Fruits and Vegetables: Foods with Unappreciated Nutritional Value as Sources of Antioxidants

J. Bruce German, Department of Food Science & Technology

Oxidation seems so confusing; chemists use rhetoric from the sixties to refer to it (free radicals), even scientists argue about it in public and yet it is apparently so important that most of the foods, cosmetics and food supplements we see are now labeled with the implied cure-all label 'Antioxidants'. The truth may turn out to be as complex as the confusion it now produces.

Chemistry of Oxidation

Large molecules, such as most of those that we are made of, contain a great deal of chemical energy. Oxidation is the main chemical process by which such molecules lose that energy by combining with oxygen. Thus, the oxidation of lipids, proteins, etc. is a very favorable reaction. Eventually we all succumb to this inevitable chemical reality. One might ask how do we manage not to combust spontaneously when we live in an atmosphere that is almost 20% oxygen! The main reason is that the reaction has a chemical barrier. The stability of biological molecules in an oxygen-rich atmosphere results from the unique spin state of the unpaired electrons in ground state molecular oxygen in the atmosphere. This property renders atmospheric oxygen relatively inert to reduced, carbon-based biomolecules, all of which have paired electrons. Hence, reactions between oxygen and protein, lipids, polynucleotides, carbohydrates, etc. proceed at vanishingly slow rates unless they are catalyzed. The reaction can be catalyzed by forming a molecule with an unpaired electron (termed a 'free radical'). Once so catalyzed, the oxidative reactions (especially of polyunsaturated lipids) will continue in what is referred to as a chain reaction, consuming one molecule after another. The products of such a chain reaction can eventually oxidize most of the energy-rich molecules present in our cells. The chain reaction path can be halted by the presence of a stabilizing molecule referred to as an antioxidant. Many different kinds of molecules can act in this way, so it is important to know which molecules are acting as antioxidants and what molecules they are protecting. In stopping the chain reaction, the antioxidant is consumed, so this strategy has at best only a slowing effect rather than a true prevention. Eventually, once all the antioxidants are used up, oxidation can proceed again, unchecked.

Thus, the rate of free radical oxidation chain reactions and hence oxidative deterioration of everything from potato chips to people is related to: (1.) the amount of polyunsaturated lipids (in human cells this is relatively constant), (2.) the rate of formation of free radicals (normal metabolism produces free radicals at a finite rate but ultraviolet light, pollutants, infections and inflammation all produce more free radicals) and (3.) the amount of antioxidants present. What is now emerging from scientific research is the fact that plants

must produce antioxidants to protect themselves from oxidation, and when humans ingest plant materials, to a certain extent they can gain those antioxidants and their protective properties through the diet.

Biology of Oxidation

If oxidation is so bad, why don't scientists just find a way to stop it altogether? Free radical reactions are extremely powerful and absolutely necessary to a large number of biochemical and cellular processes. Cells generate energy, assemble and disassemble necessary molecules, signal within and between cells and tissues and eliminate pathogens, all using free radical reactions and reaction products. Biology has evolved a very complex system of catalysts whose function is to produce free radical oxidants and reductants. Unfortunately, using this powerful chemistry comes with a risk. Virtually all free radical reactions, even beneficial ones, have the potential to promote deleterious reactions if not controlled and regulated. The use of this chemistry of free radicals was clearly a major evolutionary pathway in biology in which the successful exploitation of oxidation reactions provided selective biochemical advantage. However, this proliferation of free radical generating systems in higher animals and humans placed a substantial priority on balancing systems that could control, delimit and repair the consequences of free radical reactions. Present evidence indicates that dietary antioxidants provide a significant assistance to both preventing and regulating free radical reactions in humans.

Antioxidants from Plant

The chemistry of free radical oxidations is multistage and complex. Oxidation is not a single catastrophic event. There is no single initiating catalyst that generates all free radicals; there are a great many sources of these single electron producers. Similarly, there is no single reactive product of oxidation; there are classes of products many of which are broadly damaging. Free radicals and their products react with virtually all biological molecules, and there is no single defense against all targets of oxidative damage. Thus, plants have evolved a spectrum of mechanisms to prevent or respond to oxidative stresses and free radicals and their products at one or more of the many steps of oxidation. For example, plants produce tocopherols to protect their membranes. Even though humans can't make tocopherols, this class of molecules is so important to the protection of human membranes that if insufficient tocopherols are consumed the resulting deficiencies lead eventually to death. This is the basis for classification of tocopherols as a vitamin (vitamin E).

Plants also produce a host of other molecules that, while able to protect different molecules from oxidation, are not essential for humans. These include flavonoids, tocotrienols, simple and polymeric phenolics and carotenoids. Evidence now suggests that their presence in the diet of humans does provide a protective action that can improve the overall resistance of humans to the damaging effects of oxidation, especially over a long life span.

These antioxidant molecules are by their nature unstable and hence are easily lost during processing and storage. This is not to mean that one needs to eat only raw fruits and vegetables. Most of these molecules are actually preserved by effective food processing, hence the safety and nutritional quality can both be enhanced by appropriate food manufacturing.

Recommendations

If oxidation is so important, why shouldn't one just consume a lot of one antioxidant? It should not be surprising that with varying needs for protection, plants have developed different types and amounts of molecules that act as antioxidants. It should also not be surprising that some fruits and vegetables are more enriched than others. Nevertheless, if one message should be taken from the science to date, it would be that the strategy that plants use, of making multiple types of protective molecules, is probably equally applicable to humans, and that a spectrum of protective molecules would be optimal in the diet. No single protective molecule works best for all situations and thus, at the present time, the (boring and unexciting) recommendation of a well-balanced and complex diet including 5-a-day fruits and vegetables is probably still the most appropriate.