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Medicinal Plants as a Source of Antioxidants

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Abstract: Presently, there has been an amplified interest worldwide to identify antioxidant compounds which are pharmacologically effective and have low or no side effects for use in preventive medicine and the food industry. Plants produce significant amount of antioxidants such as flavonoids, phenolics and polyphenolics (condensed and hydrolysable tannins) to prevent the oxidative stress caused by reactive oxygen species. Ayurveda, Unani Chinese and other traditional medical systems, provide substantial lead to find active and therapeutically useful antioxidant compounds from plants. Considering the growing interest in assessing the antioxidant capacity of natural products the phytochemistry of plants having antioxidant activity has been reported.

Key words: Antioxidants, Ayurveda, flavonoids, phenolics, tannins

INTRODUCTION

Life on earth survives only due to presence of oxygen. Oxygen gives us energy by oxidation of food which is essential for living. During this process highly reactive and harmful oxygen species are also generated which can damage living organisms. Organisms contain a complex network of antioxidant molecules and enzymes that work together to prevent oxidative damage of cellular components such as DNA, proteins and lipids (Sies, 1997; Vertuani *et al.*, 2004; Nicholls and Budd, 2000; Shirwaikar *et al.*, 2004; Halliwell *et al.*, 1992). In general, we can say that these antioxidants either prevent these reactive oxygen species being formed or remove them before they can damage the cellular components. The active oxygen species create hydrogen peroxide (H_2O_2), hypochlorous acid (HOCl) and free radicals such as hydroxyl radical ($\bullet OH$) and superoxide anions (O_2^-) (Valko *et al.*, 2007). These reactive oxygen species are generated during the sequential reduction of molecular oxygen. The addition of one electron to O_2 yields the superoxide radical ($\bullet O_2^-$), which on further reduction gives hydrogen peroxide (H_2O_2), a divalent oxygen reduction product. Trivalent oxygen reduction occurs by reaction of H_2O_2 with $\bullet O_2^-$ to produce the hydroxyl radical ($\bullet OH$). The reaction rate of formation of $\bullet OH$ is enhanced in presence of metal catalyst (Fe^{+3}) via the Haber-Weiss reaction (Haber and Weiss, 1934) (Table 1). Besides $\bullet OH$ formation, experimentally induced interactions between H_2O_2 and iron chelates may also lead to the production of the reactive iron peroxocomplex and ferryl ion (Rush and Koppenol, 1986; Winterbourn, 1987). However, their role in human and microbial physiology is basically

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Table 1: Chemical reaction involving reactive oxygen species

Reaction	Formula
Haber-Weiss mechanism	$O_2^- + Fe^{3+} \rightarrow O_2 + Fe^{2+}$ $H_2O_2 + Fe^{2+} \rightarrow HO^\bullet + OH^- + O_2$ $O_2^- + H_2O_2 \rightarrow HO^\bullet + OH^- + O_2$
Myelo [eosinophil] Peroxidase	$H_2O_2 + HX \rightarrow HOX + H_2O$
Nitric oxide synthase	$L\text{-Arginine} \rightarrow L\text{-Citrulline} + NO^\bullet$
Peroxynitrite formation decomposition	$NO^\bullet + O_2^- \rightarrow ONOO^-$ $ONOO^- + H^+ \rightarrow ONOOH$ $ONOOH \rightarrow HO^\bullet + NO^\bullet$

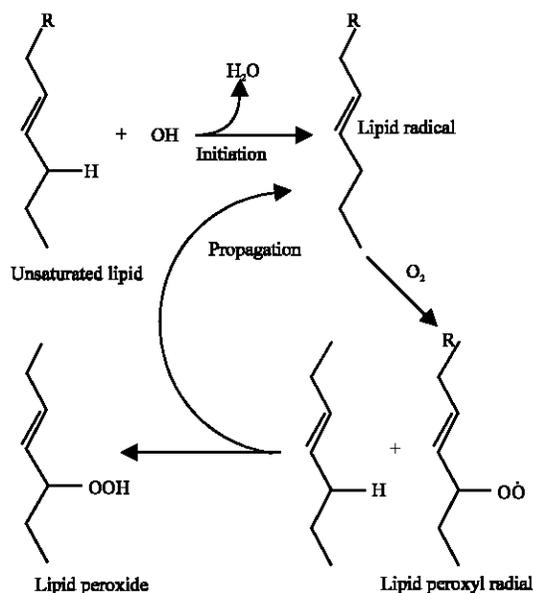


Fig. 1: The free radical mechanism of lipid peroxidation

unknown. Although most investigations have focused on $^\bullet OH$ formation by the Haber-Weiss mechanism, evidence also exists for the formation of $^\bullet OH$ from $^\bullet O_2^-$ mediated reduction of hypochlorous acid (HOCl) (Candeias *et al.*, 1993; Long and Bielski, 1980; Okolow-Zubkowska and Hill, 1982; Ramos *et al.*, 1992). HOCl is generated by the interaction of H_2O_2 with phagocyte-derived peroxidases is itself a powerful oxidant.

