CAROTENOIDS
(alpha-carotene, beta-carotene, lycopene, lutein, and cryptoxanthin)
October 2010

Introduction

Carotenoids are plant pigments with 40 carbon atoms per molecule (tetraterpenoids). Some 700 carotenoids have been isolated from natural sources, of which the structures of 563 have been elucidated [1,2]. Those carotenoids that contain oxygen are known as xanthophylls, while those that are oxygen-free are known as carotenes. They are all synthesised by higher plants (as well as by some algae and bacteria) and are widely distributed in animals, which acquire them via their diet. For example, many crustaceans and finned fish obtain carotenoids such as astaxanthin from marine plant life, which gives them a pink colour. In the plant carotenoids act as photosynthetic accessory pigments and also play a protective function as scavengers of oxygen radicals released from chloroplasts during photosynthesis, thus protecting cellular constituents such as DNA from free radical damage. Lycopene has the highest antioxidant activity among the carotenoids [3], while lycopene, β-cryptoxanthin and β-carotene are the best absorbed and hence present in the human plasma at the highest concentrations. β-carotene and α-carotene, together with β-cryptoxanthin, have a pro-vitamin A function in the human.

Food sources of carotenoids

There are about 20 carotenoids in the human diet. Their presence in leafy vegetables is masked by the green of chlorophyll, but in other foodstuffs carotenoids are more evident, contributing to their red, yellow and orange colours [4]. Carrots are the major source of β-carotene, although spinach, broccoli and watercress also contain substantial amounts. The predominant dietary source of lycopene is tomatoes. Good dietary sources of lutein include peas, sprouts, greens, broccoli, spinach and peppers. Mangoes, apricots and oranges are sources of cryptoxanthin and also contain some β-carotene.

Carotenoid	Source	Comments
lycopene	tomatoes	Absorbed well, present in plasma
β-cryptoxanthin	citrus fruit	Absorbed well, present in plasma
β-carotene	carrot, mango, spinach, broccoli, watercress	Absorbed well, present in plasma
lutein	green leafy veg	Best marker of green veg intake
zeaxanthin	green leafy veg, maize, orange peppers	Photosynthetic accessory pigment
α-carotene	peppers, carrots	½ as much in carrots as β -carotene
echinenone	marine organisms	
capsanthin	red peppers	
astaxanthin	salmon, lobster	Synthesised from echinenone
canthaxanthin	mushrooms	Food colourant

Much of the value of carotenoid analysis in serum is to determine the adequacy of fruit and vegetable intake in the diet. Cooking increases the extraction efficiency of carotenoids from the intracellular organelles in which they are located and enhances their bioavailability in humans [5]. They are absorbed by the

• The Stone House • 9 Weymouth Street • London W1W 6DB England • Tel: (+44) 020 7636 5959/5905 • Fax: (+44) 020 7580 3910 • Email: info@biolab.co.uk •

gastrointestinal enterocytes and appear unchanged in the circulation, where they are transported on lipoproteins [6].

Pro-vitamin A function of carotenoids

Until fairly recently the functions of carotenoids were discussed only in terms of their potential vitamin A activity. Approximately 50 carotenoids have "provitamin A" activity because the body can convert them into retinol. The most significant provitamin A carotenoid in humans is β-carotene, but α-carotene and β-cryptoxanthin are also be metabolised to vitamin A. Each molecule of β-carotene in the body can be converted into two molecules of vitamin A, although nutritionally the relationship is more complex due to the inefficiency of absorption and conversion of β-carotene.

The importance of this is that carotenes act as a non-toxic reserve of vitamin A, available for conversion according to metabolic demand. In contrast, dietary vitamin A from animal sources is toxic at higher levels of intake and has limited storage availability (in hepatocytes). Analysis of extracts from human organs and tissues including liver, lung, breast, and cervix has revealed the presence of the same prominent carotenoids and their metabolites as are found in human serum [7].

