

Antioxidants

What Oxidation Does

Have you noticed how fast an apple turns brown after it is cut? Have you ever tasted vegetable oil that has become rancid? Both of these changes are caused by cell damage due to oxidation.

Apple slices will not turn brown as quickly if you coat them with an acidic juice (e.g. lemon, orange or pineapple) or a commercial anti-darkening preparation (e.g. Fruit-Fresh®) according to the manufacturer's directions. Both of these contain vitamin C, an antioxidant which reduces oxidation that causes discoloration of the apple slices.

In the same way, vegetable oil won't become rancid as fast if vitamin E, another antioxidant, is added as a preservative. It slows down oxidation, also.

To prevent rancidity or discoloration, antioxidants are added to many other foods including: baked goods; beverages; bread; cheese; cured meats; margarine; fruit juice; fruit products; pie filling; table syrup and wine.

Oxidation also causes rubber tires to harden and paint colors to fade with age. It causes similar changes in your body and brain, resulting in problems such as: premature aging; wrinkled skin; stiff joints; hardened arteries; cataracts in the eyes; and loss of long-term memory and learning ability.

Antioxidants Protect Against Free Radicals

Antioxidants can protect your body's cells from damaging oxidation much like oil or paint protects your car from rust. Oxidation, which is the loss of an electron, sometimes produces free radicals that can cause oxidative stress or damage to the cells.

The Role of Antioxidants: The role of antioxidants in health is inconclusive, because antioxidant research is still relatively new. Your body's cells use antioxidants to scavenge for and counteract the negative effects of free radicals. Once antioxidants find free radicals, they generously donate molecules to neutralize them so the free radicals become harmless before they can damage body cells. If no antioxidants are present, free radicals will steal that missing part from healthy molecules to become whole.

Antioxidants can slow, prevent or repair damage to your body cells. While some antioxidants simply control free radicals, others reverse cell damage by transforming free radicals to less damaging compounds or waste products that are eliminated before they can do damage. Another group of antioxidants can repair the damaged cell itself.

Antioxidants also may lower your risk for infection and cancer, improve immune function and reduce your risk for chronic disease, such as heart disease. Recently a team of Clemson University chemists found that antioxidants bind to naturally present iron and copper in the body to prevent formation of reactive oxygen compounds that damage DNA. Cancer, cardiovascular diseases, Parkinson's and Alzheimer's often are linked to DNA damage that occurs when metal ions in the body (e.g. iron and copper) produce reactive oxygen compounds that damage human cells. Studies have shown antioxidants that neutralize this activity and that occur naturally in fruits, vegetables, green tea, garlic and onions can be effective at preventing DNA damage.

Antioxidants work together. According to Guohua (Howard) Cao, developer of the ORAC assay, “It may be that combinations of nutrients found in foods have greater protective effects than each nutrient taken alone.” Therefore, consuming an excess or having a deficiency of one antioxidant may prevent other antioxidants from being beneficial to your health.

Free Radicals: Every cell in your body needs a constant supply of oxygen to produce energy. As oxygen is burned, free radicals are formed as a by-product. Since free radicals are unstable molecules that are missing an electron, they try to make themselves whole by attacking and grabbing a part from healthy molecules. This can damage body cells, tissues and the DNA, which is the “master plan” for reproducing cells. Once free radicals are created, they will multiply unless antioxidants or other compounds neutralize them.

Damage to Cells: Health problems may develop if free-radical production becomes excessive or if antioxidants are not available. When free radicals damage the genetic material in a cell and it is not totally repaired, the damaged DNA is duplicated in new cells and can lead to development of tumors and numerous other health problems. These include:

- cancer
- artery and heart disease (including heart attack, stroke, high blood pressure)
- cataracts
- age-related macular degeneration to eyes
- diabetes
- Alzheimer’s disease
- gastrointestinal diseases
- some degenerative changes that go with aging (e.g. brain function or cognitive impairment)

Sources: Free radicals that bombard your body cells come from high-fat diets; food additives; processed foods; soft drinks; infections; air pollution; cigarette smoke; ultraviolet light; radiation; excessive sun exposure; emotional stress; pesticides and other environmental factors.

Recent research suggests that the interplay of human genetics and diet also may play a role in the development of chronic diseases.

