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ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

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# Carotenoids Contents from Various Sources and Their Potential Health Applications

Alam Zeb and Sultan Mehmood
Department of Biotechnology, University of Malakand, Chakdara, N.W.F.P, Pakistan
E-mail: Alamzeb01@yahoo.com

**Abstract:** Carotenoids are the class of hydrocarbons, widespread in nature and important pigments in living organisms. They are present in foods such as carrots, pumpkins, sweet potatoes, tomatoes, and other deep green, yellow, orange, red fruits, sea buckthorn berries, common vegetables and some numerous vegetable oils, of which Palm oil and palm oil products contains the highest known concentration of carotenoids. Palm oil products are the good sources of carotenoids in nature. The role of carotenoids in health application has been explained. The present paper describes the chemistry of important carotenoids, their various sources and uses in health applications.

**Key words:** Carotenoids, chemistry, health applications, sources, vegetables

## Introduction

The name carotenoids, is derived from the fact that they constitute the major pigment in the carrot root, *Daucus carota*, are undoubtedly among the most widespread and important pigments in living organisms. Carotenoids are the pigments responsible for the colors of many plants, fruits and flowers. Carotenoids are fat-soluble nutrients and categorized as either xanthophylls or carotenes according to their chemical composition. Carotenoids are found in common foods and vegetables. Most xanthophylls are found in green leafy vegetables and nearly all carotenes are found in yellow vegetables. The most important carotenoids are alpha-carotene, beta-carotene, and beta-cryptoxanthin, Lutein, violaxanthin, neoxanthin, and Lycopene; their structures are given in Fig. 1.

Beta-carotene, alpha-carotene, beta-cryptoxanthin are carotenes that are converted into vitamin A or retinol in the body. They are found in many yellow fruits and vegetables. Beta-carotene is the most widely studied carotenoid. Lutein and zeaxanthin are both stored in the retina of the eye. Neither converts to vitamin A. Both are powerful antioxidants and may be very important for healthy eyes. They are found in many yellow fruits and vegetables. Lutein is also present in green vegetables, such as broccoli, cabbage, and kale. Lycopene is responsible for the red color in fruits and vegetables, including tomatoes, red grapes, watermelon, and pink grapefruit. It is also found in papayas and apricots. It does not convert to vitamin A but may have important cancer fighting properties and other health benefits. Currently, interest is focusing on the nutritional and medicinal aspects of different individual carotenoid. Since they are likely to grow in importance and value, their sources is very important. Therefore the present study aimed to collect recent information on the important carotenoids contents from various sources and their relation with health aspects, so that nutritional importance of these sources is clear for our common day life.

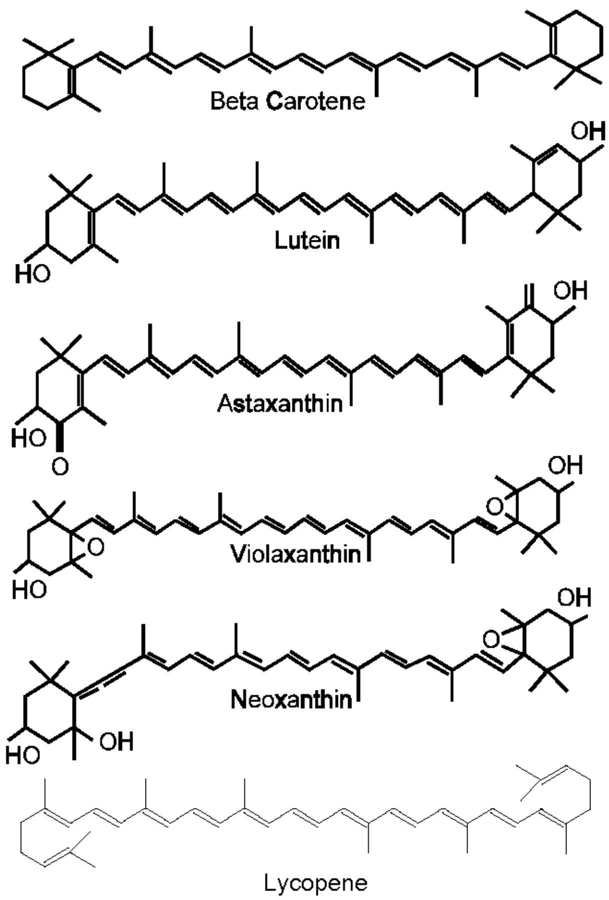


Fig. 1: Structure of selected carotenoids

**Chemistry of Carotenoids:** Carotenoids are a class of

Table 1: Carotenoids content of Sea buckthorn oil from different origins and variety

