An Overview of Dietary Antioxidants and Health

"Let food be thy medicine and medicine be thy food." What has changed over the past 2500 years since Hippocrates described his vision of medicine in this way? The answer may be both "nothing" and "everything." The quest for health has evolved from avoiding infectious diseases to reducing chronic disease risk to promoting wellness. As the population ages, people want to live a long life and live it well.

The desire for a long and healthy life has been a catalyst for the public's increasing interest in dietary antioxidants. This article will define antioxidants, review emerging health effects and dietary sources of antioxidants, and provide context to the headlines surrounding these intriguing dietary components.

Reducing Risk, Promoting Wellness

Each day, we encounter multiple environmental exposures, such as certain chemicals, ultraviolet rays and/or air pollution, which can potentially cause damage to healthy cells through the process of oxidation. For example, inflammation (a characteristic of cardiovascular disease, diabetes, obesity and some other adverse health conditions) creates conditions that favor oxidation. In fact, even normal metabolism is a steady supplier of free radicals (chemically reactive molecules that may damage healthy cells), leading to chronic diseases and other health problems associated with aging. The term *antioxidant* describes dietary components that have the ability to protect body cells by binding with free radicals to prevent oxidation in cells and DNA, much like processes that prevent the effects of rust on a car exposed to the elements.

As oxidation is a natural part of living, it is possible that antioxidants can play a role in reducing some negative aspects of aging. Nutrition research continues to sort out the most effective role for antioxidants in tertiary versus secondary prevention. Studies that seemingly contradict one another often can be understood more clearly by examining whether the intervention was tested with individuals with existing disease conditions or with those who are at risk for the conditions. Beyond reducing disease risk, however, antioxidants may play a primary prevention role in promoting wellness, affecting factors such as cognition, vision and mobility. In the words of Nancy Wellman, PhD, RD, FADA, "…'prevention, prevention, prevention' is the nutrition mantra for successful aging." (1)

Maximizing Antioxidant Power

The lure of the concept of the "top 10" antioxidants is compelling to some people, perhaps because it is perceived as simple and achievable. However, generating such a list is as complex as the list of potential foods is long, and might, in fact, be misleading, as antioxidant action in the body is determined only partly by quantity.

Antioxidants do not work in a vacuum. Absorption and utilization vary depending on the particular antioxidants ingested, the characteristics of the food or beverage delivering the antioxidants, and other foods eaten at the same time.

Dietary components with antioxidant properties range from vitamins [e.g., vitamins A (as beta-carotene), C and E] and minerals (e.g., selenium) to phytochemicals (e.g., lycopene and lutein) to enzymes (e.g., glutathione peroxidase—a selenoprotein). Particular antioxidants are usually found in a variety of different foods, and each food contains a myriad of antioxidants and other beneficial components. It is the synergy of actions stimulated by multiple dietary factors that delivers the total nutrition package for health.

The antioxidant potential of a dietary component is often expressed as the Oxygen Radical Absorbance Capacity (ORAC). The ORAC is an *in vitro* measure that has biological relevance to *in vivo* oxidation; however, it does not fully account for how well an antioxidant is absorbed or utilized.

Although there are limitations to the interpretation of the ORAC content of foods, scientists hypothesized in the late 1990s that high-ORAC foods may counter the harmful effects of aging that are related to free radical damage. Quantifying antioxidant content is an important starting point for improving understanding of the connection between the antioxidant content of foods and *in vivo* antioxidant activity provided by those foods.

A helpful list of examples of individual antioxidant components and food sources can be found on the International Food Information Council (IFIC) Foundation Web site: http://ific.org/publications/factsheets/antioxidantfs.cfm.

Recognizing the importance of dietary antioxidants, the Agricultural Research Service (ARS) of the United States Department of Agriculture (USDA) expanded its database of the antioxidant capacity of fruits, nuts, vegetables and spices in November 2007. (2) The database (at: www.ars.usda.gov/nutrientdata/ORAC) provides total ORAC per 100 grams, which facilitates comparisons between listed items. Numerous studies also have measured the antioxidant content of whole grains, as well as beverages, such as tea and coffee. (3, 4)

Quantifying the Effect of Antioxidants

In addition to quantifying the antioxidant capacity of foods, several studies document the effect of dietary antioxidants on plasma antioxidant capacity (AOC) in order to assess their ability to prevent oxidative damage *in vivo*. As noted previously, USDA scientists have found that absorption and utilization vary among different food sources. (5)

Determining the effect of a single antioxidant, an antioxidant-rich food or an antioxidant-rich diet on disease outcomes has proven challenging. Direct cause-and-effect relationships are difficult to elucidate due to the complex nature of disease states and the food matrix. Still, the relationship between an antioxidant-rich diet and reduced risk of chronic disease is biologically plausible and strengthened by extensive epidemiological evidence.

Where Are Antioxidants Found in Foods?

As the number of antioxidant sources in the diet is vast, the following discussion will focus on a few that have significant potential for the American diet. Three of four food groups that the 2005 edition of *Dietary Guidelines for Americans* identified as inadequate in the diet are antioxidant powerhouses: fruits, vegetables and whole grains. (6) A less well-known provider of antioxidants is coffee—a beverage that is commonly consumed in many countries around the world, including the United States. (7) In a presentation at the American Chemical Society Meeting in 2005, a researcher from the University of Scranton reported that coffee is the richest dietary source of antioxidants in the US population, based on the combination of antioxidants per serving and frequency of consumption. (8) Other familiar sources of antioxidants include green tea, herbs and spices, wine and nuts.