What Color is Your Diet?

Popeye, once a popular cartoon character, ate spinach when he needed extra energy and strength. He was on the right track, because this nutritious, dark green, leafy vegetable is actually high in three of the major antioxidants: vitamin C, vitamin E, and beta carotene.

We all know we should eat our fruits and vegetables, but not all fruits and vegetables are created equal in terms of nutrition. Eat the most colorful fruits and vegetables, because generally color is a clue that they are good antioxidant sources. Choose red, orange, deep-yellow, purple and some dark-green leafy vegetables every day.

Two of the most widely eaten vegetables in the United States are iceberg lettuce and white potatoes, usually in the form of French fries. They do not compare nutritionally to red berries, orange carrots, or green broccoli. Therefore, we shouldn’t just be eating our fruits and vegetables. We should be eating the most colorful fruits and vegetables.

Color groups of foods may help the body in the following ways.

Blue/purple: lower risk of some cancers; urinary tract health; memory function; and healthy aging.

Green: lower risk of some cancers; vision health; and strong bones and teeth.

Yellow/orange: lower risk of some cancers; a healthy heart; vision health; and a healthy immune system.

Red: lower risk of some cancers; a healthy heart; memory health; and urinary tract health.

Try adding one or two new colorful fruits and vegetables to your meals every week. For example, add grated carrots to muffins, diced fruit to pancake batter, and serve black bean dip with whole wheat crackers or tortilla chips. Colorful vegetables and fruits will enhance the visual appeal of your meals and increase the nutritional value of your diet.

“For optimum health, scientists say eat a rainbow of colors. Your plate should look like a box of CRAYOLAS.” Janice M. Horowitz, TIME, January 12, 2002.

Sources of Antioxidants

Eat high antioxidant foods at every meal. Colorful fruits and vegetables are excellent antioxidant sources. Antioxidants also are present in whole grains, legumes, herbs, spices, nuts, seeds, wine and tea. These plant foods provide vitamins and minerals, as well as thousands of other types of compounds that contribute to the overall dietary intake of antioxidants.

A few vitamins, minerals, phytochemicals, and enzymes in foods qualify as antioxidants. Carotenoids, flavonoids and polyphenols are examples of phytochemicals.

Vitamins and Minerals: The most well-known antioxidants are: vitamins A, C, and E; beta carotene; the mineral selenium; and more recently lycopene, a carotenoid. Carotenoids are plant pigments—usually red, orange, or deep yellow—that provide the array of colors in fruits and vegetables. Other antioxidants include the trace minerals copper, zinc, and manganese, as well as some phytonutrients and enzymes.

See Table 1 at the end of the fact sheet for examples of the most well-known antioxidant vitamins and minerals. Table 1 also includes some of their food sources, the amounts you need to consume daily, and what each vitamin or mineral does for the body. Strive to eat at least one food source from each of these antioxidant groups daily.

Phytochemicals: There are about 4,000 phytochemicals, also called plant chemicals, or phytonutrients. Some of the familiar ones being researched include lycopene, lutein, resveratrol, anthocyanins, and zeaxanthin.

With the ability to protect human health, these naturally occurring chemicals are found in plant-based foods, especially fruits, vegetables, whole grains, beans, nuts, seeds, herbs, spices, wine and tea. A diet based on fruits, vegetables and whole grains gives your body the phytochemicals it needs.

Rich color represents health. The deeper and richer the color of a fruit or vegetable, the more vitamins, minerals and phytochemicals it contains. Red grapefruit and onions are healthier than white varieties, and deep green romaine lettuce is a better choice than iceberg lettuce.

Here are two types of phytochemicals and some foods that contain them.

Carotenoids: Green, leafy vegetables and red, orange and yellow fruits and vegetables contain carotenoids.

Polyphenols: Polyphenols are found in all fruits, vegetables and herbs. Subgroups include:

Flavonoids: Sources include citrus fruits, apples, grapes, red wine, spices, dark chocolate and cocoa powder that is derived from beans that contain hefty amounts of flavonoids. Tea, another source of flavonoids, ranks as high as or higher than many fruits and vegetables in ORAC units, which measures the antioxidant power of foods.

