

Antioxidants: Chemistry and Their Impact on Health

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1. Introduction

In the aerobic environment, the most dangerous by product are the species of reactive oxygen. The role of antioxidants is to detoxify reactive oxygen intermediates (ROI) in the body. Over the past several years, nutritional antioxidants have attracted considerable interest in the popular press as potential treatment for a wide variety of disease states, including cancer and other causes e.g. cancer, chronic inflammatory diseases and aging (Delany L. 1993).

Naturally occurring inhibitors of oxidation in food generally originate from plant-based materials. The active components, namely phenolics and polyphenolics, including tocopherols, are secondary plant metabolites and are first derived from phenylalanine and in certain cases and in some plants from tyrosine. The resultant phenylpropanoids may then undergo further transformation to yield benzoic acid derivatives as well as flavonoids, isoflavons, and other complex polyphenols. Thus, natural food phenolics are present as a complex mixture of compounds that provide a cocktail of many active components present in the free, esterified, glycosylated and bound forms (Shahidi and Naczki, 1995). The potency of preparations is therefore dictated by their chemical structures and governed by the hydrophilic-lipophilic balance (HLB) of the participating molecules in a concentration- and system-dependent manner. Thus, the mode of action of natural antioxidants may involve multiple mechanisms, depending on the source material and possible presence of synergists and antagonists.

In order to use any antioxidant preparation in food, it must be safe, easy to incorporate, effective at low concentrations, with no undesirable odour, flavour or colour, heat stable, nonvolatile and with good carry through properties and cost-effective. In addition, presence and possible effects of antagonists must be carefully considered, as an antioxidant may become a prooxidant in the presence of certain other molecules. As an example, chlorophylls may overwhelm the antioxidant effect of phenolics due to photosensitized oxidation and transition metal ions such as those of iron and copper may render conditions that favour oxidation. Synergism among different phenolic antioxidants and between phenolics and non-phenolics should be considered in all application areas.

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Definition

Free radicals are atoms or groups of atoms with an odd (unpaired) number of electrons and can be formed when oxygen interacts with certain molecules. Once formed these highly reactive radicals can start a chain reaction. Their chief danger comes from the damage they can do when they react with important cellular components such as DNA, or the cell membrane. Cells may function poorly or die if this occurs. To prevent free radical the body has a defence system of antioxidants.

An antioxidant is a substance that when present in low concentrations relative to the oxidizable substrate significantly delays or reduces oxidation of the substrate (Halliwell, 1995).

Antioxidants get their name because they combat oxidation. They are substances that protect other chemicals of the body from damaging oxidation reactions by reacting with free radicals and other reactive oxygen species within the body, hence hindering the process of oxidation. During this reaction the antioxidant sacrifices itself by becoming oxidized. However, antioxidant supply is not unlimited as one antioxidant molecule can only react with a single free radical. Therefore, there is a constant need to replenish antioxidant resources, whether endogenously or through supplementation.

2. Review of Literature

Qin Yan Zhu et. al.(2001) studied antioxidant property of oolong tree. Inhibitory effect on $\text{FeCl}_2/\text{H}_2\text{O}_2$ – induced damage and the inhibitory effect on erythrocyte hemolysis of an oolong tea extract (OTE) were evaluated. The OTE was found to have strong antioxidant activity in all model system. When OTE was separated into fractions according to molecular weight it was found that fraction with higher amount of phenolic compound (with low molecular weight) have strong antioxidative activity.

Yi Fang Chu and Xianzona Wu (2002) reported that increased consumption of fruits and vegetables containing high levels of phytochemicals have been recommended to prevent chronic diseases related to oxidative stress in human body. 10 common vegetables were selected. The study showed that Red peeper had highest total antioxidant activity followed by Broccoli, Carrot, Spinach, Cabbage, Onion, Potato etc.

Jie Sun and Yi Fang (2002) reported that consumption of fruit & vegetable associated with reduced risk to Chronic disease due to present of antioxidant. According to them vitamin C is the major antioxidant in fruit.

