EUROPEAN ACADEMIC RESEARCH
Vol. II, Issue 10/ January 2015

Impact Factor: 3.1 (UIF)
DRJI Value: 5.9 (B+)

ISSN 2286-4822
www.euacademic.org

Antioxidants versus Free Radicals: An informative review

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Abstract:

The aim of the paper is to review the substantial literature existing about various types, sources and function of antioxidants & free radicals in the human body. The information provided in this article regarding danger of free radicals and oxidative stress will definitely assist the readers about the preventive measures that must be taken against oxidative degeneration by incorporating antioxidant containing foods in to daily diet. Dietary antioxidants present in fruits, vegetables and grains etc are potent weapons for demolishing the deleterious effects of the oxidative stress by neutralizing free radicals.

Key words: Antioxidants, Free Radicals and Oxidative stress.

1. Introduction

1.1. Free Radicals and their Status in the Human Body

Free radicals or oxidants are great deal of concern in recent days. Any atom or molecule or ion that has a single unpaired electron in its outer most orbits, which can be shared by

unstable and highly reactive component in the body and may commence pathogenesis in the system, is termed as free radical. A normal cell maintains an equilibrium between the formation and removal of free radicals, however an imbalance mechanism in the formation and elimination of free radical in cell, excessive formation of free radicals or impairment of antioxidants may leads towards a state named as "Oxidative stress" (Ashok, 2012). An excess of free radicals in human body is the major reason of oxidative stress which can induce a variety of chronic and degenerative diseases, destructive pathways and progression towards disorders and disease. Free radicals cause biological oxidation and thus are involved in onset of many degenerative diseases like CVDs, cancer, asthma, atherosclerosis, inflammatory joint disease, senile dementia, diabetes, autoimmune disorders, neurodegenerative diseases, lung diseases, vascular diseases, dental and eye disorders (Florence, 1995; Lian *et al*, 2008).

1.2. Advantages and Disadvantages of Free Radicals

It is not surprising that many of the free radicals are strongly involved in maintaining haemostasis and normal physiological functions of the body, for example, expression of gene, cellular growth, biosynthesis of thyroxin, prostaglandin and other essential biomolecules as well as formation of defensive agents for bactericidal activity from macrophages and neutrophils (Schreck and Baeuerele 1991; Knight, 2000). They also impart their role as a stimulating agent for some of the biological processes (Droge, 2002). Free radicals are beneficial up to an extent. They can alter chemical characteristic of Proteins (structural changes and loss of enzymatic activity), lipids (peroxidation of unsaturated fatty acid in membranes), Deoxy Ribonucleic Acid (mutation) and can impart frequent aging and disease progression progression in human, they are highly reactive and capable of damaging many biomolecules (Young &

Woodside, 2001; Devasagayam *et al*, 2004; Halliwell *et al*, 2007; Velavan, 2011; Ashok, 2012).

1.3. Species of Free Radicals

Many of the free radicals can be formed within the body. Reactive oxygen species (ROS) and reactive nitrogen species (RON) derived from oxygen and nitrogen respectively, are chief free radicals synthesized in human body via endogenous system and may also accumulate within the human body through exposure (ingestion or inhalation) into various physicochemical processes (Lobo *et al*, 2010). Hydroxyl radical, hydrogen peroxide, superoxide anion radical, oxygen singlet, hypochlorite, peroxynitrite radical and nitric oxide radical are chief oxygen containing (ROS) free radicals having intensive potency to invade and damage the cellular skeleton including nucleus and membrane structure (Young & Woodside, 2001).

1.4. Antioxidants and their Role against oxidative stress

An antioxidant or redox-active compound is a substance that posses the ability to reduce the oxidative stress caused by overabundance of free radicals. Oxidative stress is a deleterious condition in which bioavailability of nitric oxide in blood vessels is retarded which leads to endothelial disturbance (Frombaum *et al*, 2012). The oxidative stress is associated with atherosclerosis plaque formation as well. Antioxidants can neutralize the demolishing effects of free radicals and can control the degree of oxidative stress. Antioxidants act as radical scavenger, donor of hydrogen, donor of electron, peroxide decomposer, singlet oxygen quencher, inhibitor of enzyme, synergist, and metal-chelating agents. They are stable and effective to give up their own electron(s) to free radicals. When a free radical takes the electron from an antioxidant then it do not remain able to attack cell and disturb cellular reactions (Dekkers *et al*, 1996). In this way, defensive mechanism of an antioxidant plays imperative role in

protecting and preventing a body from oxidative stress. Antioxidants can delay or inhibit damage of cellular composition greatly via their free radical scavenging property (Helliwell, 1995). Antioxidants are also effective against substantial loss of food colour, flavour, vitamins content etc. They can stabilize the components involved in deterioration of food commodity.