An updated, easy-to-use database of the levels of 26 key flavonoids found in about 400 fruits, vegetables and other foods is now available from USDA Agricultural Research Service (ARS) nutrition researchers. The *USDA Database for the Flavonoid Content of Selected Foods, Release 2.1 (2007)* is available at: www.ars.usda.gov/nutrientdata/flav

Catechins: Tea is a source of catechins.

Anthocyanins: Anthocyanins provide purple and red pigment to vegetables and fruits like berries.

Phenolic acids: Rosemary, raspberries and pomegranates are sources of phenolic acids.

ORAC Score

The current standard for testing and measuring the antioxidant effectiveness of foods is called the ORAC Score, which stands for Oxygen Radical Absorbance Capacity. This relatively simple but sensitive scientific scoring method was developed in the 1990's by the USDA Human Nutrition Research Center on Aging at Tufts University to determine values of specific foods against disease.

The ORAC system measures the ability of foods, and just about any substance, to subdue oxygen free radicals in a test tube. In other words, ORAC score (or value) is a test tube analysis that partially measures the potential antioxidant capacities of foods and other chemical substances, including blood plasma.

ORAC Scores of Specific Foods: Here are the ORAC units found in about 3½ ounces (100 grams) of a few fruits and vegetables tested in the 1990's.

Fruits: prunes, 5,770; raisins, 2,830; blueberries, 2,400; blackberries, 2,036; strawberries, 1,540; raspberries, 1,220; plums, 949; oranges, 750; red grapes, 739; cherries, 670; kiwi fruit, 602 and pink grapefruit, 483.

Vegetables: kale, 1,770; spinach, 1,260; Brussels sprouts, 980; alfalfa sprouts, 930; broccoli flowers 890; beets, 840; red bell pepper, 710; onions, 450; corn, 400 and eggplant, 390.

A few additional high scoring foods that are becoming more popular and available to consumers are tart cherries, wolf berries, Goji berries and Acai berries. Whole grains also can have high ORAC scores due to the vitamin E, selenium and other natural antioxidant nutrients they contain. Tea, a source of flavonoids, ranks as high as or higher than many fruits and vegetables in ORAC units.

The higher the ORAC score, the higher the concentration of antioxidants present. However, a high ORAC value doesn't always mean that a food performs better as a source of antioxidant, because antioxidants in some foods apparently are easier to absorb and use than others. Cooking processes also may affect antioxidant levels.

ORAC score has become the international testing standard for antioxidant capacity. It is beginning to show up on more and more food, beverage and supplement labels, including polyphenol-rich fruit juices and teas. This label information may be helpful in choosing foods to include in your diet.

USDA researchers developed the ORAC method, and Brunswick Laboratories modified it for commercial use. Specializing in the science of antioxidants and oxidative stress, Brunswick Labs provides the highest quality assurance standards for food products and nutraceuticals that promote the antioxidant benefits of their products.

Updated ORAC Values: In November 2007 the USDA Agricultural Research Service released a new, expanded database of antioxidant values for 277 foods, including fruits, vegetables, nuts, spices, chocolates, teas, wines, etc. The new list expands upon the 171 foods included in the 2004 data released by ARS. This database will help guide research into how antioxidants may correlate to health benefits. To access it, go to:
<http://www.ars.usda.gov/nutrientdata/ORAC>.

ORAC Units Needed: Currently there are no established U.S. guidelines for how many ORAC units you need. Generally USDA researchers suggest that you consume a variety of foods that contain 3,000 to 3,500 ORAC units daily. However, further research may help establish national guidelines that indicate the kinds and amounts of antioxidants needed for optimal health.

High-ORAC Foods and Aging: Foods with high ORAC values may help slow aging in the body and brain. They improve metabolism, reduce toxicity, increase vitality, promote healthy aging and reduce disability. By the year 2050, almost one-third of the U.S. population is expected to be over age 65. If further research supports early findings, millions of aging people may be able to guard against diseases or dementia by adding high-ORAC foods to their diets. This could save people much suffering, as well as reduce the staggering cost of treating and caring for the elderly.