Jeong- Chae Lee (2002) assessed an ethanol extract of stem of opuntia to determine the mechanism of its antioxidant activities. The ethanol extract exhibited a concentration dependent inhibition of linoleic acid oxidation.

Keni Chi Ya na Gimoto et. al. (2002) investigated the antioxidant activity of column chromatographic fractions obtained from brewed coffee to find antioxidant and to assess benefits of coffee drinking. Coffee contain many antioxidant and consumption of antioxidant rich brewed coffee may inhibit disease caused by oxidative damage.

Anaberta Cardadose et.al. (2003) showed that fraction extracted with ethyl acetate have antioxidant activity with potent free radical scavenging activity.

Joon Hee Lee et. al. (2003) reported that Muscadine Grapes and its winery bi product have antioxidant capacity.

Kizhiyedathu et. al. (2003) reported that extract obtained from sesame cake and oil have free radical scavenging capacity i.e. antioxidant property.

K.S. Shivashankara and Seiichiro Isobe (2004) reported that if greenhouse- grown tree ripe (TR) and mature green (MG) mangoes (cv. Irwin) were exposed to high electric field treatment before 20 and 30 days of storage at 5⁰ C. MG fruits were allowed to ripen at room temperature after low- temperature storage and antioxidant capacity were estimated before and after the storage period. Antioxidant capacity of fruits remained unchanged up to 20 days of storage period and decreased thereafter. Antioxidant capacity of fruits was significantly correlated only to ascorbic acids.

Joseph O. Kuti et.al. (2004) reported that total phenolics and antioxidant capacity were higher in raw than in cooked leaf extracts. Cooking reduced antioxidant activity. The results of their study indicate that tree spinach leaves are a rich source of natural antioxidants.

Mahinda Wella singh and Kirk Parkin (2004) studied a broad range of antioxidant activities in crude extract of beet root tissues. Betalain pigment have been shown to posses various antioxidant function.

3. Classification of antioxidants

Table 1. Classification of antioxidants based on their roles

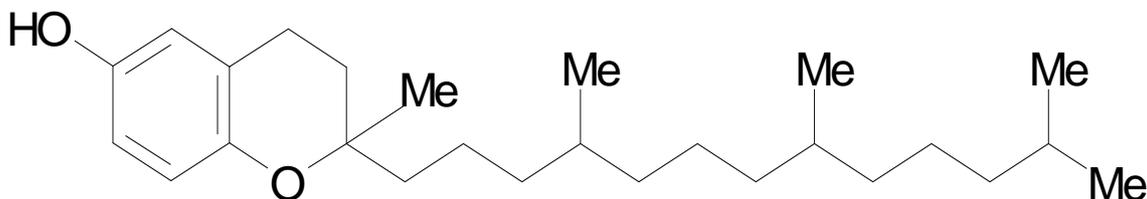
Enzymes	Antioxidant	Role	Remarks
	Superoxide dismutase (SOD) Mitochondrial Cytoplasmic Extracellular	Dismutates O_2^- to H_2O_2	Contains Manganese (Mn.SOD) Contains Copper & Zinc (CuZnSOD) Contains Copper (CuSOD)
	Catalase	Dismutates H_2O_2 to H_2O	Tetrameric hemoprotein present in peroxisomes
	Glutathione peroxidase (GSH.Px)	Removes H_2O_2 and lipid peroxides	Selenoproteins (contains Se^{2+}) Primarily in the cytosol also mitochondria Uses GSH
Vitamins	Alpha tocopherol	Breaks lipid peroxidation Lipid peroxide and O_2^- and $\cdot OH$ scavenger	Fat soluble vitamin
	Beta carotene	Scavenges $\cdot OH$, O_2^- and peroxy radicals Prevents oxidation of vitamin A Binds to transition metals	Fat soluble vitamin
	Ascorbic acid	Directly scavenges O_2^- , $\cdot OH$, and H_2O_2 Neutralizes oxidants from stimulated neutrophils Contributes to regeneration of vitamin E	Water soluble vitamin

