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Review Article

Plants as natural antioxidants

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Abstract

Oxygen free radicals induce damage due to peroxidation to biomembranes and also to DNA, which lead to tissue damage, thus cause occurrence of a number of diseases. Antioxidants neutralise the effect of free radicals through different ways and may prevent the body from various diseases. Antioxidants may be synthetic or natural. Synthetic antioxidants such as butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) have recently been reported to be dangerous for human health. Thus, the search for effective, non-toxic natural compounds with antioxidative activity has been intensified in recent years. The present review includes a brief account of research reports on plants with antioxidant potential.

Keywords: Reactive oxygen species, Antioxidant, Free radicals, Oxidative stress, Natural antioxidants.

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Introduction

About 5% or more of the inhaled oxygen (O_2) is converted to reactive oxygen species (ROS) such as O_2^-, H_2O_2, and OH by univalent reduction of O_2(ref.1). Antioxidants can act by scavenging reactive oxygen species (SOD removing O_2^-), by inhibiting their formation (e.g. by blocking activation of phagocytes), by binding transition metal ions and preventing formation of OH and/or decomposition of lipid hydroperoxides, by repairing damage (e.g. α-tocopherol repairing peroxyl radicals and so terminating the chain reaction of lipid peroxidation) or by any combination of the above[2].

In nature there are a wide variety of naturally occurring antioxidants which are different in their composition, physical and chemical properties, mechanisms and site of action[3]. Some of the main categories can be described as follows:

Enzymes: Superoxide dismutase (SOD), Catalase (CAT), Glutathion peroxidase (GPx), etc. are the well known enzymes present in plasma which act as antioxidants by transforming reactive oxygen species and reactive nitrogen species into the stable compounds[4].

High molecular weight compounds: These include proteins like albumin, transferin, ceruplasmin. They restrict the production of metal catalysed free radicals[5].

Low molecular weight compounds: These can be further divided into two categories i. e. lipid soluble antioxidants and water soluble antioxidants. Tocopherol, quinines, bilirubin and some polyphenols come under lipid soluble antioxidants; and ascorbic acid, uric acid and some polyphenols come under water soluble antioxidants[6].

Minerals: Minerals like selenium, copper, manganese, zinc, etc. are well known antioxidants[7]. Now-a-day chromium is also used in antioxidant formulation.

Vitamins: Vitamin A, C and E are the popular antioxidants, which play a crucial role in preventing peroxidation damage in the biological system[8, 9].

Plants as antioxidants: There is a long list of antioxidant plants of which some have been discussed in Table 1. Screening of plants is done by measuring the antioxidant activity through various *in vitro* models like DPPH method[10], Nitric oxide method[11], DMPD method[12], ABTS method[13], ORAC method[14], TBARS assay[15], etc. and *via* various *in vivo* models[16, 17] using rats or mice.

An antioxidant is any substance that, when present at low concentrations significantly delays or prevents oxidation of cell content like proteins, lipids, carbohydrates and DNA. Antioxidants can be classified into three main types: first line defence antioxidants, second line defence antioxidants and third line defence antioxidants.

SOD, CAT, GTx, glutathione reductase and some minerals like Se, Mn, Cu, Zn come under first line defence

antioxidants. SOD mainly acts by quenching of superoxide (O_2^-), catalase by catalyzing the decomposition of hydrogen peroxide (H_2O_2) to water and oxygen. Glutathione peroxidase is a selenium containing enzyme which catalyses the reduction of H_2O_2 and lipid hydroperoxide, generated during lipid peroxidation, to water using reduced glutathione as substrate. Selenium and vitamin E both appear to be necessary for efficient scavenging of peroxides from cytosol and cell membrane, respectively. Cu exerts its antioxidant activity through the cytosolic superoxide dismutase. Zinc is an element essential for normal growth, reproduction and other different functions of the body. It is a component of several enzymes like cytosolic superoxide dismutase, alcohol dehydrogenase, alkaline phosphatase, carbonic anhydrase, etc[14].