Top 20 Antioxidant Foods

In 2004 the United States Department of Agriculture (USDA) researchers released the following list of the top 20 antioxidant-rich foods. The foods are ranked from highest to lowest in antioxidant activity, based on these serving sizes:

1. small red beans, (dry, cooked), ½ cup
2. **wild blueberries***, 1 cup
3. red kidney beans, (dry, cooked), ½ cup
4. pinto beans, (dry, cooked), ½ cup
5. **blueberries (cultivated)***, 1 cup
6. **cranberries***, 1 cup whole
7. artichokes (cooked), 1 cup hearts
8. **blackberries***, 1 cup
9. prunes, ½ cup
10. **raspberries***, 1 cup
11. **strawberries***, 1 cup
12. Red Delicious apples, 1
13. Granny Smith apples, 1
14. pecans, 1 ounce
15. sweet cherries, 1 cup
16. black plums, 1
17. Russet potato, (cooked), 1
18. black beans (dry, cooked), ½ cup
19. plums, 1
20. Gala apples, 1

*Note that berries took six of the top 11 spots. There has been no review conducted by the U.S. Food and Drug Administration (FDA) on health benefits from eating berries, however.

USDA researchers cautioned that the antioxidant activity of these foods in the laboratory may differ from their antioxidant activity in the body. Antioxidants in some foods are easier to absorb and use than others, and cooking processes may affect antioxidant levels in foods. For example, cooking increased the antioxidant content of tomatoes but decreased antioxidant levels in carrots. Many foods that didn't make the Top 20 list for antioxidant activity may still provide other health benefits.

Amount of Antioxidants Needed

Much research is needed on antioxidants and phytochemicals. Unlike vitamins and minerals, there are no established guidelines for the kinds and amounts of antioxidants needed in the daily diet for optimal health. Most health authorities recommend that you get your antioxidants from a variety of whole plant foods including fruits, vegetables, whole grains, nuts and legumes.

The U.S. Government and several national health organizations recommend consuming a varied diet that follows MyPyramid and includes numerous fruits, vegetables, whole grains, nuts and seeds. You should consume a balanced diet that includes at least 2½ cups of vegetables and 2 cups of fruit daily, based on a 2,000-calorie diet. Equivalents are: 2 cups raw leafy greens = 1 cup of vegetable and ¼ cup dried fruit = ½ cup fruit. You also should eat 6 ounces of grain products daily, with at least three or more of those being whole grains.

The 2005 *Dietary Guidelines for Americans* states: "Increased intakes of fruits, vegetables, whole grains and fat-free or low-fat milk and milk products are likely to have important health benefits for most Americans." In particular, choose fruits and vegetables that contain dietary fiber and vitamins A and C. For more information, refer to [HGIC 4000, 2005 Dietary Guidelines for Americans](#).

The Food and Drug Administration (FDA) released a health claim for fruits and vegetables in relation to cancer. The following claim may now be placed on food packages that meet FDA criteria: "Diets low in fat and high in fruits and vegetables may reduce the risk of some cancers." The FDA, in cooperation with the National Cancer Institute (NCI), shares this dietary guidance message with consumers: "Diets rich in fruits and vegetables may reduce the risk of some types of cancer and other chronic diseases."

For more information on healthy choices from all the food groups in MyPyramid, refer to: [HGIC 4010, MyPyramid](#); [HGIC 4016, Focus on Fruits](#); [HGIC 4017, Vary Your Veggies](#); [HGIC 4018, Get Your Calcium-Rich Foods](#); [HGIC 4019, Whole Grains](#) and [HGIC 4020, Go Lean With Protein](#).

Many foods are fortified with antioxidants (e.g. vitamins C, E, the mineral selenium, and beta carotene, which forms vitamin A in the body). However, fresh fruits and vegetables contain other phytochemicals along with antioxidants, making them better choices than cooked or processed foods. Many antioxidant-rich foods lose some antioxidant capacities in processing. For example, blueberries picked fresh from the meadow make a much healthier treat than blueberries cooked in a recipe. Produce that is fresh frozen may be as healthy, or healthier than fruits and vegetables that become over-mature on grocery shelves.

Supplements

Mom was right when she said: "Be sure to eat your fruits and vegetables!" Eating antioxidant-rich foods is a better way to maximize the benefits of antioxidants than taking supplements. Foods contain many different combinations or interactions of phytochemicals that supplements can't duplicate. Food sources of antioxidants, including fruits, vegetables, whole grains, nuts and seeds, are potentially active in reducing risk for disease and can benefit your overall health.