Table 2. Classification of antioxidants based on their sources

Source Material	Example	Antioxidant
Vegetable Oils	Soybean oil	Tocopherols
Tropical Oils	Palm oil	Tocotrienols
Plant Oils	Palm oil	Carotenoids
Herbs and Spices	Rosemary and Sage	Complex phenolics
Cereals	Wheat and buckwheat	Flavenoids
Legumes	Soybean	Isoflavones
Oil Seeds	Canola and Mustard	Phenolic acids & Phenylpropanoids
Teas	Green Tea	Catechins and Polyphenols
Fruit skin and seeds	Grape seed and skin	Polyphenols and Tannins

4. Antioxidant chemistry of some vitamins

4.1 Alpha tocopherol (vitamin E)



Vitamin E -2D structure - C₂₆H₄₄O₂

4.1.1 Nomenclature

It is the major lipid soluble antioxidant found in cells. The name originated in the early 1920s when vegetable oil was discovered to restore fertility in rats. This unknown substance was designated vitamin E by Sure in 1924. The term *tocopherol* was first used by Evans. Because this compound permitted an animal to have offspring, he named it *tocopherol* from the Greek word *tokos*, meaning childbirth, and added the verb *phero*, meaning to bring forth. To indicate the alcohol nature of the molecule, *ol* was added to the ending.

Vitamin E is a generic term that includes all entities that exhibit the biological activity of natural vitamin E, d-alpha-tocopherol. In nature, eight substances have been found to have vitamin E activity: d-alpha-, d-beta-, d-gamma- and d-delta-tocopherol (which differ in methylation site and side-chain saturation (*Kellof et al. 1996*); and d-alpha-, d-beta-, d-gamma- and d-delta-tocotrienol. Also, the acetate and succinate derivatives of the natural tocopherols have vitamin E activity, as do synthetic tocopherols and their acetate and succinate derivatives.

Of all these, d-alpha-tocopherol has the highest biopotency, and its activity is the standard against which all the others must be compared. It is the predominant isomer in plasma.

4.1.2 Source and Nature

Vitamin E is an essential nutrient that functions as an antioxidant in the human body. It is essential, by definition, because the body cannot manufacture its own vitamin E and thus it must be provided by foods and supplements.

Tocopherols are present in oils, nuts, seeds, wheat germ and grains. Absorption is believed to be associated with intestinal fat absorption. Approximately 40% of the ingested tocopherol is absorbed. Most tocopherols enter the blood via lymph where they are associated with chylomicrons. Vitamin E was shown to be stored in adipose tissue. Phospholipids of the mitochondria & endoplasmic reticulum & plasma membranes possess affinities for alpha tocopherol & the vitamin tends to concentrate in these sites.

4.1.3 Mechanisms of Action

Vitamin E is more appropriately described as an antioxidant than a vitamin. This is because, unlike most vitamins, it does not act as a co-factor for enzymatic reactions.

Also, deficiency of vitamin E does not produce a disease with rapidly developing symptoms such as scurvy or beriberi. Overt symptoms due to vitamin E deficiency occur only in cases involving fat mal absorption syndromes, premature infants and patients on total parenteral nutrition. The effects of inadequate vitamin E intake usually develop over a long time, typically decades, and have been linked to chronic diseases such as cancer and atherosclerosis.

Hence, its main function is to prevent the peroxidation of membrane phospholipids, and avoids cell membrane damage through its antioxidant action. The lipophilic character of tocopherol enables it to locate in the interior of the cell membrane bilayers (*Halliway and Gutteridge, 1992; Borg, 1993*). Tocopherol-OH can transfer a hydrogen atom with a single electron to a free radical, thus removing the radical before it can interact with cell membrane proteins or generate lipid peroxidation. When tocopherol-OH combines with the free radical, it becomes tocopherol-O \cdot , itself a radical. When ascorbic acid is available, tocopherol-O \cdot plus ascorbate (with its available hydrogen) yields semidehydroascorbate (a weak radical) plus tocopherol-OH (*Halliway and Gutteridge,*

1992). By this process, an aggressive ROI(Reactive Oxygen Intermediate) is eliminated and a weak ROI (dehydroascorbate) is formed, and tocopherol-OH is regenerated. Despite this complex defence system, there are no known endogenous enzymatic antioxidant systems for the hydroxyl radical.