1.5. Endo and Exogenous Sources of Free Radicals and antioxidants

Free radicals can enter in the human body from many sources and exert their deleterious and injurious impacts on health (Alhassane and Xu, 2010). They continuously produced by the body's normal use of oxygen (Tiwari, 2004). They are by products of normal cellular function and metabolic intermediates of many biochemical reaction of the physiological system. Body synthesizes them by two different ways: endo and exogenously. Majority of free radicals are produced within the body during the conversion of calories in to chemical energy (ATPs). Free radicals are produced by the mitochondria through ETC when cells use oxygen to generate energy (Ashok, 2012), they may be produced during endoplasmic reticulum oxidation, phagocytosis, inflammation, Exercise (Ebadi, 2001) and during many enzymatic reactions in the body (Tandon *et al*, 2005; Bandyopadhyay *et al*, 1999). The exogenous factors involve in the accumulation of free radicals in human body are radiation, oxidation of engine exhaust, pollutants including cigarette smoke (Slater, 1985), pesticides, industrial wastes, metal ions, food and drug supplements. A number of cellular reactions take place in body produce ROS (i.e. hydrogen peroxide and superoxide). These include iron-catalysed Fenton reaction and reactions by various enzymes such as lipoxygenases, peroxidases, xanthine oxidase and NADPH oxidase. The production of free radicals in the human body is also related with the quality and quantity of food stuff consumed. Degree of

oxidative stress can be controlled by acquiring a balance between free radicals and antioxidants. Antioxidants widely distributed in nature and may used in the food industry. Natural antioxidants are of two kinds, primary (chain-breaking) and secondary (preventive). Primary antioxidants react with lipid radicals and can transform these radicals into stable form while secondary antioxidants lower the oxidation rate by various ways (Decker *et al*, 2005). Many of the food items contain ingredients (free radicals) that have potential to deteriorate the quality characteristics of food by oxidizing it. The efforts are therefore increasingly enhanced to retard the oxidation by adding antioxidants in food commodities. The supplements with antioxidant have great potential to alleviate the atherosclerotic damage caused by excessive production of reactive oxygen species (Marina *et al*, 2010). A huge number of natural antioxidants are phenolic compounds present in plants and herbs. Antioxidants can synthesize endo and exogenously, it means that they are manufactured within the body and can be extracted from the food such as from tomato, barriers, cherries, citrus, prunes, olives, potato, ginger, spinach, legumes, seeds, nuts, fish, meats, thyme, oregano, rosemary, pepper, sage, nutmeg, cinnamon, clove, basil, turmeric powder, green & black tea, grape seed and oil. Antioxidants that occur in processed food could be natural or synthetic. Food products fortified with synthetic natural antioxidants (butylated hydroxytoluene, butylated hydroxyanisole and propyl gallate) are also good source of antioxidants. The substance like, Chelating agents (i.e. EDTA or others) have enough potency to bind metals for mitigating the process of oxidation.

1.6. Types of Antioxidants in food

The Antioxidants found in nature are of three types. These include phytochemicals, vitamins and enzymes and are described as under.