It is thought that phytochemicals (also called phytonutrients or naturally occurring plant chemicals), vitamins, minerals, fiber, hormones, and other compounds in foods work synergistically to promote health and reduce disease risk. Therefore, authoritative organizations like the U.S. National Cancer Institute and The American Heart Association recommend getting phytochemicals from whole foods, such as fruits and vegetables, rather than from supplements.

The American Heart Association (AHA) states: "At this time, the scientific evidence supports a diet high in food sources of antioxidants and other heart-protecting nutrients, such as fruits, vegetables, nuts, and whole grains instead of antioxidant supplements to reduce risk of CVD (coronary vascular disease). Some studies even suggest that antioxidant supplement use could have harmful effects."

Relying on supplements can leave you shortchanged. Supplement pills contain none of the fiber found in whole foods. Research has not proven that taking beta carotene, vitamins C or E, or other antioxidant supplements prevents disease or provides the same health benefits found in antioxidant-rich foods. If you take a supplement, however, make sure it is a whole food supplement.

High doses of antioxidants as pills can be harmful. For example, large amounts of vitamin C increase the risk of diarrhea and urinary stones. Too much vitamin A (not beta carotene) can build up in the body and become toxic. In addition, high doses of antioxidants from supplements may promote oxidation rather than neutralize it. Research has shown that the risk of lung cancer is increased in smokers who take beta-carotene supplements.

Some free radicals are harmless, protecting the body by attacking harmful bacteria or cancer cells. Large doses of supplemental antioxidants may destroy or keep these protective free radicals from working.

Unless your doctor or health care provider prescribes an antioxidant supplement, let foods be your primary source. Foods such as fruits and

vegetables contain more than just vitamins, minerals, antioxidants and other nutrients found in supplements. These foods also are made up of other naturally occurring substances that may help protect you from chronic diseases.

For More Information

For more information, refer to: [HGIC 4073, Zinc](#); [HGIC 4079, Vitamin C](#); [HGIC 4080, Vitamin A](#) and [HGIC 4082, Vitamin E](#).

The Family and Consumer Sciences (FCS) agent at your county Extension office may have more written information and nutrition classes for you to attend. Also, your doctor, health care provider, or a registered dietitian (RD) can provide reliable information.

Reliable nutrition information may be found on the Internet at the following sites:

- <http://hgic.clemson.edu>
- <http://virtual.clemson.edu/groups/NIRC/>
- <http://www.eatright.org>
- <http://www.nutrition.gov>
- <http://www.nal.usda.gov/fnic>

Table 1. Examples of Antioxidant Vitamins and Minerals

Vitamins	Daily Reference Intakes*	Antioxidant Activity	Sources
Vitamin A	300-900 µg/d	protects cells from free radicals	liver, dairy products, fish
Vitamin C	15-90 mg/d	protects cells from free radicals	bell peppers, citrus fruits
Vitamin E	6-15 mg/d	protects cells from free radicals, helps with immune function and DNA repair	oils, fortified cereals, sunflower seeds, mixed nuts
Carotenoids	A Dietary Reference Intake (RDA, AI, or UL) has not been established, except as precursors to vitamin A.	<i>Lycopene</i> reduces the risk of coronary artery disease and certain types of cancer.	tomatoes, watermelon, red/pink grapefruit
		<i>Lutein</i> and <i>Zeaxanthin</i> decrease the risk of age-related macular degeneration and help maintain healthy vision.	spinach, collards, kale, corn, eggs, citrus
		<i>Beta carotene</i> may reduce risk of cancer.	carrots, pumpkin, sweet potato, cantaloupe
Selenium	20-55 µg/d	helps prevent cellular damage from free radicals	Brazil nuts, meats, tuna, plant foods

*DRIs provided are a range for Americans ages 2-70.

mg = milligrams
µg = micrograms

Sources: International Food Information Council (IFIC). *Functional Foods Fact Sheet: Antioxidants*. March 2006. Cornell University. *Aging and the Free Radical Theory: What are Antioxidants?* 2004. Duyff, Roberta Larson. American Dietetic Association *Complete Food and Nutrition Guide, 3rd Edition*. 2006.

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