in the same row with different superscripts are significantly different at $p < 0.05$

FUNDING SOURCE

Egg Nutrition Center (ENC eggnutritioncenter.org)

This study was funded Egg Nutrition Center

RESULTS

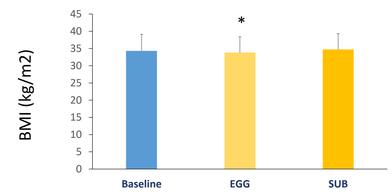


Figure 1: Body Mass Index was lower after the EGG treatment ($P < 0.025$) as indicated by the *

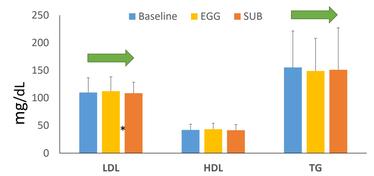


Figure 2: Plasma LDL cholesterol and TG did not change among treatments while plasma HDL cholesterol was higher with egg indicated ($P< 0.05$) as indicated by the *

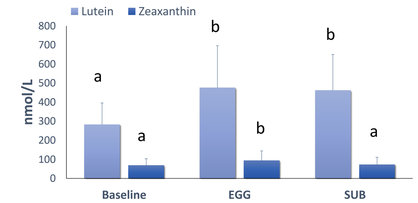


Figure 3: Concentrations of lutein and zeaxanthin at baseline and after intervention. Both EGG and SUB interventions resulted in higher concentrations of lutein ($P < 0.01$) but only EGG increased plasma zeaxanthin ($P < 0.01$) as indicated by different superscripts

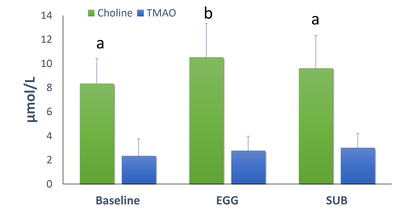


Figure 4: Concentrations of plasma choline and TMAO at baseline and after intervention. Choline was increased after EGG intervention ($P < 0.01$) as indicated by different superscripts while TMAO did not change among treatments.

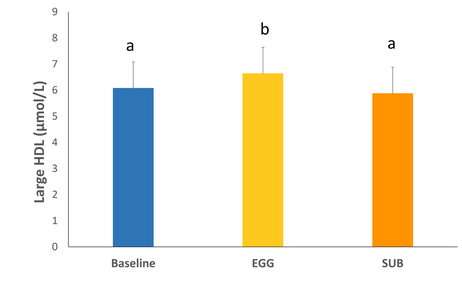


Figure 5: Concentrations large HDL at baseline and after intervention. The EGG breakfast resulted in higher concentrations of Large HDL ($P < 0.01$)

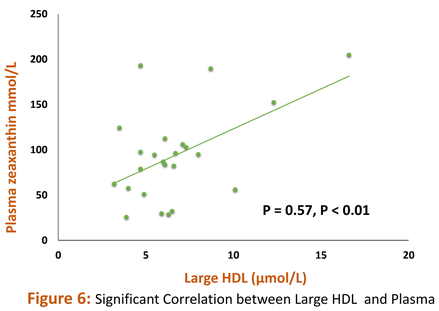
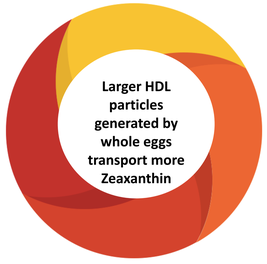


Figure 6: Significant Correlation between Large HDL and Plasma Zeaxanthin

SUMMARY

EGG vs SUB	Both Treatments vs Baseline
• Body Weight • Body Mass Index	• Dietary carbohydrate
• Dietary Choline • MUFA • Large HDL • Plasma Zeaxanthin	• Dietary protein • Plasma lutein
• Plasma Lutein • Dietary carotenoids and Selenium • Dietary protein and Dietary carbohydrate	



CONCLUSION

Inclusion of eggs in a plant-based diet reduced dyslipidemias, generated higher numbers of large HDL particles, increased plasma antioxidants and plasma choline providing additional benefits to individuals with Metabolic Syndrome.