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Color Your Customers Healthy With Carotenoids

By Yousry Naguib, PhD

Fruits and vegetables get their vibrant colors from carotenoids, a class of closely related chemicals. Approximately 600 carotenoids have been isolated from plants and animals; of these about 50 are present in a typical diet containing fruits and vegetables, and about 20 of them have been found in plasma and tissues.

Carotenoids are generally classified as hydrocarbon carotenoids known as carotenes, such as alpha-carotene, beta-carotene, and lycopene; and oxygen-containing carotenoids known as xanthophylls, such as cryptoxanthin, lutein and zeaxanthin. The six prevalent carotenoids present in human plasma are: alpha-carotene, beta-carotene, beta-cryptoxanthin, lycopene, lutein, and zeaxanthin.

Leafy green vegetables such as spinach and Brussels sprouts contain mostly lutein and zeaxanthin, while orange and yellow vegetables such as carrots, sweet potatoes, and squash contain predominantly carotenes. Cooked vegetables contain higher amounts of carotenoids than raw ones, presumably because cooking disrupts cell membranes and frees the carotenoids.

Of all the carotenoids, alpha-carotene, beta-carotene and cryptoxanthin are the main vitamin A precursors. Most carotenoids have antioxidant activity, particularly against singlet oxygen and oxygen-free radicals, which have been implicated in biological systems, and are capable of damaging proteins, lipids and DNA, leading to inflammatory diseases, cancer, cardiovascular disease, and all aspects of aging.

People who eat a variety of antioxidant-rich foods, including vegetables and fruits that contain carotenoids are less likely to develop certain cancer than people whose diets lack antioxidants.

A study published in 1994 reported that men with high serum carotenoid levels had a coronary artery disease event rate 60 percent lower than those with the lowest carotenoid levels.

This finding was stronger in men who had never smoked.

Beta-carotene

Beta-carotene is the carotenoid that gives carrots their orange color. Beta carotene from vegetables and fruits is associated with reduced risks of breast, stomach, esophageal, and pancreatic cancers, and is also converted in the liver to retinol, more commonly known as vitamin A. Retinol is an essential component of the retina that makes vision possible.

In contrast to epidemiological studies, which show lower risk of cancer among individuals eating fruits and vegetables rich in carotenoids, clinical trials indicate that beta-carotene supplements increase the incidence of lung cancer in cigarette smokers. This effect has been attributed to pro-oxidant action under the considerable oxidative stress of smokers.

These major clinical trials which were critical of beta-carotene involved male heavy smokers (ATBC trial, alpha-tocopherol beta-carotene), male asbestos workers and male and female smokers (CARET, beta-carotene and retinal efficacy trial), and U.S. male physicians' study (included 11 percent smokers). All three trials concluded that beta-carotene provided no protection against lung cancer; and two trials found a higher risk for lung cancer for those subjects given beta-carotene.

However, research published in the December, 1999 issue of the Journal of the National Cancer Institute appears supportive of taking supplemental beta-carotene as a preventive against cancer and cardiovascular disease.

Researchers at Johns Hopkins University reported that patients with rheumatoid arthritis had lower blood levels than others of beta-carotene. This finding was ascribed to the antioxidant ability of beta-carotene to scavenge free radicals. Rheumatoid arthritis is a disease in which the body's immune system engages in battle against its own tissues. This results in inflammation, which in turn triggers the release of chemicals including free radicals into the joint lining, making it difficult to manipulate areas such as the knuckles and knees.

In another study, researchers at the Johns Hopkins University School of Medicine found that smokers with the lowest blood levels of beta-carotene had about three and half times the risk of heart attack of people who had high levels of beta-carotene and did not smoke.

A recent epidemiological study involving 644 postmenopausal women found that women whose diets included beta-carotene for 20 years or longer had a lower risk of breast cancer than

women whose diets included beta-carotene only in more recent years. Eye Protection

Some of the newest and most exciting research on the carotenoids have focused on its role in preventing eye disease.