1.6.1. Phytochemicals

The phytochemicals with antioxidant activity occur widely in fruits and vegetables as a diverse group of secondary metabolite and are also known as phenolic compounds. They contain an aromatic ring with hydroxyl groups (one or more) and they may occur as simple phenolic molecule or even as complex polymer. It is also suggested that type of structure, OH-group substitution property within the aromatic ring, number and positions of the OH-groups are all strongly related with antioxidant activity of phenolic compounds (Nagendran *et al*, 2006). Many phenolic compounds are possible antioxidants and may act as ROS-scavenging compounds (Olga *et al*, 2003). They have tendency to inhibit free radical synthesis and auto-oxidation. They are potent H-donating compounds and extremely active antioxidants (Brewer, 2011). This wide variety of naturally occurring antioxidants is differing to each other in their composition, physical and chemical properties and mode of action (Naik SR, 2003). These molecules present antioxidant, antimutagenic, antiviral, antibacterial (bactericidal, bacteriostatic), algicidal, antifungal, insecticidal, estrogenic and keratolytic activities that may serve to protect the organism from diseases. There is evidence in literature that about 8000 different kinds of phenolic compounds are widely present in nature and are essential part of human diet. They also impart their role in conferring taste, flavour and health therapy (Tomas and Epsin, 2001). Some of them are described here:

Flavonoids: Flavonoids are special class of phenolic compounds with structural formula C_6–C_3–C_6. More than half of the phenolic compounds are consisting of it. About 5000 naturally occurring flavonoids occur in different plant sources. They ubiquitously present inplants (Spencer, 2008). Foods having high flavonoid content are banana, citrus fruits, parsley, Ginkgo biloba, onion, blueberries and other berries, green,

black and oolong tea, sea-buckthorns, red wine, and chocolates. Flavinoids are responsible for performing countless functions in plant body and in human health (Harborne and Williums, 2000).This diverse class of phenolic antioxidants is classified into various sub-groups on the basis of their chemical structure into flavonones (naringenin and esperetin), flavanols (taxifolin), flavonols (quercetin, kaempferol and galangin), flavans (catechin, epicatechin and epigallocatechin), isoflavones (qanistein and daidzein) and flavones (apigenin, luteolin and chrysin). Until now, neither the FDA nor EFSA has suggested any of the health claims for using flavonoids in food and drugs. They exhibit a wide range of beneficial activities in living system (such as anti-oxidants, anti- microbial, anti-inflammatory, anti-cancer, anti-aging and anti-allergic agents) and are most intensively studied compounds against CVDs. Synergistically with anti-biotic components, they can act as an anti-bacterial agent.

Phenolic acids: Phenolic acids belong to the family of Phenolic compounds. Benzoic acid with seven (C_6-C_1) and cinnamic acid with nine (C_6-C_3) carbon atoms are two main groups of phenolic acid. They are widely distributed in nature as derivatives of hydroxybenzoic acids (benzoic acid, gallic acid, vaillinic acid, salicylic acid) and derivatives of hydroxycinnamic acids (*p*-coumaric, caffeic, ferulic, and sinapic acids). Fruits and vegetables are abundant sources of phenolic acids (Liu, 2004). Phenolic acids are highly active against many degenerative diseases such as CVDs, inflammatory disorders, cancer/tumour and leukaemia caused by oxidative stress (Battisti *et al*, 2008). Apart from food sources, phenolic acids can be derived from metabolic consequences of stomach, intestine and hepatic cells (Lafay and Gil-Izquierdo, 2008) Phenolic acids have strong affinity against ROS (Battisti *et al*, 2008). Cinnamic acid is found to exert therapeutic effect against oxidative stress (Fresco *et al*, 2006). Hydroxycinnamic acids (HCAs) are

important members of the family of phenolic acids, they abundantly occur in plants such as in tea leave, fruits, vegetables, grains and in coffee beans (Jose *et al*, 2013). The derivatives of hydroxycinnamic acids like *p*-coumaric, caffeic, ferulic, and sinapic acids play essential roles in nature. HCAs are powerful antioxidants, potent free radical scavengers, chelating agents, and are effective ROS/ RNS inhibitors (Nguyen *et al*, 2003; Jacob *et al*, 2012). Magnificent applications of phenolic acids are also related with the fields of agriculture and medicine (Gryglewski *et al*, 1987).