Vitamin E also stimulates the immune response. Some studies have shown lower incidence of infections when vitamin E levels are high, and vitamin E may inhibit cancer initiation through enhanced immunocompetence.

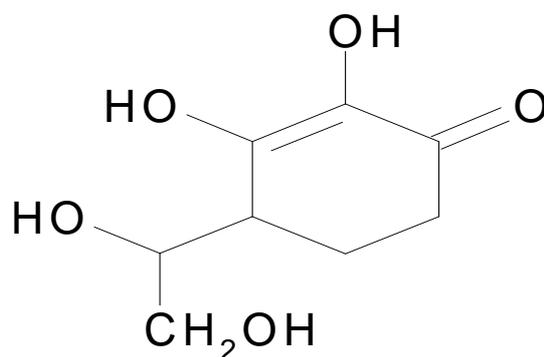
Vitamin E also has a direct chemical function. It inhibits the conversion of nitrites in smoked, pickled and cured foods to nitrosamines in the stomach. Nitrosamines are strong tumour promoters.

Alpha-tocopherol has been shown to be capable of reducing ferric iron to ferrous iron (i.e. to act as a pro-oxidant). Moreover, the ability of alpha-tocopherol to act as a pro-oxidant (reducing agent) or antioxidant depends on whether all of the alpha-tocopherol becomes consumed in the conversion from ferric to ferrous iron or whether, following this interaction, residual alpha-tocopherol is available to scavenge the resultant ROI (Yamamoto and Nike, 1988).

4.1.4 Possible therapeutic effects

- Vitamin E decreases the incidence of ischaemic heart disease (Gey *et al.* 1991).
- Decreases the incidence of cataract (Packer, 1991; 1992).
- Decreases the incidence of osteoarthritis (Blankenhorn, 1986).
- Decreases the incidence of rheumatoid arthritis (Kheir El-dein *et al.* 1992).

4.2 Ascorbic acid (vitamin C)



Vitamin C -2D structure C₆H₈O₆

4.2.1 Source and Nature

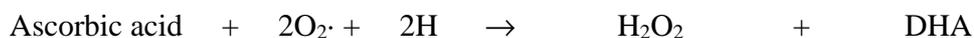
Ascorbic acid (vitamin C) is a water-soluble, antioxidant present in citrus fruits, potatoes, tomatoes and green leafy vegetables.

Humans are unable to synthesize l-ascorbic acid from d-glucose due to absence of the enzyme L-gulacolactone oxidase (*Ensimnger et al.1995*). Hence, humans must therefore obtain ascorbic acid from dietary sources.

4.2.2 Mechanism of Action

The chemopreventive action of vitamin C is attributed to two of its functions. It is a water-soluble chain breaking antioxidant (*Ishwarial et at 1991*). As an antioxidant, it scavenges free radicals and reactive oxygen molecules, which are produced during metabolic pathways of detoxification. It also prevents formation of carcinogens from precursor compounds (*Block and Menkes, 1988*). The structure of ascorbic acid is reminiscent of glucose, from which it is derived in the majority of mammals.

One important property is its ability to act as a reducing agent (electron donor). Ascorbic acid is a reducing agent with a hydrogen potential of +0.08V, making it capable of reducing such compounds as a molecular oxygen, nitrate and cytochromes a and c. Donation of one electron by ascorbate gives the semi-dehydroascorbate radical (DHA). Ascorbate reacts rapidly with $O_2^{\cdot-}$ and even more rapidly with $\cdot OH$ to give DHA. DHA, itself can act as a source of vitamin C.