| Sources | Carotenoids (mg/100g) | | Reference | Variety |
|---|---|---|---|---|
| | Ranges | Average | | |
| Carotenoids content | 314 - 2139 | 1167 | Zhang *et al*., 1989 | Caucaus |
| Seed oil | 50 - 85 | 67.5 | Mironov, 1989 | Caucaus |
| Pulp oil | 330 - 370 | 350 | Mironov, 1989 | Caucaus |
| Seed coat oil | 180 - 220 | 200 | Mironov, 1989 | Pamirs |
| Seed oil | Trace | -- | Mironov, 1989 | Pamirs |
| Pulp oil | 900 - 1000 | 950 | Mironov, 1989 | |

Table 2: Retinol equivalents of red palm oil compared with other foods products

| Fruits and vegetables | Carotene derived (ppm) |
|---|---|
| Red palm oil | 30,000 |
| Carrots | 2,000 |
| Leafy vegetables | 685 |
| Apricots | 250 |
| Tomatoes | 100 |
| Bananas | 30 |
| Orange juice | 8 |

hydrocarbons consisting of eight isoprenoid units joined in such a manner that the arrangement of isoprenoid units is reversed at the center of the molecule so that the two central methyl groups are in a 1,6-positional relationship and the remaining non-terminal methyl groups are in a 1,5-positional relationship (Fig. 1). Carotenoids are defined by their chemical structure. The majority carotenoids are derived from a 40-carbon polyene chain, which could be considered the backbone of the molecule. This chain may be terminated by cyclic end-groups (rings) and may be complemented with oxygen-containing functional groups (McCollum and Kennedy, 1916). These hydrocarbons are commonly known as carotenes, while oxygenated derivatives of these hydrocarbons are known as xanthophylls. Beta-carotene, the principal carotenoid in carrots, is a familiar carotene, while lutein, the major yellow pigment of marigold petals, is a common xanthophyll. The structure of a carotenoid ultimately determines what potential biological function that pigment may have. The characteristic pattern of alternating single and double bonds in the polyene backbone of carotenoids allows them to absorb excess energy from other molecules, while the nature of the specific end groups on carotenoids may influence their polarity. The former may account for the antioxidant properties of biological carotenoids, while the latter may explain the differences in the ways that individual carotenoids interact with biological membranes (Britton, 1995).

**Sources of Carotenoids:** About 600 carotenoids have been isolated from natural sources (Ong and Tee, 1992). The most important sources for carotenoids are plants, where often the brilliant colors of the carotenoids are covered by the green chlorophyllic pigments (i.e. in green vegetables and leaves). In a number of cases, as plants mature, the chlorophyll content decreases leaving the carotenoids responsible for the beautiful colors of most fruits (pineapple, oranges, lemons, grapefruit, strawberry, tomatoes, paprika, rose hips) and many flowers (Eschscholtzia, Narcissus). Carotenoids are also responsible for the colors of some birds (flamingo, canary), certain insects, and marine animals (shrimp, lobster and salmon) (Mangels *et al*., 1993).