Glutathione (GSH), vitamin C, uric acid, albumin, bilirubin, vitamin E (mainly α-tocopherol), carotenoids, flavonoid, etc., comes under second line defence antioxidants. β-carotene is an excellent scavenger of singlet oxygen. Vitamin C interacts directly with radicals like O_2^-, HO (hydroxyl). GSH is a good scavenger of many free radicals like O_2^-, HO and various lipid hydroperoxides and may help to detoxify many inhaled oxidizing air pollutants like ozone, NO_2 and free radicals in cigarette smoke in the respiratory tract. Vitamin E scavenges peroxyl radical intermediates in lipid peroxidation and is responsible for protecting PUFA (poly unsaturated fatty acid) present in cell membrane and low density lipoprotein (LDL), against lipid peroxidation. Flavonoids are phenolic compounds, present in several plants, which inhibit lipid peroxidation and lipoxygenases[14].

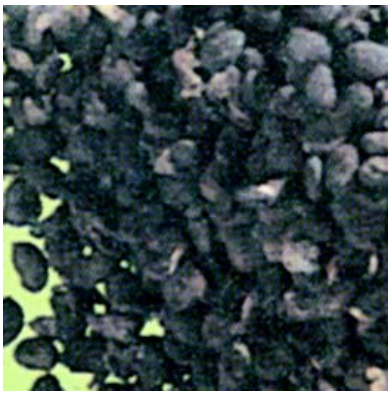
The most important chain-breaking antioxidant is α-tocopherol, present in human membranes. Vitamin C and α-tocopherol both help to minimize the consequences of lipid peroxidation in membranes. A major antioxidant defence of human body is to prevent O_2^- and H_2O_2 from reacting to form dangerous species such as hydroxyl ions, by binding transition metal ions in forms that will not stimulate free radical reactions. Thus, safe sequestration of iron and copper ions into forms that will not catalyse free radical reactions is an important antioxidant strategy in the human body[15].

Third line antioxidants are a complex group of enzymes for repair of damaged DNA, damaged protein, oxidized lipids and peroxides and also to stop chain propagation of peroxyl lipid radical. These enzymes repair the damage to biomolecules and reconstitute the damaged cell membrane, e.g. lipase,

Cuscuta reflexa

Picrorrhiza kurroa

Tinospora cordifolia



Psoralea corylifolia

Ginkgo biloba

proteases, DNA repair enzymes, transferase, methionine sulphoxide reductase, etc[14].

In Ayurveda formulation of some *rasayanas* with well defined antioxidant properties has been done[16, 17]. Rasayanas are a group of non-toxic polyherbal drug preparation, which are immunostimulatory and thereby prevent the causation of disease[18] and promote health and longevity[19].

It is reported that when the balance between ROS production and antioxidant defenses is lost, 'oxidative stress' results which through a series of events deregulates the cellular functions and leads to various pathological conditions, viz. AIDS, ageing, arthritis, asthma, atherosclerosis, autoimmune diseases, broncho-pulmonary dysplasia, carcinogenesis, cardiovascular dysfunction, cataract, diabetes, gastro-duodenal pathogenesis, genetic disorders, inflammatory diseases, ischemia reperfusion injury, liver disorders, muscular dystrophy, neurodegenerative diseases, parkinsons dementia, Alzheimer's disease, amyotropic lateral sclerosis, pulmonary fibrosis, radiation damage, retinopathy, rheumatism, skin disease porphyria and senile dementia stroke[20-26].

A brief description including part of the plant used, chemical constituents and other biological activities of common antioxidant plants[27-57] is given in Table 1. In addition to plants discussed in this table there are some more plants which possess antioxidant property (Table 2)[58-85] and need further studies for exploring their antioxidant potential.

Table 1 : A brief description of common antioxidant plants[27-57]