Fruits and vegetables, long associated with reduced risk of chronic diseases, are recognized as rich sources of antioxidants and the list of antioxidants in produce is extensive. (5, 9)

While studies conducted on the antioxidant content and health effects of fruits and vegetables are too numerous to review here, there is broad agreement in the scientific community that fruits and vegetables play an important role in health promotion and chronic disease risk reduction, in part due to their antioxidant content. For example, a healthful diet rich in fruits and vegetables is believed to reduce risk for some cancers. (10) The American Heart Association's (AHA) Dietary Guidelines also emphasize fruits and vegetables as having important roles in preventing cardiovascular disease. (11)

Whole grains provide water soluble, fat soluble and insoluble antioxidants, including vitamin E, selenium, and numerous phytochemicals (e.g., phytates and phenolic compounds, flavonoids, avenanthramides, cinnamic acid esters). While the majority of antioxidants delivered by whole grain foods are insoluble, requiring hydrolysis by microbial enzymes in the colon, antioxidant benefits of whole grains are realized both in the colon and throughout the body. Current scientific research recognizes that whole grains provide a significant quantity of antioxidants that are unique and highly bioavailable. (3, 12)

Coffee is also currently the subject of extensive health research. As evidence has emerged regarding coffee's protective effects against diabetes and inflammatory and cardiovascular diseases, scientists have hypothesized that antioxidants may be partly responsible. (13, 14) Polyphenols, volatile aroma compounds and heterocyclic compounds contribute to coffee's antioxidant potential. Importantly, the antioxidants in coffee have been shown to reduce biomarkers of oxidative stress. (15)

Impact of Food Processing and Preparation

Food processing significantly affects antioxidant activity in foods. For example, milling grain flour to remove the germ and bran removes components that are essential nutrients and antioxidants, including vitamin E and selenium. On the other hand, baking and toasting grain-based foods increases antioxidant activity. In fact, the brown crust of white bread has more antioxidant activity than crustless bread or the white flour used as an ingredient. (12)

In another example, coffee beans have been shown to contain more antioxidants after roasting. When it comes to preparation, brewing coffee through a filter has little, if any, effect on coffee's antioxidants, but it removes substances that have been linked to atherogenesis. In fact, a recent study found that coffee consumption was associated with a decreased risk of death due to inflammatory and cardiovascular diseases in a cohort

of postmenopausal women in Iowa, where filtered coffee is typically consumed. (14)

The findings from these and numerous other studies regarding the effects of food processing and preparation are twofold. First, these practices affect antioxidant activity in foods. Second, there is a wide range of effects—some of which are positive and some negative. The key is to optimize processing and preparation methods to achieve desired outcomes.

Lessons Learned on the Path to Health

More is not always better. There is no magic pill. One size does not fit all. These important lessons apply throughout the field of nutrition, and antioxidants are no exception.

In the quest for evidence from randomized controlled trials, individual antioxidants have been isolated and tested for physiological effects as dietary supplements, individually and in combination with other dietary supplements. Testing relatively high doses of antioxidants has demonstrated thresholds above which benefits are no longer realized, and, in some cases, toxic effects may occur.

Perhaps the most famous examples are the Alpha-Tocopherol Beta-Carotene (ATBC) Cancer Prevention Study and the Carotene and Retinol Efficacy Trial (CARET). These studies found that beta-carotene supplementation was associated with significantly higher incidences of lung cancer and mortality. The CARET study was stopped early when the increased mortality risk was identified. (16)

It is important to recognize that isolating dietary components from the foods in which they would normally be eaten may also eliminate complementary dietary constituents. In contrast to the studies of isolated beta-carotene, numerous studies have supported the protective effect of beta-carotene-rich fruits and vegetables on disease risk, including lung cancer. Taken together, these studies and others demonstrate that risk decreases with moderate intake, but may increase at high levels. A study by Neuhouser et al (17) found that intakes of fruits and vegetables correlated with lower risk of lung cancer, but supplementation with beta-carotene nullified the protection. Based on the recognized importance of the total diet and the lack of evidence for benefits derived from isolated nutrients, *Dietary Guidelines for Americans* 2005, as well as many organizations, including the American Cancer Society (ACS), American Dietetic Association (ADA) and AHA, recommend deriving antioxidants from foods rather than dietary supplements. (6, 18-20)

Finally, individualization is an emerging area of interest when applying nutrition findings. *Nutrigenomics* is the study of interactions and synergies between ingested dietary substances and genomic expression. One's genetic makeup influences the way in which one's body utilizes nutrients and other dietary components. Conversely, one's dietary intake can influence genomic expression. Importantly, the interactions between dietary substances and genes work in both directions. Nutrigenomics may one day provide the means to truly individualize nutrition advice, based not only on preferences, lifestyle and readiness to change, but also on one's personal genetic information. It is likely that this field of study will help sort out the seeming inconsistencies in nutrition research over the years.

The Future of Antioxidants

Considerable effort is underway to identify the range of dietary components that have antioxidant action, quantify these components and assess their potential for *in vivo* antioxidant activity. Many researchers are working to confirm the epidemiological evidence that antioxidant-rich foods reduce the risk of chronic disease and promote wellness. As clinical evidence emerges and our understanding of genomic differences improves, the appropriate role for antioxidants in human health will become more apparent. Today, encouraging a varied diet (achieved through choosing a range of healthful foods and beverages) remains the best advice for helping consumers get the benefits of antioxidants and the many other bioactive components available from food.

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