Sea buckthorn fruits are rich in carotenoids pigments located in membranes and the fleshy mesocarp. Caroteno-lipoprotein complexes are located particularly in fruit membranes where polar lipids may function as bridge compounds between the polar (protein) and non-polar (carotenoids) moieties (Pintea *et al.,* 2001). It was found that the carotenoids to consist of nearly 20% β-carotene, 30% γ-carotene, and 30% lycopene as well as 15% oxygen containing carotenoids (Zeb, 2004). Pulp oil shows higher levels of β- carotene than seed oil, and *H. salicifolia* appears to have the highest level of β-carotene in both pulp and seed oil among species (Table 1). It was establish that more the β-carotene greater will be stability of oils (Lutfullah *et al.,* 2003; Zeb and Ahmad 2004; Zeb *et al.,* 2004). Within *H. rhamnoides*, subsp. mongolica shows the lowest β-carotene level in seed and pulp oil (Lian *et al*., 2000). Concentration of β-carotene constitute 15–55% of total carotenoids, depending on the origin (Lian *et al*., 2000; Yang and Kallio, 2001). However the concentration of β-carotene and of the total carotenoids are affected substantially by berry maturity, and practices of fertilization (Zhang *et al*., 1989; Yang, 2001).

Carotenoids are present in numerous vegetable oils, including corn, groundnut, soybean, rapeseed, linseed, olive, barley, sunflower, and cottonseed oils (NRC, 1989; Olson, 1990; Goodman, 1984; UNICEF, 1992; Int Vit A Con Group, 1989; Zeitlin *et al*., 1992; Gibson, 1990). The concentration of carotenoids in these vegetable oils is generally low, less than 100 ppm. Of the vegetable oils that are widely consumed, Palm oil contains the highest known concentration of agriculturally derived carotenoids (Jain *et al*., 1990). In fact, crude palm oil is the world's richest natural plant source of carotenes in terms of retinol. It contains about 15 to 300 times as many retinol

Table 3: carotenoids contents (percentages) of palm oil from different species and sources

| Type | E. guineensis | | | E oleifera | Hybrids | | Back cross | Pressed fibre oil | Second pressed oil | Carot-enoid conce-ntrate | Red palm oil |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | tenera | pisifera (P) | Dura (D) | (O) | O x P | O xD | ODxP | | | | |
| Phytoene | 1.27 | 1.68 | 2.49 | 1.12 | 1.83 | 2.45 | 1.30 | 11.87 | 6.50 | 1.5 | 2.0 |
| Phytofluene | 0.06 | 0.90 | 1.24 | trace | trace | 0.15 | trace | 0.40 | 1.63 | 0.3 | 1.2 |
| Cis-β-carotene | 0.68 | 0.10 | 0.15 | 0.48 | 0.38 | 0.55 | 0.42 | 0.49 | 0.28 | 0.9 | 0.8 |
| β-carotene | 56.02 | 54.39 | 56.02 | 54.08 | 60.53 | 56.42 | 51.64 | 30.95 | 31.10 | 49.9 | 47.4 |
| α-carotenes | 35.16 | 33.11 | 24.35 | 40.38 | 32.78 | 36.40 | 36.50 | 19.45 | 20.68 | 33.3 | 37.0 |
| Cis-α-carotene | 2 49 | 1.64 | 0.86 | 2.30 | 1.37 | 1.38 | 2.29 | 1 77 | 1.70 | 5.5 | 6. 9 |
| ζ-carotene[a] | 0.69 | 1.12 | 2.31 | 0.36 | 1.13 | 0.70 | 0.36 | 7.56 | 4.62 | 1.7 | 1.3 |
| δ-carotene | 0.83 | 0.27 | 2.00 | 0.09 | 0.24 | 0.22 | 0.14 | 6.94 | 2.13 | 0.6 | 0.6 |
| γ-carotene[b] | 0 33 | 0.48 | 1.16 | 0.08 | 0.23 | 0.26 | 0.1 9 | 2.70 | 2.48 | 1.3 | 0.5 |
| Neurosporene[b] | 0.29 | 0.63 | 0.77 | 0.04 | 0.23 | 0.08 | 0.08 | 3.38 | 1.88 | 0.1 | trace |
| β-zeacarotene | 0.74 | 0.97 | 0.56 | 0.57 | 1.03 | 0.96 | 1.53 | 0.37 | 0.58 | 1.3 | 0.5 |
| α-zeacarotene | 0.23 | 0.21 | 0.30 | 0.43 | 0.35 | 0.40 | 0.52 | trace | 0.15 | 0.4 | 0.3 |
| Lycopene[c] | 1.30 | 4.50 | 7.81 | 0.07 | 0.05 | 0.04 | 0.02 | 14.13 | 26.45 | 3.4 | 1.5 |
| Total (pmp) | 673 | 428 | 997 | 4,592 | 1,430 | 2,324 | 896 | 5,162 | 2,510 | 80,560 | 545 |

a. With two cis isomers. b. With one as isomer. c. With three cis isomers.