S. No.	Botanical/ Family name	Common/ English name	Part used	Chemical Constituents	Biological Activities
1.	***Curcuma domestica* Valeton** syn. *C. longa* Linn. Zingiberaceae	Turmeric	Leaf	Curcumin, β-pinene, camphene, eugenol, β-sitosterol	For cleaning blood, in cough and dysponoea management, antifertility agent, for malarial fever, effective in senile pruritis, in gastro-intestinal complaints, antifungal, insecticide.
2.	***Cuscuta reflexa* Roxb.** Convolvulaceae	*Akashabela*	Stem	Flavonoids, dulcitol, bergenin, coumarins, glycosides, lactone	Expectorant, carminative, anthelmintic, purgative, diuretic, in jaundice, in bilious disorders, antifertility drug.
3.	***Daucus carota* Linn.**/Apiaceae	Carrot	Root	Carotenes, carotenoids, glycosides, flavonoids, sugars, quaternary bases	Used in bronchitis, chest troubles, urinary complaints, aphrodisiac, piles, leprosy, tumours, jaundice.
4.	***Emblica officinalis* Gaertn.** syn. *Phyllanthus emblica* Linn. Euphorbiaceae	*Amla*/Emblic Myrobalan	Fruit	Vitamin C (L-ascorbic acid), polyphenols (ellagic acid, gallic acid, tannins)	Useful in burning sensations, vomiting, urinary discharges, leprosy, constipation, inflammations, piles, anaemia. Amla is reported to be more potent antioxidant than vitamin C.
5.	***Foeniculum vulgare* Mill.** Apiaceae	*Saunf* Fennel	Fruit oil	Volatile oil, fenchone, anethole, limonene, anisaldehyde, estragole	Stimulant, aromatic, carminative, purgative, diuretic, in venereal diseases, vermicide, useful in chest, spleen and kidney troubles, estrogenic. Fennel oil antioxidant

S. No.	Botanical/ Family name	Common/ English name	Part used	Chemical Constituents	Biological Activities
					activity is comparable to that of α-tocopherol and butylated hydroxytoluene (BHT), used as reference antioxidants.
6.	***Glycyrrhiza glabra* Linn.** Fabaceae	*Mulethi* Liquorice	Root	Glycyrrhizin, flavonoids, liquiritin, isoliquiritin, rhamnoliquiritin, 2-methylisoflavones	Diuretic, emmenagogue, in vomiting, asthma, bronchitis, in acute conjunctivitis, for curing wounds, in peptic ulcer.
7.	***Mangifera indica* Linn.** Anacardiaceae	*Am* Mango	Root, Leaf, Fruit	Cyanogenetic glycosides, polyphenols, vitamin A & C, mangiferin, β-sitosterol, quercetin, ellagic acid, gallic acid	Leucorrhea, dysentery, bronchitis, biliousness, urinary discharges, in haemorrhage from the uterus, lungs, or intestine.
8.	***Momordica charantia* Linn.** Cucurbitaceae	*Karela* Bitter Melon	Root, Leaf, Fruit, Seed	Stearic acid, triterpene glycosides	Root as laxative, antipyretic, anthelmintic for asthma, ulcer, bronchitis, cholera. Fruit as carminative, stomachic, aphrodisiac, in syphilis, rheumatism antimutagenic and antidiabetic. It is a strong scavenger of superoxide and hydroxyl radicals[17].
9.	***Ocimum sanctum* Linn.** Lamiaceae	*Tulsi* Sacred Basil	Leaf	Volatile oil, terpenoids, eugenol, thymol, estragole	Expectorant, in catarrh, bronchitis, ringworm and other cutaneous diseases, stomachic, gastric disorders of children, in earache.
10.	***Psoralea corylifolia* Linn.** Fabaceae	*Babchi*	Seed	Essential oil, fixed oil, resin, bakuchiol (monoterpene phenol)	Purgative, stomachic, anthelmintic, stimulant, aphrodisiac, leucoderma, scabies, biliousness, in various blood and skin diseases. Bakuchiol is reported to be effective to protect mitochondrial functions against oxidative stress.
11.	***Santalum album* Linn.** Santalaceae	*Safed-chandan* Sandal	Heartwood, Bark	Volatile oil Santalol, α-santalol, β-santalol, β-sitosterol	Antipyretic, aphrodisiac, useful in diseases of the heart, bronchitis, smallpox, seeds in skin diseases, used in various perfumery products.

S. No.	Botanical/ Family name	Common/ English name	Part used	Chemical Constituents	Biological Activities
12.	***Solanum nigrum* Linn.** Solanaceae	*Makoi*/Common Nightshade	Leaf	Polyphenolic compounds, flavonoids, steroids	Diuretic, laxative, dropsical affections, virulent gonorrhoea, malaria, dysentery, hepatoprotective.
13.	***Swertia chirayita* (Roxb. ex Flem.) Karst.** Gentianaceae	*Chirayita* Chiretta	Whole plant	Xanthones, mangiferin, swertinin, chiratin, arginine	Febrifuge, anthelmintic, laxative, antimalarial, chronic fever.
14.	***Withania somnifera* Dunal** Solanaceae	*Ashwagandha*	Root, Leaf, Seed	Steroidal lactone, withanolides, glycene, withanine	Analgesic, increases immunity, hepatoprotective.