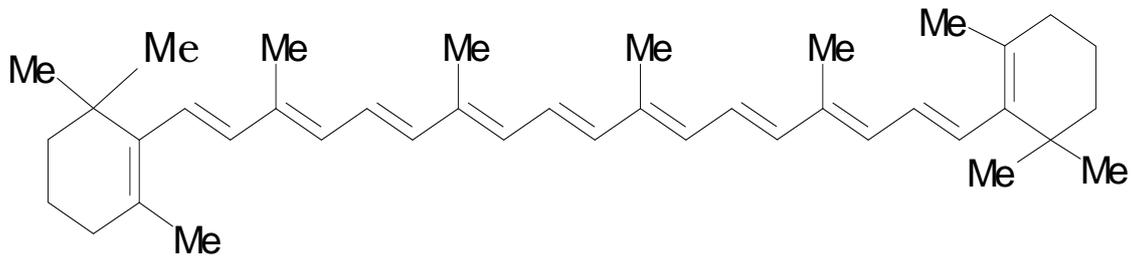


It has also been shown that ascorbate is more potent than α -tocopherol in inhibiting the oxidation of LDL (Low Density Lipoprotein) in a cell free system (*Jialal et at 1990*). Co-incubation of LDL with ascorbate during similar oxidative condition inhibited LDL oxidation and resulted in preservation of the endogenous antioxidant in the LDL particle (*Ishwarial et at, 1991*). The concentration of ascorbate used to inhibit LDL oxidation (40-60 μ m) is well within the normal plasma range (23-85 pm).

Vitamin C also contributes to the regeneration of membrane bound oxidized vitamin E. It will react with the α -tocopheroxyl radical, resulting in the generation of tocopherol in this process itself being oxidized to dehydroascorbic acid (*Ward & Peters 1995*). Vitamin C supplementation in animals leads to increased plasma and tissue levels of vitamin E.

In vitro studies suggest that the antioxidant properties of ascorbic acid may not increase linearly as ascorbic acid concentrations rise (*Frei et al. 1989*). Moreover, ascorbic acid alone can act as a "pro-oxidant" or reducing agent to react with copper or iron salts. Ferric iron (Fe^{3+}) formed by the reaction, $Fe^{2+} + H_2O_2 \rightarrow HO + \cdot OH + Fe^{3+}$, is converted by ascorbic acid to ferrous (Fe^{2+}) ion. Ferrous iron is therefore recycled to promote the conversion of more H_2O_2 to $\cdot OH$ (*Halliway et al. 1992*).

4.3 Beta Carotene



2-D Structure of Beta Carotene

4.3.1 Source and Nature

Carotenoids are pigmented micronutrients present in fruits and vegetables. Carotenoids are precursors of vitamin A and have antioxidant effects. While over 600 carotenoids have been found in the food supply, the most common forms are alpha-carotene, beta-carotene, lycopene, crocetin, canthaxanthin, and fucoxanthin. Beta-carotene is the most widely studied. It is composed of two molecules of vitamin A (retinol) joined together. Dietary beta-carotene is converted to retinol at the level of the intestinal mucosa.

4.3.2 Mechanisms of Action

The antioxidant function of beta-carotene is due to its ability to quench singlet oxygen, scavenge free radicals and protect the cell membrane lipids from the harmful effects of oxidative degradation (Krinsky and Deneke, 1982; Santamaria et al. 1991). The quenching involves a physical reaction in which the energy of the excited oxygen is transferred to the carotenoid, forming an excited state molecule (Krinsky, 1993). Quenching of singlet oxygen is the basis for *beta-carotene's* well known therapeutic efficacy in erythropoietic protoporphyria (a photosensitivity disorder) (Matthews-Roth, 1993). The ability of *beta-carotene* and other carotenoids to quench excited oxygen, however, is limited, because the carotenoid itself can be oxidized during the process (autoxidation). Burton and Ingold (Burton and Ingold, 1984) and others have shown that *beta-carotene* autoxidation in vitro is dose-dependent and dependent upon oxygen concentrations. At higher concentrations, it may function as a pro-oxidant and can activate proteases.

In addition to singlet oxygen, carotenoids are also thought to quench other oxygen free radicals. It is also suggested that beta carotene might react directly with the peroxy radical at low oxygen tensions; this may provide some synergism to vitamin E which reacts with peroxy radicals at higher oxygen tensions (Cotgreave et al. 1988).