Table 4: Carotenoid content of various palm oil fractions [9]

| Palm oil fractions | Carotene derived (ppm) |
|---|---|
| Crude palm oil | 630-700 |
| Crude palm olein | 680-760 |
| Crude palm stearin | 380-540 |
| Residual oil from fibre | 4,000-6,000 |
| Second-pressed oil | 1,800-2,400 |
| Red Palm oil | 500-700 |

Total carotenoids estimated at 446 nm

equivalents as carrots, leafy green vegetables, and tomatoes, which are considered to have significant quantities of provitamin A activity (Zachman, 1988) (Table 2).

Palm forests are found in West Africa, oil palms are actually cultivated in East Africa, South America, Malaysia, and Java. Palm oil from the Far East and from Zaire contains 500-800 ppm of carotenes, whereas that from Côte d'Ivoire and especially Benin contains 1,000-1,600 ppm, but the oil yield is less (Ostrea *et al*., 1986; Ala-Houhala *et al.,* 1988). Oil from the tenera variety that is widely planted in Malaysia has a carotenoids content of about 500-700 ppm (Zeitlin *et al*., 1992).

Other oil palm species, such as *Elaeis oleifera*, a South American palm, have been found to contain a higher concentration of carotenes (Nichols and Nichols, 1981). Hybrids of *E oleifera and E. guineensis* also produce oils with high concentrations of carotenoids. The following values have been found for the total carotenoid content of oil from different species, varieties, and hybrids: *E. guineensis var. pisifera* (P), 428 ppm; var. *dura* (D), 997 ppm; *E. oleifera* (O), 4,592 ppm; the hybrid O x P. 1,430 ppm; O x D, 2,324 ppm; and the back-cross OD x P, 896 ppm (Table 3). *E. oleifera* oil has the highest carotenoid content and *E. guineensis* oil the lowest, with the hybrids and the backcross having intermediate concentrations. It can be seen from the table that the species and hybrids are comparable with regard to the major components, α- and β-carotene. The Table 4 shows the carotenoids contents of various palm products.

The primary odor constituents derived from carotenoids are $C_{13}$, $C_{11}$, $C_{10}$ and $C_9$ derivatives formed via enzymatic oxidation and photo-oxidation of the various carotenoids found in plants, flowers and fruits. While other aroma constituents such as esters, terpenes, pyrazines, etc. are usually also present, these $C_9$ to $C_{13}$ compounds often are essential to the odor profile. Table 5 shows common oxidative/ degradation products of Carotenoids, responsible for the different odor of the material they contains.

**Health Applications of Carotenoids:** In human beings, carotenoids can serve several important functions. The most widely studied and well-understood nutritional role for carotenoids is their provitamin A activity. Deficiency of vitamin A is a major cause of premature death in developing nations, particularly among children. Vitamin A, which has many vital systemic functions in humans, can be produced within the body from certain carotenoids, notably beta-carotene (Britton *et al*., 1995; Patton *et al.,* 1990; Ibrahim *et al.,* 1991). Dietary beta-carotene is obtained from a number of fruits and vegetables, such as carrots, spinach, peaches, apricots, and sweet potatoes (Mangels *et al*., 1993). Other provitamin A carotenoids include alpha-carotene (found in carrots, pumpkin, and red and yellow peppers) and cryptoxanthin (from oranges, tangerines, peaches, nectarines, and papayas).

