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Antioxidants: A Way to Curb Oxidative Stress

Sabeeha Naaz*

Department of Chemistry, Dr. Ambedkar Govt. P. G. College, Unchahar- Raebareli (UP)

[Affiliated to CSJM University, Kanpur (U.P.)]

Abstract – Free radicals such as reactive oxygen species (ROS) are produced and quenched during normal cellular metabolism in a balance in human body. The imbalance generates oxidative stress which is associated with weak immune system causing several diseases. Antioxidants play a crucial role in reducing this oxidative stress by terminating the chain reactions of free radicals and reinstating the balance.

Keywords: Free Radicals, ROS, Oxidative Stress.

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INTRODUCTION

The latest highly infectious COVID-19 disease has already raised a significant danger and severe global public health issue. The pandemic has until now had no unique medical strains, leaving us with the only alternative to maintain our immune system healthy. In addition to genetic causes, food patterns influence our immunity. The immune cell activity of antioxidants against homeostatic stress disorders is widespread.

The chemistry of human physiology and metabolism encapsulated a variety of redox reactions and appears dynamically regulated between free and quenching radicality [1]. Certain drugs and xenobiotics are also impaired. Free radicals are reactive chemical species with unpaired electrons in the orbit of other species or molecules that enable them to quickly respond to broad chains of chemical reactions [2] in which free radicals are used to oxidise other chemical species. Free radicals may help combat pathogens when they work properly. Infection is triggered by bacteria. The class of reactive free radicals generally comprises oxygen-free radicals including superoxide anion (O2−.), radical hydroxylic (•OH) and hydrogen peroxide (H2O2) as reactive oxygen species (ROS) and non-nazote radicals such as nitric oxide (NO) and peroxynitrite (ONOO−).

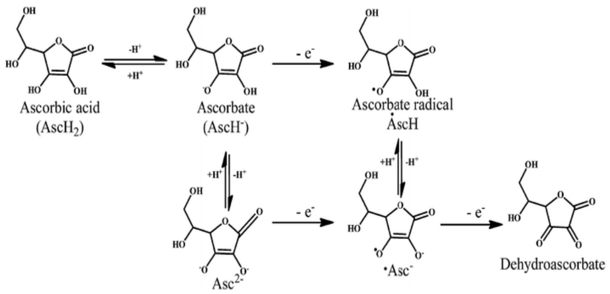
Endogenous and exogenous, synthetic and natural antioxidants are the chemical species that inhibit or minimise the oxidation of others [3] and may donate the electron to a free radical without being dysfunctional. This stabilises the free radical and makes it less reactive. Normally, a good person's human body combines free radical behaviour with antioxidant activity.

OXIDATIVE STRESS

The term "oxidant tension" relates to the disturbance of the oxidant-antioxidant balance [4]. As the equilibrium between free radical generation and antioxidant defenses declines, immune cells adversely affect the body's functions, often contributing to life-threatening cell damage; the immune system is primarily susceptible to oxidative stress. "Chronic stress oxidative to chronic diseases including heart failure, type 2 diabetes and cancer may raise risk. A diet high in antioxidants leads to sustaining a good antioxidant protection that activates the immune system and may effectively mitigate oxidative stress by ending the wide chain chemistry reactions. The most important dietary antioxidants are vitamin C, vitamin E, carotenoids and polyphenols.

VITAMIN C (ASCORBIC ACID)

The L-enantiomer of ascorbic acid is vitamin C ($C_6H_8O_6$); the opposite D-enantiomer does not have physiological significance [6]. Being a powerful antioxidant and "scavenger of free radicals throughout the biological system, it contributes to the cellular protection against antioxidants, defends lipid membranes and proteins.. It may function within and outside the cells, becoming water soluble and neutralizing free radicals and preventing free radical damage. It is an ideal supply of electrons for free radicals finding electron stability. It will donate electrons to free radicals and remove their reactivity. Furthermore, vitamin C regenerates another type of vitamin E antioxidant by reducing tocopherol radicals" (8). It also interferes in replication of viruses, enhances the function and maturation of phagocytes, T-lymphocytes respectively.



Scheme 1 : Mechanism of radical scavenging activity of ascorbic acid (Vitamin C)

VITAMIN E

"Vitamin E is the collective term for four tocopherols (α-, β-, γ-, and δ-tocopherols) and four tocotrienols (α-, β-, γ-, and δ-tocotrienols) found in food. Such forms have antioxidant activity, but cannot be interconverted, and the requirement for human vitamin E is fulfilled only by α-tocopherol (figure 1). Vitamin E is an essential fat-soluble antioxidant which scales peroxyl radicals and ends the oxidation of poly-unsaturated fatty acids (PUFAs). The chain reaction of peroxyl radical development is halted if vitamin E reacts with α-tocopherol rather than lipid hydroperoxide, and further oxidation of PUFAs in the membrane is prevented. Tocopheroxyl radicals—produced from α-tocopherol and peroxyl radicals are reduced by vitamin C or glutathione" [10] [Scheme 2] [11]