Carotenoids also have been reported to have a number of other biologic actions, including immuno-enhancement; inhibition of mutagenesis and transformation; and regression of premalignant lesions

5. Antioxidant chemistry of some enzymes

This includes superoxide dismutase, catalase, and peroxidases.

5.1 Superoxide dismutase (SOD)

5.1.1 Source and Nature

SOD is an endogenously produced intracellular enzyme present in essentially every cell in the body. Cellular SOD is actually represented by a group of metalloenzymes with various prosthetic groups. The prevalent enzyme is cupro-zinc (CuZn) SOD, which is a stable dimeric protein (32,000 D). SOD appears in three forms: (1) Cu-Zn SOD in the cytoplasm with two subunits, and (2) Mn-SOD in the mitochondrion (*Mayes, 1993; Warner, 1994*). A third extracellular SOD recently has been described contains Copper (CuSOD).



5.1.2 Mechanism of action

SOD is considered fundamental in the process of eliminating ROI by reducing (adding an electron to) superoxide to form H₂O₂. Catalase and the selenium-dependent glutathione peroxidase are responsible for reducing H₂O₂ to H₂O.

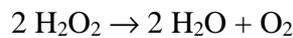
The respective enzymes that interact with superoxide and H₂O₂ are tightly regulated through a feedback system. Excessive superoxide inhibits glutathione peroxidase and catalase to modulate the equation from H₂O₂ to H₂O (see Fig.5). Likewise, increased H₂O₂ slowly inactivates CuZn-SOD. Meanwhile, catalases and glutathione peroxidase, by reducing H₂O₂, conserve SOD; and SOD, by reducing superoxide, conserves catalases and glutathione peroxidase. Through this feedback system, steady low levels of SOD, glutathione peroxidase, and catalase, as well as superoxide and H₂O₂ are maintained, which keeps the entire system in a fully functioning state (*Fridovich, 1993*).

SOD also exhibits antioxidant activity by reducing O₂⁻ that would otherwise lead to the reduction of Fe³⁺ to Fe²⁺ and thereby promote ·OH formation. When the catalase activity is insufficient to metabolize the H₂O₂ produced SOD will increase the tissue oxidant activity. Hence, it was found that the antioxidant enzymes function as a tightly balanced system, any disruption of this system would lead to promotion of oxidation .

5.2 The catalase enzyme

This enzyme is a protein enzyme present in most aerobic cells in animal tissues. Catalase is present in all body organs being especially concentrated in the liver & erythrocytes. The brain, heart, skeletal muscle contains only low amounts.

Catalase and glutathione peroxidase seek out hydrogen peroxide and convert it to water and diatomic oxygen. An increase in the production of SOD without a subsequent elevation of catalase or glutathione peroxidase leads to the accumulation of hydrogen peroxide, which gets converted into the hydroxyl radical. Indeed research in the pathogenesis of Down's syndrome has revealed that the existence of trisomy 21 leads to the overproduction of SOD, the gene for which is located also on chromosome 21. This finding is intriguing in that it reveals the possibility of a genetic link to the increased activity of free radicals. (*Krinsky, 1992*)



5.3 Glutathione peroxidase enzyme

The glutathione redox cycle is a central mechanism for reduction of intracellular hydroperoxides.

5.3.1 Source and Nature

It is a tetrameric protein 85,000-D. it has 4 atoms of selenium (Se) bound as seleno-cysteine moieties that confers the catalytic activity. One of the essential requirements is glutathione as a cosubstrate.

Glutathione peroxidase reduces H_2O_2 to H_2O by oxidizing glutathione (GSH) (Equation A). Rereduction of the oxidized form of glutathione (GSSG) is then catalysed by glutathione reductase (Equation B). These enzymes also require trace metal cofactors for maximal efficiency, including selenium for glutathione peroxidase; copper, zinc, or manganese for SOD; and iron for catalase (*Halliwell, 1995*).