Other physiological actions of carotenoids

Most carotenoids are free radical-scavenging antioxidants. Carotenoids, particularly β-carotene, are also believed to enhance the function of the immune system. In addition, carotenoids have been shown stimulate cell to cell communication (poor cell to cell communication can lead to unregulated cell growth, which is potentially a pre-cancerous condition). They are also believed to have a role in reproduction, since the corpus luteum has the highest concentration of β-carotene of any organ, suggesting that it plays a role in the female cycle. Lutein and zeaxanthin, in a possible extension of their role as photosynthetic accessory pigments in the plant, apparently act to absorb damaging blue and near-ultraviolet light in the human retina, where they are concentrated in the macula lutea or "yellow spot" [1,2,3]. It has been hypothesised that that lutein and zeaxanthin protect the macula against photo-oxidative damage which can cause age-related macular degeneration and blindness. Lycopene ingestion has been suggested to produce a significant reduction in blood pressure, serum lipids and oxidative stress markers in some subjects [8].

Carotenoids in serum

Biolab currently measures 5 carotenoids in serum with reasonable confidence (α-carotene, β-carotene, lycopene, lutein and β-cryptoxanthin) using a high-pressure liquid chromatography technique which is internally and externally quality controlled. Serum lutein appears to be the best marker of recent fresh vegetable ingestion [9,10] and our results suggest a good correlation with paraoxonase activity (an antioxidant enzyme whose activity falls with a poor diet).

The Biolab reference intervals for serum carotenoids are as follows:

α-carotene	0.30 – 1.50 μmol/L
β-carotene	0.40 – 3.00 μmol/L
lycopene	0.30 – 4.50 μmol/L
lutein	0.40 – 1.10 μmol/L
β-cryptoxanthin	0.13 – 0.45 μmol/L

Patient preparation: Patients should refrain from taking nutritional supplements for 48 hours before the collection of the sample.

Specimen requirements: 8 mL of whole blood taken into a serum separator tube (SST). Postal samples (overnight delivery) are acceptable.

Turn around time: 5 working days.

References:

1. Britton G, Liaaen-Jensen S, Pjander H. Carotenoids, volume 4 Natural Functions. Birkhauser Verlag 2008, Basel ISBN 978-3-7643-7499-0.
2. Bendich A, Olson JA. Biological actions of carotenoids. FASEB J 1989:3;1927-32.
3. Miller NJ, Sampson J, Candeias LP, Bramley PM, Rice-Evans CA. Antioxidant activities of carotenoids and xanthophylls. FEBS Letters 1996;384:240-242.
4. Lea, A. G. H. HPLC of natural pigments in foodstuffs. In: HPLC in food analysis. Macrae, R. (Editor) Academic Press Ltd. London 1988 (2nd edn) pp 277-333.
5. Gartner C, Stahl W, Sies H. Lycopene is more bioavailable from tomato paste than from fresh tomatoes. Am J Clin Nutr 1997;66:116–22.
6. Erdman JW, Bierer TL, Gugger ET. Absorption and transport of carotenoids. Ann NY Acad Sci 1993;691:76-85.
7. Khachik F. Distribution and metabolism of dietary carotenoids in humans as a criterion for development of nutritional supplements. 14th International Symposium on Carotenoids 2006;78:1551-1557.
8. Paran, E. and Engelhard, Y.N. (2001) Effect of lycopene, an oral natural antioxidant on blood pressure. J Hypertens 2001;19: S74
9. Scott KJ, Thurnham DI, Hart DJ, Bingham SA, Day K. The correlation between the intake of lutein, lycopene and b-carotene from vegetables and fruits and blood plasma concentrations in a group of women ages 50–65 years in the UK. Br J Nutr 1996;75:409–18.
10. Thurnam DI, Northrop-Clewes CA, Chopra M. Biomarkers of vegetable and fruit intakes. Am J Clin Nutr 1998;68:756-757