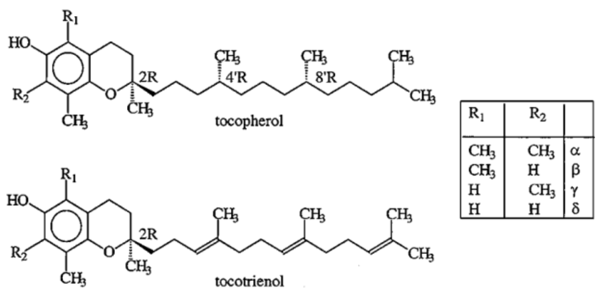
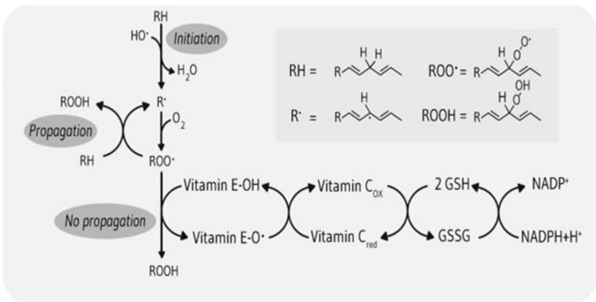


Figure 1: Chemical structure of Vitamin E



The peroxidation of unsaturated lipids leads to the formation of lipid peroxyl radicals (ROO·), which easily diffuse in biological systems. Peroxyl radicals react 1,000 times faster with α-tocopherol than with unsaturated lipids (RH). The hydroxyl group in the chromanol head of α-tocopherol can donate hydrogen to scavenge lipid peroxyl radicals, which halts their propagation in membranes and circulating lipoproteins. The presence of other antioxidants, such as vitamin C (ascorbate), is required to regenerate the antioxidant capacity of α-tocopherol. *GSSH, oxidized glutathione; GSH, reduced glutathione, NADP, nicotinamide adenine diphosphate; NADPH, reduced NADP; RH, unsaturated lipid; R·, lipid (carbon-centered) radical;* ROO·, hydroperoxide; Vitamin E-OH, α-tocopherol (reduced form); *Vitamin E-O·, tocopheroxyl radical (oxidized form); Vitamin C_{ox}, dehydroascorbate (oxidized vitamin C); Vitamin C_{red}, ascorbate (reduced vitamin C).*

Scheme 2 : Antioxidant activity of α-tocopherol

CAROTENOIDS

Carotenoids are A diverse omnipresent group of natural isoprenoid polyene pigment types with a perfectly straight symmetrical skeleton formed by a tail-to-tail connection of the two moieties of the C20. The C40 hydrocarbon linear backbone is vulnerable to numerous structural adjustments. Till date more than 700 carotenoids have been described. The most important include β-carotene, α-carotene, δ-carotene , γ-carotene, lycopene, ζ-carotene [Figure 2] [12], lutein, zeaxanthin, β-cryptoxanthin, α-cryptoxanthin, neurosporene etc. They are known to be very efficient physical and chemical quenchers of singlet oxygen ($^1O_2$) [13], peroxyl radicals add rapidly to polyenes structural unit of carotenoids, where the resulting C-radicals are strongly stabilized by resonance [Scheme 3] [14] playing the role of potent scavengers of other reactive oxygen species (ROS) thereby reduces oxidative stress.

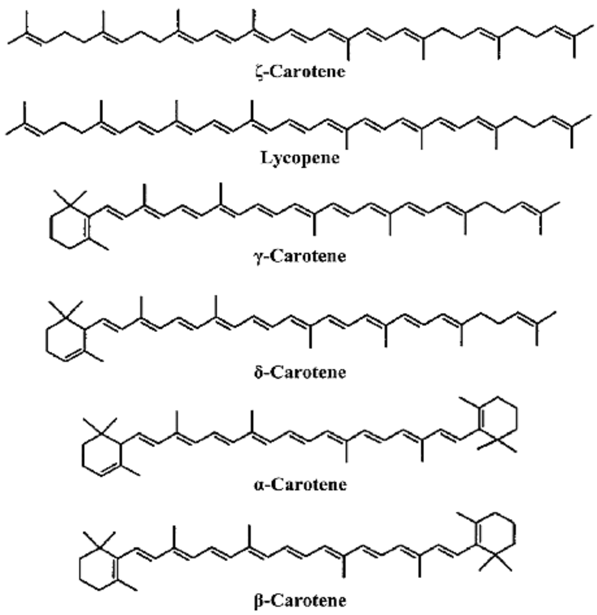
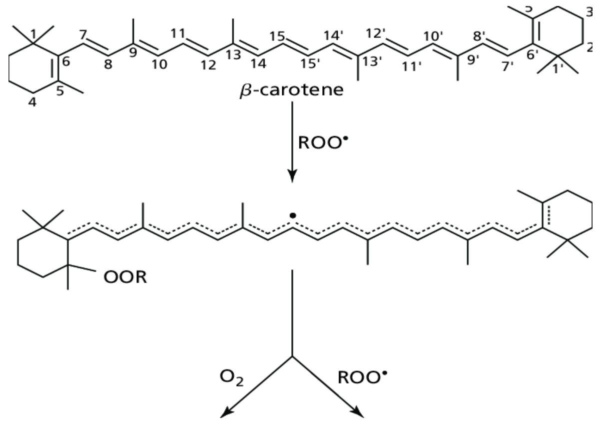