Carotenoids also play an important potential role in

Table 5: Common Carotenoids Degradation Products Found in Plants

| Name | Examples of Occurrence |
|---|---|
| Beta-Ionone | Osmanthus, Rose, Black Tea, Tomato, Blackberries, Raspberries, Passion fruit, Carrots, Tobacco, Apricot, Carambola, Cherries, Mango, Bell Pepper, Plum |
| Alpha-Ionone | Black currant, Osmanthus, Black Tea, Blackberries, Raspberries, Carrots, Tobacco, Banana, Cherries, Plum, Celery, Peach, Popcorn, Tomato |
| Beta-Damascone | Rose, Osmanthus, Black tea, Mountain papaya, Rum, Tobacco |
| Beta-Damascenone | Apricot, Rose, Beer, Carambola, Grape, Kiwi, Mango, Tomato, Wine, Rum, Raspberries, Passion fruit, Blackberries |
| Oxo-Edulan I | Purple Passion fruit, Osmanthus, Burley tobacco, Virginia tobacco |
| Oxo-Edulan II | Purple Passion fruit, Osmanthus, Burley tobacco, Virginia tobacco |
| Theaspirone | Yellow Passion fruit, Black Tea, Burley tobacco |
| 4-Oxo-beta-ionone | Red Fox, Black Tea, Osmanthus, Burley tobacco, Freesia flower, Boronia |
| 3-Oxo-alpha-Ionone | Osmanthus, Virginia tobacco, |
| Dihydroactinodiolide | Osmanthus, Black Tea, Tomato, Cassia, Cassie, Ambergris, Tobacco |
| 4-Oxoisophorone | Osmanthus, Black tea, Saffron |
| Safranal | Saffron, Osmanthus, Black tea, Grapefruit juice, Mate, Paprika |
| Beta-Cyclocitral | Roasted Mate, Rum, Tea, Tomato, Cantaloupe, Paprika, Peas, Apricot, Broccoli, Melon |

human health by acting as biological antioxidants, protecting cells and tissues from the damaging effects of free radicals and singlet oxygen. Lycopene, the hydrocarbon carotenoid that gives tomatoes their red color, is particularly effective at quenching the destructive potential of singlet oxygen (Di Mascio *et al*., 1989). Lutein and zeaxanthin, xanthophylls found in corn and in leafy greens such as kale and spinach, are believed to function as protective antioxidants in the macular region of the human retina (Snodderly, 1995; Handelman *et al*. 1988; Landrum *et al*., 1997). Astaxanthin found in salmon, shrimp, and other seafoods, is another naturally occurring xanthophyll with potent antioxidant properties (Di Mascio *et al*., 1991). Other health benefits of carotenoids that may be related to their antioxidative potential include enhancement of immune system function (Bendich, 1989), protection from sunburn (Matthews-Roth, 1990), and inhibition of the development of certain types of cancers (Nishino, 1998). Lycopene prevents oxidation of low-density lipoprotein (LDL) cholesterol and reduces the risk of developing atherosclerosis and coronary heart disease (Agarwal and Rao, 1998). This study showed that daily consumption of tomato products providing at least 40 mg of lycopene was enough to substantially reduce low-density lipoprotein (LDL) oxidation. High LDL oxidation is associated with increased risk of atherosclerosis and coronary heart disease. This lycopene level can be achieved by drinking just two glasses of tomato juice a day. Research shows that lycopene in tomatoes can be absorbed more efficiently by the body if processed into tomato juice, sauce, paste and ketchup. The bound chemical form of lycopene found in tomatoes is converted by the temperature changes involved in processing to make it more easily absorbed by the body. A considerable wealth of research data has been accumulated regarding the efficacy of various carotenoids in prevention, treatment and adjuvant treatment of cancers; combined with chemotherapy and/or radiotherapy (Lu *et al*., 2003; Mannisto *et al*., 2004; Karp and Tsao, 2003; Van Zandwijk and Hirsch, 2003; Russell, 2004; Kristal, 2004; Murtaugh *et al*., 2004). Despite of the toxic behavior of carotenoids toward some tumor patient especially the smokers; carotenoids are good source of anti-tumor agent.

**Conclusion:** Carotenoids are present in different edible and non-edible materials; of which the highest amount are present in palm oil and their various products; secondly, the sea buckthorn berries and yellow vegetables placed on the third position. So from the easiest availability of carotenoids from the various sources, describe above and their importance in various health applications, it is therefore easy to suggest that palm oil products, sea buckthorn berries and yellow vegetables; can be used as alternative low outlay medicine in combating serious health conditions.

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