6. Mode of action of antioxidants

There are four routes:

- 1.Chain breaking reactions, e.g. alpha-tocopherol which acts in lipid phase to trap "ROD" radical.
- 2.Reducing the concentration of reactive oxygen species e.g. glutathione.
- 3.Scavenging initiating radicals e.g. superoxide dismutase which acts in aqueous phase to trap superoxide free radicals.
- 4.Chelating the transition metal catalysts: A group of compounds serves an antioxidant function by sequestration of transition metals that are well-established pro-oxidants. In this way, transferrin, lactoferrin, and ferritin function to keep iron induced oxidant stress in check and ceruloplasmin and albumin as copper sequestrants.

7. Antioxidant System in our body

The body has developed several endogenous antioxidant systems to deal with the production of ROI. These systems can be divided into enzymatic and nonenzymatic groups.

The enzymatic antioxidants include superoxide dismutase (SOD), which catalyses the conversion of $O_2^{\cdot-}$ to H_2O_2 and H_2O ; catalase, which then converts H_2O_2 to H_2O and O_2 ; and glutathione peroxidase, which reduces H_2O_2 to H_2O .

The nonenzymatic antioxidants include the lipid-soluble vitamins, vitamin E and vitamin A or provitamin A (beta-carotene), and the water-soluble vitamin C and GSH. Vitamin E has been described as the major chain-breaking antioxidant in humans (*Packer, 1992*). Because of its lipid solubility, vitamin E is located within cell membranes, where it interrupts lipid peroxidation and may play a role in modulating intracellular signalling pathways that rely on ROI (*Kagan et al. 1990; Azzì et al. 1993*). Vitamin E can also directly quench ROI, including $O_2^{\cdot-}$, $\cdot OH$, and (*Algayer et al. 1992*) O_2 .

8. Commercial Sources of Natural Antioxidants

The most common natural antioxidant preparations in the market are mixed tocopherols, which are by-products of vegetable oil refining. In addition, spices or their oleoresins and extracts, such as those of rosemary and sage, green tea extracts, other plant-based mixtures, such as those of mustard and certain unsaponifiables of edible oils, and, of course, carotenoids are also important (Table 2) (*Ho et al., 1994; Shahidi, 1997*).

9. Efficacy of anti oxidants in different systems

The chemical composition and structures of active extract components are important factors governing the efficacy of natural antioxidants in different foods. Thus, phenolic compounds with ortho- and para- dihydroxylation or a hydroxy and a methoxy group are more effective than simple phenolics. In addition, phenylpropanoids with extended conjugation are more effective than benzoic acid derivatives. Furthermore, hydrophilicity and lipophilicity of the active components is dictated by the appropriateness of antioxidants in systems. In general, more hydrophilic antioxidants are better in stabilizing bulk oil than oil-in-water emulsions while the activity of lipophilic antioxidants follows the opposite trend. There are also many other factors that must be taken into account when considering and selecting antioxidants and extracts for food application. Specifically, attention should be paid to the photosensitizing effect of chlorophylls in natural extracts. In addition, the level of incorporation of antioxidants in foods should be optimized and the use of chelating agents considered, when and where appropriate. Many antioxidants behave prooxidatively at high concentrations or when present together with ions of transition metals; such effects are also important when considering the in-vivo activity of antioxidants (Shahidi and Ho, 2000). Some chelators, such as polyphosphates, in addition to metal sequestration, may also exert other beneficial effects such as to improve the cooking yield and juiciness of meat and poultry products or keeping quality of fresh seafoods. The role of natural antioxidants in foods is expected to rise over the years to come.

10. Summary

Antioxidant are molecules that can safely interact with the free radicals and terminate the chain reactions before the vital molecules are damaged. Although there are several enzyme system and vitamins that scavenges free radicals the principle antioxidant in the body are Vitamin E, Vitamin C, beta carotene, catalase enzyme, super oxide dismutase enzyme, glutathion peroxidase enzyme etc. Vitamin E, a lipid soluble antioxidant prevent peroxidation of phospholipid. Vitamin C is a water soluble chain breaking antioxidant. Beta carotene protect cell membrane lipid from harmful effect of antioxidant damage. Catalase, glutathion peroxidase, super oxide dismutase etc. enzyme systems also prevent our body oxidative damage by free radicals.

