Impact of Composition and Quantity of Triglycerides on Micellarization of Dietary Carotenoids during Simulated Digestion

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Abstract

A carotenoid-rich salad purée with varying amounts of either a structured lipid or dietary oil was digested using simulated gastric and small intestinal conditions. Lutein and carotenoids (β, β’-carotene, α-carotene, and lycopene) in chyme and micelle fraction were quantified to determine digestive stability and efficiency of micellarization (“bioaccessibility”). Relative micellarization was as follows: lutein > α-carotene > β-carotene > lycopene. Micellarization of carotenoids, but not lutein, was enhanced (P<0.05) by addition of lipid (2.5% v/w) to purée and dependent on fatty acid chain length in structured TG (c18:1 > c8:0 > c4:0). Micellarization efficiency for each carotenoid was similar when equivalent amounts of tri-oleate (c18:1), tri-linoleate (c18:2), and tri-linolenate (c18:3) were added to purée. Relatively low amounts of tri-oleate and canola oil (0.5-1.0%) were required for maximum micellarization of carotenoids, but more oil (≥2.5%) was required when TG with medium chain saturated fatty acids (e.g., tri-octanoate and coconut oil) was added to salad purée. The results suggest transfer of carotenoids from chyme to mixed micelles during digestion is inversely correlated with hydrophobicity of the pigment, generally requiring minimum (0.5-1%) lipid in the purée, and is influenced by chain length, but not degree of saturation, of fatty acids in TG. (Supported in part by OARDC Graduate Student Scholarship to TH.)

Hypothesis

Efficiency of micellarization of carotenoids during digestion will be dependent on chain length and degree of saturation of fatty acids in TG, as well as amount of the dietary TG.

Materials and Methods

1. Materials

1.1 Test Salad purée

Salad purée was prepared by homogenizing carotenoid-rich ingredients (10g). Lutein and carotenoids (α-carotene, β-carotene, β’-carotene, and lycopene) were added to the homogenate at concentrations of 1.95mg/100g, 1.17mg/100g, 3.83mg/100g, and 3.72mg/100g, respectively. Carotenoids were stable in the frozen puree for 30 days at -80°C. Equivalent amounts of triglycerides were added to 3.0g salad purée immediately before initiating simulated digestion.

2. Methods

2.1 Simulated gastric and small intestinal digestion

The digestion of the test salad purée was simulated with 0, 0.25, 0.5, 1, and 2.5% (v/w) of either safflower, canola, or coconut oil added to 3.0g salad purée. The efficiency of micellarization was calculated for each carotenoid in each digestion sample. Values are expressed as means ± SD.

2.2 Carotenoid extraction and analysis

Carotenoids were extracted from the digesta with 95% aqueous methanol. Microcrystalline and pigment phases of the digesta were isolated by ultracentrifugation (50,000 g, 15 min). The xanthophylls and lutein were quantified by HPLC as described previously.

Introduction

Carotenoids are lipid-soluble pigments plant pigments with various biological properties that include pro-vitamin A activity, antioxidant activity, photoprotection of eye and skin, and vitamin A independent regulation of cell signaling and gene transcription. In order to deliver carotenoids and their metabolites to target tissues to mediate these activities, these compounds must be released from the food matrix and incorporated into bile micelles, b) taken up by enterocytes and c) incorporated in chylomicrons and secreted into lymph for distribution to target tissues. The absorption of carotenoids is affected by numerous post-harvesting, physicochemical, dietary, physiological and pathological factors. Dietary lipid is recognized as a potent promoter of carotenoid bioavailability. This is likely associated with the ability of dietary fat to a) provide a “sink” for transfer of carotenoids from food matrix to oil droplets, b) stimulate secretion of bile and pancreatic enzymes, and c) promote the synthesis and secretion of chylomicrons. The effects of quantity and composition of dietary lipids on processes required for the absorption of carotenoids have not been systematically investigated. The primary goal of this research is to clarify the influence of amount and type of dietary triglycerides (TG) on the following processes: micellarization; uptake of carotenoids by enterocytes; and carotenoid digestion across the intestinal epithelium. This study utilized a designed experiments that investigated the influence of composition and quantity of dietary TG on micellarization of carotenoids during simulated gastric and small intestinal digestion.

2.3 Statistical analysis

Statistical analysis was performed using SPSS/Win 14.0. The efficiency of micellarization was calculated for each carotenoid in each purée sample. Values were expressed as means ± SD. Significant differences for effects of amount and type of oil were tested by one-way ANOVA followed by Dunnett’s post hoc test. Three or six observation was made to determine whether there are significant differences among different groups (data not shown) of triglycerides (TG) on micellarization of carotenoids during simulated gastric and small intestinal digestion.

Results

Experiment 1: Chain length, but not degree of saturation of fatty acids in TG influences micellarization of carotenoids from salad purée.

Experiment 2: Dietary oils enhanced micellarization of carotenoids from salad purée.

Experiment 3: Maximum micellarization of carotenoids requires relatively low amounts of TG and the amount of required TG is dependent on the type of TG.

Summary

- Partitioning of carotenoids in aqueous fraction (i.e., micellarization) during in vitro digestion of salad purée was enhanced by addition of TG in salad purée.
- Efficiency of micellarization of carotenoids from the salad is influenced by carotenoid structure: lutein > α-carotene, β-carotene > lycopene.
- Micellarization of carotenoids is dependent on chain length, but not the number and position (data not shown) of double bonds, of TG fatty acids.
- Relatively low amounts (approx. 0.5-1.0%, v/w) of trioleate and canola oil are required for maximum micellarization of carotenoids, but more oil (approx. 0.5%, v/w) if TG contains medium chain saturated fatty acids, e.g., trioctanole and coconut oil.

References


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Abbreviations used: TG, triglyceride; LUT, lutein; BC, β-carotene; AC, α-carotene; LYY, lycopene.