NUTRITION RESEARCH 36 (2016) 679–688

Available online at www.sciencedirect.com

ScienceDirect

www.nrjournal.com

Original Research

Consumption of canned citrus fruit meals increases human plasma ß-cryptoxanthin concentration, whereas lycopene and ß-carotene concentrations did not change in healthy adults

Chenghao H. Zhu[a], Erik R. Gertz[b], Yimeng Cai[a], Betty J. Burri[a,b,*]

[a] University of California Davis, 1 Shields Ave, 430 W Health Sciences Dr, Davis, CA 95616
[b] Western Human Nutrition Research Center, USDA/ARS, 430 W Health Sciences Dr, Davis, CA 95616, USA

ARTICLE INFO

Article history:
Received 15 December 2015
Revised 10 March 2016
Accepted 17 March 2016

Keywords:
Carotenoid
Plasma response
Citrus
Human
β-Cryptoxanthin
Lycopene

ABSTRACT

Several studies suggest that β-cryptoxanthin has a greater plasma response from its common food sources than other carotenoids such as β-carotene and lycopene. The hypothesis of this study is that changes in plasma β-cryptoxanthin concentrations will be greater than changes in plasma β-carotene or lycopene concentrations even if these carotenoids are fed in a similar food matrix, such as citrus fruit. We tested this hypothesis by measuring changes in plasma concentrations of β-cryptoxanthin, lycopene, and β-carotene after feeding measured amounts of canned tangerines and pink grapefruit to healthy nonsmoking adult humans. Volunteers served as their own controls and received both citrus fruit treatments randomly. In the first study, 8 subjects ate single meals of 234-304 g of tangerines or 60-540 g of pink grapefruit. The second study compared changes in plasma carotenoid concentration caused by feeding 234 g of tangerines or 540 g of pink grapefruit to 11 subjects. Blood was collected 5 times within 24 hours after each citrus meal. Carotenoid concentrations were analyzed by reversed-phase high-performance liquid chromatography. Plasma β-cryptoxanthin concentrations increased within 5 hours and then stabilized, remaining high throughout the 24 hours measured. Plasma concentrations of lycopene and β-carotene did not change. These results show that β-cryptoxanthin concentrations increased after a citrus fruit meal, but lycopene and β-carotene concentrations did not change after a similar citrus fruit meal. These results support our hypothesis that changes in plasma β-cryptoxanthin are greater than changes in plasma lycopene or β-carotene, even when these carotenoids are fed in a similar food matrix.

Abbreviations: AUC, area under the curve; BMI, body mass index; BCO1, 15,15′-β-carotene oxygenase; HDL, high-density lipoprotein; HPLC, high-performance liquid chromatography; LDL, low-density lipoprotein.

* *Corresponding author at:* Western Human Nutrition Research Center, USDA/ARS, 430 W Health Sciences Dr, Davis, CA, USA 95616. Tel.: +1 530 752 4764; fax: +1 530 752 4390.
E-mail addresses: chzhu@ucdavis.edu (C.H. Zhu), erik.gertz@ars.usda.gov (E.R. Gertz), ymcai@ucdavis.edu (Y. Cai), bjburri@ucdavis.edu, bburri@pacbell.net (B.J. Burri).

http://dx.doi.org/10.1016/j.nutres.2016.03.005
0271-5317/Published by Elsevier Inc.

1. Introduction

β-Cryptoxanthin, α-carotene, and especially β-carotene are vitamin A–forming carotenoids found in fruits and vegetables [1,2]. Vitamin A activity of pro-vitamin A carotenoid-rich foods depends partially on the absorption of the carotenoid from foods [3–5] and on the carotenoid's suitability as a substrate for 15,15′-β-carotene oxygenase (BCO1) [6]. Thus, differences in carotenoid absorption from a food may be important in determining the amount of vitamin A formed from that food.

β-Carotene is found in a wide variety of vegetables, fruits, oils, and supplements [7]. The absorption and thus the bioavailability of β-carotene in food vary greatly, being highest in oils and lowest in green leafy vegetables. These differences in bioavailability are well known and are represented by the estimates of retinol activity equivalents, which vary from 1 μg retinol activity:2 μg β-carotene in oils to 1 μg:12 μg for β-carotene in fruits up to 1 μg:28 μg β-carotene in vegetables [4,5]. Once absorbed, β-carotene is a highly effective substrate for BCO1 [6]. Therefore, the decrease of retinyl activity equivalent estimates (from 1 μg:2 μg in oil to 1 μg:28 μg in vegetables) suggests that the absorption and bioavailability of β-carotene from most fruits and vegetables are relatively poor.