Table 2 : Additional list of plants showing antioxidant activity [58-85]

S. No.	Name of the plant	Family	Part used
1.	***Allium sativum* Linn.**	Liliaceae	Bulb
2.	***Asparagus racemosus* Willd.**	Liliaceae	Shoot
3.	***Baccharis coridifolia* DC.**	Asteraceae	Aerial parts
4.	***Bryonia alba* Linn.**	Cucurbitaceae	Root
5.	***Cichorium intybus* Linn.**	Asteraceae	Leaf
6.	***Cinnamomum zeylanicum* Breyn.**	Lauraceae	Bark
7.	***Crithmum maritimum* Linn.**	Apiaceae	Essential oil
8.	***Cynara scolymus* Linn.**	Asteraceae	Leaf
9.	***Emilia sonchifolia* DC.**	Asteraceae	Leaf
10.	***Eucalyptus camaldulensis* Dehnh.** syn. *Eucalyptus rostrata* Schl.	Myrtaceae	Leaf
11.	***Eucommia ulmoides* Oliver**	Eucommiaceae	Leaf
12.	***Garcinia kola* Heckel**	Clusiaceae	Fruit
13.	***Ginkgo biloba* Linn.**	Ginkgoaceae	Leaf
14.	***Lavandula angustifolia* Mill.**	Lamiaceae	Aerial parts
15.	***Lycium barbarum* Linn.**	Solanaceae	Fruit
16.	***Melissa officinalis* Linn.**	Lamiaceae	Aerial parts

S. No.	Name of the plant	Family	Part used
17.	***Murraya koenigii* (Linn.) Spreng.**	Rutaceae	Leaf
18.	***Myrica gale* Linn.**	Myricaceae	Fruit
19.	***Panax ginseng* Mey.**	Araliaceae	Root
20.	***Picrorrhiza kurroa* Royle ex Benth.**	Scrophulariaceae	Rhizome, Root
21.	***Piper nigrum* Linn.**	Piperaceae	Fruit
22.	***Plantago asiatica* Linn.**	Plantaginaceae	Seed
23.	***Prunus domestica* Linn.**	Rosaceae	Fruit
24.	***Rhazya stricta* Decne**	Apocyanaceae	Leaf
25.	***Rosmarinus officinalis* Linn.**	Lamiaceae	Aerial parts
26.	***Salvia officinalis* Linn.**	Lamiaceae	Aerial parts
27.	***Salvia triloba* Linn. f.**	Lamiaceae	Leaf
28.	***Solanum melongena* Linn.**	Solanaceae	Fruit
29.	***Solanum tuberosum* Linn.**	Solanaceae	Tuber
30.	***Syzygium caryophyllatum* (Linn.) Alston** syn. *Eugenia caryophyllus* Wight	Myrtaceae	Flower buds
31.	***Thymus zygis* Sibth. & Sm.**	Lamiaceae	Aerial parts
32.	***Tinospora cordifolia* (Willd.) Miers. ex Hook. f. & Thoms.**	Menispermaceae	Root
33.	***Uncaria tomentosa* DC.**	Rubiaceae	Bark
34.	***Zingiber officinale* Rosc.**	Zingiberaceae	Rhizome

Conclusion

The imbalance between reactive oxygen species and antioxidant defense systems may increase the oxidative burden and lead to the damage of macromolecules such as DNA, carbohydrates or proteins. Such processes are thought to play a role in pathological processes of various diseases. Plants having vitamins (C, E, carotenoids, etc.), flavonoids (flavones, isoflavones, flavonones, anthocyanins and catechins), polyphenols (ellagic acid, gallic acid and tannins) possess remarkable antioxidant activity. Antioxidant activity is neither restricted to a particular part of the plant nor the specific families. It is reported that folic acid present in fruits, vegetables and orange juices may reduce hypomethylation of DNA, which is thought to initiate cancer. It is also found that the risk of cervical dysplasia is high in women with a low folic acid intake.

All plants discussed in this review exhibited significant clinical and pharmacological activity with fewer side effects. Different combination of the active constituents after isolation and identification can be made and have to be further evaluated for the synergetic effect. Preparation of standardized dose and dosage regimen may play a crucial role in therapeutics for the mankind.

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