Figure 2 : Chemical structure of six carotenoids peroxy radicals quenching products



Scheme 3: Reaction of β-carotene with peroxyl radicals

POLYPHENOLS

This natural product category is a particularly complex group of compounds with phenolic structural properties which includes many classes and subgroups of phenolic compounds. Polyphenols were classified according to their chemical composition, their biological function and their sources. It can be grouped into four major classes on the basis of chemical structure: flavonoids, phenolic acids, polyphenolic amides and other polyphenols.

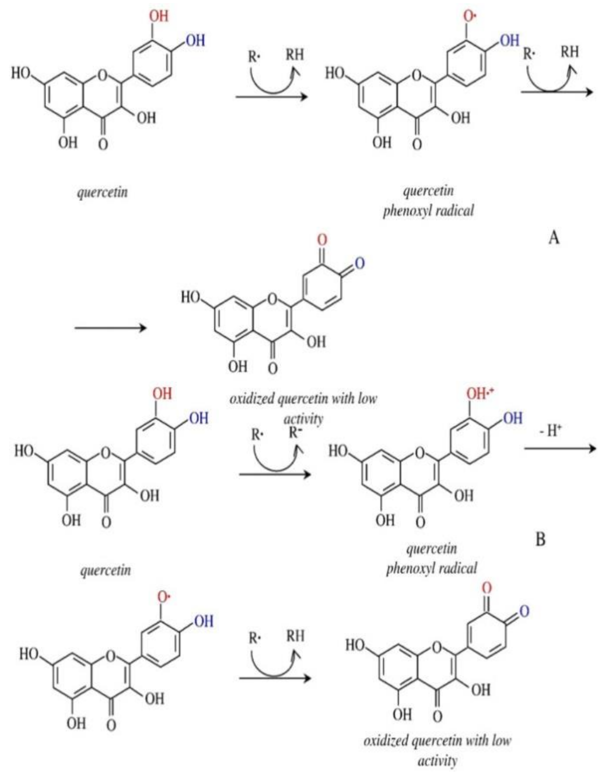
Querquetin, catechin and anthocyanin, such as apples, onions, black chocolate and red chocolate, are in flavonoids of subgroups including falvones, flavonols. It represents around 60% of all polyphenols [15] and has the general structural backbone C6–C3–C6 of which all units are phenolic.

No flavonoid polyphenolic acids constitute nearly 30% of all polyphenols[15] and further categorised into two subgroups, gallic acid and ferulic acid. Phenolic acids are non-flavonoid polyphenolic substances.

Polyphenolic amides, polyphenols with an amide element. Two other groups are avenanthramids, chilli pepper capsaicinoids and oats. Capsaicinoids such as capsaicin have major antioxidant and anti-inflammatory properties and modulate the oxidative function of cell defence. Avenanthramides include an antioxidant that prevents LDL oxidation [16]

Ellagic acid and its berry fruit compounds comprise, for instance, strawberries or raspberries, orange-containing resveratrol and lignans contained in linens, several grain links and curcumins.

In an electron or hydrogen molecule, polyphenols are used to neutralise free radicals. In quercetin, for example (3, 4′dihydroxyl), the strongly conjugated mechanism and some hydroxylated patterns are considered important for non-oxidants behaviours, where the chain end of the reaction is rapidly broken off by the free radical (R). Polyphenols hinder free radical growth and destroy active organisms and free radicals. They function as a chain breaker for lipid peroxidation chain reactions by electron free radical reactivity, free and safe (without reactivity) radical reactivity, stopping chain reactions. The Fenton reaction rate can be decreased by transitional metal chelation such as Fe2 +, which can resist oxidation by highly reactive hydroxy radicals. Polyphenols should not function on their own. Polyphenols effectively serve as co-antioxidants and are involved in the regeneration of essential vitamins [16].



Scheme 4: Hypothetical mechanisms for free radical scavenging activity of quercetin. (A) Hydrogen atom donation. (B) Electron transfer—proton transfer

CONCLUSION

Oxidative stress results from the imbalance of free radical generation and its quenching in the human body, which needs a balanced and powerful immune system to help battle many diseases. The antioxidant supplements may be effective for combating this oxidative stress. This is achieved by scavenging the over-produced free, reactive radicals, rendering the chemical structures more stable and low reactivity and thereby ending the chain reaction, maintaining the complex balance of free radicals inside the human body.

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Corresponding Author

Sabeeha Naaz*

Department of Chemistry, Dr. Ambedkar Govt. P. G. College, Unchahar- Raebareli (UP)

[Affiliated to CSJM University, Kanpur (U.P.)]

nsabeeha11@rediffmail.com