11. Conclusion

Antioxidant plays an important role to prevent cancer, and other disease. They also have a role in slowing the ageing process and preventing heart disease. So antioxidants are very much necessary for our body. But our body can't manufacture these chemicals, so they must be supplied through diet. Although there is a little doubt that antioxidants are necessary components for good health, no one knows if supplements should be taken or not and if so how much is optimum. Though antioxidant supplements were thought to be harmless but as we are becoming more aware of these chemicals we come to know that antioxidants may be harmful for our body in some cases. In normal concentration vitamin C and beta carotene are antioxidants but at higher concentrations they are pro-oxidant and thus harmful. Also very little is known about the long-term consequences of megadoses of antioxidants. The body's finely tuned mechanisms are carefully balanced to withstand a variety of insults. Taking chemicals without understanding of all their effects may disrupt this balance. So we should follow the following recommendations.

1. It will be helpful for us to follow a balanced training program that emphasizes regular exercise and to eat 5 servings of fruit or vegetables per day. This will ensure that we are developing our inherent antioxidant systems and that our diet is providing the necessary components.
2. Weekend warriors should strongly consider a more balanced approach to exercise. Failing that, consider supplementation.
3. For extremely demanding races (such as an ultra distance event), or when adapting to high altitude, it will be helpful to take a vitamin E supplement @ 100 to 200 IU per day for several weeks up to and following the race.
4. We should look for upcoming FDA recommendations, but we should be wary of advertising and media hype.
5. We should not over supplement.

12. Future Scope of Research

Antioxidants are necessary for our health but we do not know the exact dose and the way how to supplement it. So further research is required to know more about antioxidants. There are so many flora and fauna in our environment which may contain antioxidant chemicals. So there is a huge scope to conduct research work in this interesting topic to know

- 1) How much antioxidant supplementation is required.
- 2) Natural sources of different antioxidants.
- 3) To discover antioxidant properties of different chemicals.
- 4) To know whether they have any other pharmacological and toxicological effects.

Bibliography

Anaberta Cardadose et.al. (2003). Antioxidant Activity In Common Beans. Journal of Agricultural and Food Chemistry. pp. 6975-80.

Jeong- Chae Lee (2002). Antioxidant Property of An Ethanol Extract of the Stem of *Opuntia fiscus*. Journal of Agricultural and Food Chemistry. pp. 6490-6496.

Jie Sun and Yi Fang (2002). Antioxidant and Antiprofilactive Activities of Common Fruits. Journal of Agricultural and Food Chemistry. pp. 7449-7454.

Joon Hee Lee et. al. (2003). Antioxidant Polyphenolics in Muscadine Grapes Journal of Agricultural and Food Chemistry. pp 480-485.

K.S. Shivashankara and Seiichiro Isobe (2004). Fruit Antioxidant Activity of Irwin Mango Fruits Stored at Low Temperature. Journal of Agricultural and Food Chemistry. pp. 1281-1286.

Kagan et al. 1990; Azzi et al. (1993).<www.envistrc.com>

Keni Chi Ya na Gimoto et. al. (2002). Antioxidative Activities of Fractions Obtained From Brewed Coffee. Journal of Agricultural and Food Chemistry. pp 1281-1290.

Mahinda Wella singh and Kirk Parkin (2002). Phase II Enzyme Inducing Activities of Beet Root From Phenotypes of Different Pigmentation. Journal of Agricultural and Food Chemistry. pp. 6704-09.

Qin Yan Zhu et. al.(2001). Antioxidant Activities of Oolong Tea. Journal of Agricultural and Food Chemistry. pp. 1280-1286.

Shahidi and Ho. (2000).Valcic, S; Burr ,J.A. Timmermann BN, Liebler DC. Department of Pharmacology and Toxicology, College of Pharmacy, The University of Arizona, Tucson, Arizona 85721, USA.

Yi Fang Chu and Xianzona Wu (2002). Antioxidant and Antiprofilactive Activities of Common Vegetables. Journal of Agricultural and Food Chemistry. pp. 381-385.