A six-year follow-up study of more than 3,600 patients age 69 on average with early stages of macular degeneration, conducted by the National Eye Institute has shown that a combination of high doses of antioxidants (500 mg vitamin C, 400 IU vitamin E, 15 mg of beta-carotene, plus 80 mg zinc) daily can reduce progression of the disorder by about 25 percent.

While these are substantially higher than the recommended daily doses, no side effects were reported. High doses of zinc can cause anemia, but participants received 2 mg of copper daily to counter that effect. The benefit of the supplement was lower in patients receiving antioxidants alone or zinc alone. The study suggested that high doses of antioxidant vitamins, including beta-carotene, plus zinc can slow or prevent vision loss in people with early stages macular degeneration. Age-related macular degeneration (ARMD) affects at least six million Americans and causes visual impairment in nearly a third of them.

In a separate study reported in the same journal, the researchers found that the supplement combination had no effect on the development of cataracts. Because cataracts progress much more slowly, the study may not have lasted long enough to observe an effect.

Lutein and Zeaxanthin

Lutein and zeaxanthin are the carotenoids that give corn kernels their yellow color. The green vegetables spinach and kale also contain substantial amounts of lutein and beta-carotene, but their yellow color is masked by the green color of chlorophyll. Lutein and zeaxanthin are carotenoids abundant in the retina of the eye. They are present mostly in the macula, a small portion of the retina at the back of the eye that creates the sharpest vision.

ARMD occurs when the cells of the macula become damaged and stop functioning. Its symptoms include blurring of vision, colors appearing dim and difficulty reading or performing work up close. It is the leading cause of blindness in people over 65 years. Oxidative stress has been implicated in ARMD. The retina is highly susceptible to oxidative stress because of its high consumption of oxygen, its high content of polyunsaturated fatty acids, and its exposure to light.

The most likely physiological functions of lutein and zeaxanthin in the eye are protection against oxidative damage of the lipid matrix and protection against harmful ultraviolet radiation. These carotenoids act as optical filters, absorbing blue- and near-ultraviolet light. These effects were evaluated in a test tube experiment, where both lutein and zeaxanthin were found to protect lipid membranes against ultraviolet radiation and oxygen-free radical attack.

Observational studies have indicated that high intake of lutein and zeaxanthin from food, such as spinach, broccoli, is associated with a reduced risk of ARMD.

A recent case-control study involving 56 subjects with ARMD and 56 without ARMD showed that people with the highest quartile of lutein and zeaxanthin level had an 82 percent lower risk for ARMD compared with those in the lowest quartile.

Researchers at the University of Utah Medical School examined the association of dietary alpha-carotene, beta-carotene, lycopene, lutein, zeaxanthin, and beta-cryptoxanthin and the risk of colon cancer of more than 2,000 subjects. The study found that lutein is inversely associated with colon cancer in both men and women. The major dietary sources of lutein were spinach, broccoli, oranges and greens.

Lycopene

Lycopene is most abundant in tomatoes (up to 10 mg per tomato) and is responsible for its red color, and as a consequence, tomatoes and tomato-based foods provide a convenient source of lycopene. Lycopene is also present, in small amounts, in guava, rose hip, watermelon and grapefruit. The edible berries of the autumn olive shrub, commonly planted along highways were found to contain up to 18 times more lycopene than tomatoes.

Lycopene appears to act as an antioxidant in the body, repairing damaged cells and scavenging free radicals, the molecules responsible for most types of degenerative diseases and aging. Lycopene protects against breast, lung and digestive tract cancers; and helps prevent atherosclerosis, and promotes immune function.

Reviewing 72 epidemiological studies, Giovannucci at Harvard Medical School reported an inverse association between tomato intake and cancer risk. The evidence was particularly strong for cancers of the prostate, lungs and stomach.

Researchers at Harvard Medical School also followed 48,000

male physicians for six years, and found that men who ate tomato-based products more than twice per week had prostate cancer, the most common form of cancer in men with more than 200,000 new cases diagnosed annually, risk one-third that of those eating less than two servings per week. Pizza appeared to offer the most protection, indicating that lycopene may be better absorbed when cooked with fat.

In another study, researchers found that women with the highest consumption of lycopene had one-third the risk of getting cervix cancer, compared with women who had the lowest intakes. Eating one tomato a day appeared to stave off the cancer.