Tannins: Tannins are water soluble phenolic compounds. They are grouped into three classes (Condensed tannins, gallotannins and ellagitannins). The general characteristics of tannins are different from each other on the basis of their chemical structure. Tannins are known antinutrient within the plant and are supposed to precipitate proteins, mitigate the vitamin and mineral utilization and inactivate digestive enzymes (Ryszard, 2007 and Koleckar *et* al, 2008). The health promoting properties of tannins are also important to notice. Tannins can chelate metal ions (Magdalena, 2009 and Koleckar *et* al, 2008). Many food and beverages originated from plant sources contain tannins and are exerted their effect as antioxidants, antiradicals, antimicrobial, anticarcinogenic and antimutagenic agents (Ryszard , 2007). Tannins can also prevent from cardiovascular diseases and are antiinflammatory agents (Koleckar *et* al, 2008).

Stilbene: Stilbenes occur in variety of foods (barriers, nuts, grapes, red currants and hopes). Fruit and fruit products containing stilbene are getting more and more importance among the consumers. This is obviously due to the beneficial activities of this unique phenolic compound against chronic disorders. Effects of stilbenes are reported in human as a potent cardio and neuroprotective components. They also exhibit

antileukemic effects in the body. Trans and cis-type of stilbenes may occur in nature. The hydroxylated derivatives of stilbene are Stilbenoids. Resveratrol is an example of stilbenoid which is found in grapes and is related to many health benefits (Jang *et al*, 1997)

Lignins: Lignin abundantly occurs in plants. Recent attention towards lignin in the field of food and pharmaceuticals are making it an imperative component of the nature. Liginin is an effective antimicrobial agent, food additive and is considered as a potent prebiotic (Baurhoo *et al*, 2008).

1.6.2. Antioxidant vitamins

Antioxidant vitamins is a group of vitamin (or precursor of vitamin) that bear antioxidant property, they play an essential role in preventing body from a number of severe diseases and disorders. They exert their role as strong agents against oxidative stress in animals while in food products. They impart their function in opposition to deterioration or rancidity Some important antioxidant vitamins are discussed here:

Vitamin C or Ascorbic acid: Vitamin C is a water soluble vitamin, imperative against oxidation and oxidative stress. It must be taken through diet because body cannot synthesize or store it. This will not wrong to mention that vitamin C is potent antioxidant. Its property of donating electron makes it able to perform vital functions in the body against oxidative degeneration (Padayatty *et al*, 2003). Vitamin C is widely present in citrus fruits, tomatoes, broccoli, green papper, watermelon, papaya, barriers, kiwi and mangoes.

Vitamin E or Tocopherol: All the naturally occurring forms of vitamin E exhibit their less or more role as antioxidants. Among other forms (α-, ß-, γ-, and δ) of the vitamin E that occur

in foods, α-Tocopherol is considered as a major form that works more effectively against free radicals (FNB, 2000) and is a peroxyl radical scavenger (Pryor *et al*, 1988). Lipid peroxidation can be prevented by incorporating diet containing Vitamin E.

Carotenoids: The α-carotene, ß-carotene, α-cryptoxanthin and other forms of carotenoids exhibit strong antioxidant activity. They are precursor for synthesis of vitamin A. Their efficient free radical neutralizing ability makes them essential nutrients against oxidative stress. They enhance the immune system and are anticarcinogenic agents.

1.6.3. Antioxidant Enzymes

Antioxidant defence mechanism is divided into (a) indirect enzymatic antioxidant enzymes and (b) direct action against oxidative stress through low molecular weight components (Carmen *et al*, 2004). Many Enzymes represent their functions as new category of potentially applicable natural antioxidants in the field of food technology. Antioxidant enzymes are first line of defense against free radicals in organisms. The regulation of these enzymes is dependent on the oxidant status of the cell. Peroxidases and Catalase are two well known enzymes exert their action against hydrogen peroxide (Carmen *et al*, 2004). Superoxide dismutase also exerts its function as an antioxidant.

2. Conclusion

An imbalance in concentration of free radicals and antioxidants in cellular environment leads to oxidative stress. Oxidative stress causes deleterious effects in the human body and exhibit progressiveness in diseases if not treated properly with antioxidants. Nature has also designed a satisfactory self regulating system to overcome such condition with synergetic

support of both dietary antioxidants and regulatory antioxidant enzymes. It is concluded from this article that dietary antioxidants are essential components of the plant originated food products and they must be incorporated in the diet to decrease chances of diseases related with oxidative stress or elevated free radicals.

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