Lycopene is a non–vitamin A forming carotenoid that has a limited distribution in foods, with tomatoes, watermelon, pink grapefruit, pink guava, and papaya being good sources [7]. Lycopene consumption is high in many populations, including those from the United States and much of Europe [8]. The impact of food matrix on lycopene bioavailability is well established. Specifically, including fat in the food matrix increases bioavailability dramatically. Food processing is also important, with more processed foods tending to have greater bioavailability [9–13]. Even with processing and the addition of fat, the absorption and bioavailability of lycopene are also relatively poor from most foods [9–13].

β-Cryptoxanthin is found in high concentrations in only a few foods such as tangerines, oranges, and pumpkin [7]. Unlike β-carotene and lycopene, β-cryptoxanthin is present in modest amounts (about 1 mg/100 g) even in its richest food sources. Therefore, typical dietary intakes of β-cryptoxanthin in the United States are lower than intakes of β-carotene and lycopene. However, despite its scarcity in foods, β-cryptoxanthin is one of the most abundant carotenoids in blood [14]. The abundance of β-cryptoxanthin in blood compared with its scarcity in foods suggests that β-cryptoxanthin may be more bioavailable than β-carotene and lycopene from common food sources. Currently, there is little information on β-cryptoxanthin absorption and bioavailability from food [15], and indeed, there are only a few studies of any aspect of β-cryptoxanthin metabolism in humans [3,16–18]. Even so, several studies suggest that β-cryptoxanthin is better absorbed from foods and more bioavailable than β-carotene or lycopene [3,14,18].

There are a few reasons why β-cryptoxanthin may be more bioavailable than other common carotenoids from food. First, β-cryptoxanthin is a xanthophyll and therefore more polar and potentially more easily absorbed from food than more hydrophobic carotenes such as β-carotene and lycopene [1,2]. Second, the most common food sources for β-cryptoxanthin, β-carotene, and lycopene differ. A common food source of β-cryptoxanthin is citrus fruit, whereas lycopene is found primarily in tomatoes and β-carotene in a wide variety of fruits and vegetables [1,2,7,14]. Carotenoids in citrus fruit may be more bioavailable than carotenoids in tomatoes and vegetables. Third, carotenoid cleavage activity in intestinal mucosal cells differs between carotenoids [19], so it is possible that the rate or extent of β-cryptoxanthin cleavage to its metabolites might be much lower than lycopene or β-carotene cleavage.

The hypothesis of these studies is that feeding equivalent amounts of β-cryptoxanthin, β-carotene, and lycopene from a similar food matrix will result in higher plasma concentrations of β-cryptoxanthin compared with the other carotenoids. We tested this hypothesis by comparing the changes in concentrations of plasma β-cryptoxanthin, β-carotene, and lycopene after feeding healthy well-nourished humans single meals of canned citrus fruit. These studies will generate useful information for scientists investigating carotenoid absorption and metabolism.

2. Methods and materials

2.1. Chemicals

Lycopene, β-carotene, β-apo-8-carotenal, and butylated hydroxytoluene were purchased from Sigma-Aldrich Chemical Co (St Louis, MO, USA). β-Cryptoxanthin, α-carotene, and zeaxanthin were from Santa Cruz Biotechnology, Inc (Dallas, TX, USA). Lutein was from ChromaDex, Inc (Irvine, CA, USA). Hexanes, dichloromethane, and methanol (high-performance liquid chromatography [HPLC] grade) were purchased from Fisher Scientific Inc (Waltham, MA, USA). Ethanol (100%) was purchased from Decon Labs, Inc (King of Prussia, PA, USA). Interday variance was measured with human plasma purchased from UTAK Laboratories, Inc (Valencia, CA, USA). Geisha JFE SHOJI Trade America, Inc, canned mandarin oranges segments and Dole Food Company grapefruit segments were purchased from local markets in Davis, CA, USA.

2.2. Study design

Two studies are described. The first study determined the amount of tangerine and pink grapefruit needed to be consumed to cause carotenoid concentration changes in plasma. It compared carotenoid plasma responses after feeding single meals of 60, 105, or 540 g of pink grapefruit vs 234 or 304 g of tangerines to healthy adult humans (Table 1). Eight volunteers participated in this crossover study (with 1 man and 1 woman testing each treatment).

After analyzing results from this study, the second study was conducted as a randomized, crossover, single-blind study (with researchers analyzing carotenoid concentrations blinded to the intervention) by feeding 540 g of pink grapefruit or 234 g of tangerines as single meals to 11 volunteers (6 men, 5 women). Aside from the amount of citrus fruit fed during the studies, the studies followed similar procedures for