A case-controlled study involving 400 patients and 405 control subjects showed that intake of lycopene as well as vegetables, fruits, vitamin C and vitamin E, and folate were inversely associated with breast cancer risk .

Research also showed that patients with Type II diabetes who received tomato juice (500 ml/day), vitamin E (800 IU / day) and vitamin C (500 mg/day) had a three-fold increase in plasma lycopene levels and a 40 percent decrease in the susceptibility of LDL (bad cholesterol) to oxidation. The study concluded that consumption of tomato juice provides protection of LDL from oxidation, and hence reduces the risk of coronary heart diseases.

A case-controlled study, comprising 108 subjects with atherosclerosis and controls, revealed an inverse relationship between serum lycopene and the risk of atherosclerosis, suggesting a protective role for lycopene against the development of atherosclerosis.

Cryptoxanthin

Beta-cryptoxanthin is a major source of vitamin A, often second only to beta-carotene, and is present in fruits such as oranges, tangerines, and papayas. Sources of cryptoxanthin esters in the human diet include tropical and subtropical fruits. The contents ranged from 8 mcg per 100 g beta-cryptoxanthin laurate in Tunisian orange to 892 mcg per 100 g beta-cryptoxanthin laurate in papaya.

Dietary cryptoxanthin increases the resistance to lipid peroxidation in liver homogenate by enhancing the antioxidant efficiency of vitamin E and by providing direct antioxidant activity.

The anticarcinogenic activity of beta-cryptoxanthin was demonstrated in an animal study. Rats received methyl

nitroso-urea, to induce colon cancer, and either a diet with cryptoxanthin or a diet without cryptoxanthin. At week 30, the colon cancer incidence was significantly lower in the cryptoxanthin-group, suggesting a protective effect of cryptoxanthin against colon cancer.

The association between vitamins and carotenoids intake and bladder cancer incidence was examined in a study on more than 120,000 subjects aged 55 to 69 years. After six years follow-up, the study found that only beta-cryptoxanthin intake appeared to be inversely associated with bladder cancer risk.

Astaxanthin

As a member of the carotenoid group known as xanthophylls, astaxanthin possesses oxygen in its chemical structure. Astaxanthin is best known for its commercial use in the aquaculture industry. In its pure, synthetic form, farmers use it to provide the pinkish-red color to salmon, trout, and crustaceans such as crabs, krill, and shrimp.

Astaxanthin is found naturally in salmon, shrimp, lobster, and other shellfish, in certain plants, the yeast *Phaffia rhodozyma*, and the microalgae *Haematococcus*. Among the natural sources, *Haematococcus* contains the highest level of astaxanthin, which exists mainly as esters of various fatty acids.

The antioxidant activity of astaxanthin has recently been evaluated by the author (*Journal of Agricultural and Food Chemistry*, 2000), and found to be five times stronger antioxidant than beta-carotene. A United States patent claimed that astaxanthin protects rats' retinas from damage caused by exposure to high light flux.

A novel use of astaxanthin, and its ester derivatives, is claimed for the treatment and prevention of stress, and to alleviate decreased immunological function (*Current Drugs* 1997)

A placebo-controlled study showed astaxanthin enhanced the immune system in mice with cancer. Rats with cancer fed astaxanthin for three weeks showed a reduction in tumors to approximately half the size of those in the control group. Treatment of mice infected with *Helicobacter pylori* with astaxanthin resulted in reduction of growth of the bacteria. The study concluded that antioxidant might be effective in treating *H. pylori* infection in humans.

Summary

Research studies show that carotenoids quench free radicals,

inhibit lipid peroxidation, enhance eye health and immune system, and reduce mutagenesis. Studies support the beneficial role of lutein in reducing the risk of age-related macular degeneration, and incidence of cataracts and various cancers.

Lycopene makes people less likely to develop heart disease and cancers of the prostate, mouth, esophagus, rectum, stomach, and colon. Research also suggests that astaxanthin boosts the immune system, and alleviates stress. A cocktail of carotenoids provides a full spectrum of health benefits. **VR**

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