These reactive oxygen species are extremely reactive and initiate the chemical chain reactions with biological molecules. Due to these chain reactions the cell may function feebly or get damaged such as lipid peroxidation or oxidation of DNA or proteins (Fig. 1).

There is abundant evidence to connect free radicals in the development of degenerative diseases (Huong *et al.*, 1998; Haraguchi *et al.*, 1997). Active oxygen species (or reactive oxygen species) and free radical-mediated reactions are involved in degenerative or pathological processes such as aging (Yagi, 1987; Harman, 1982; Ames *et al.*, 1993; Harman, 1995), cancer, coronary heart disease and alzheimer's disease (Ames, 1983; Gey, 1990; Smith *et al.*, 1996; Diaz *et al.*, 1997). In addition to medicinal uses of antioxidants these compounds also possess lots of industrial applications such as preservatives in food and cosmetics and put off the degradation of rubber and gasoline. In food industries free radicals are found to be responsible for lipid oxidation that is a major determinant in the deterioration of foods during processing and storage (Nunez-Delicado *et al.*, 1997; Chen and Ho, 1997). Due to this fact considerable interest has been shown to the addition of antioxidants in food

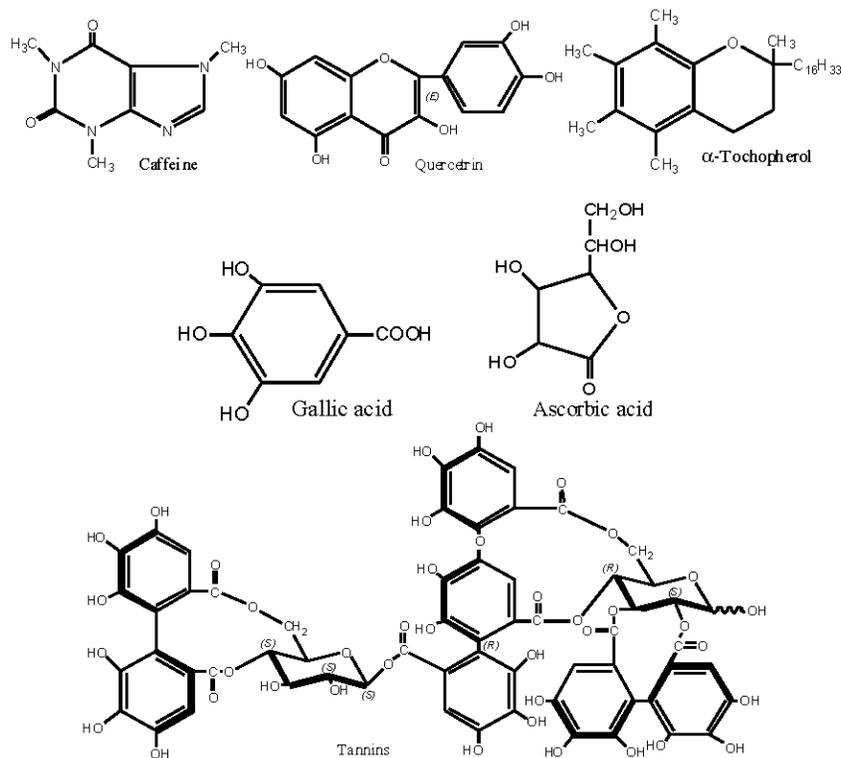


Fig. 2: Natural antioxidant

and biological systems to scavenge free radicals. Antioxidants which are widely used in the food industries since the beginning of this century are synthetic materials such as Butylated Hydroxyl Anisole (BHA), ethoxyquin, metabisulfite and Butylated Hydroxyl Toluene (BHT). The toxicological and nutrition studies showed that use of these synthetic antioxidants are toxic and harmful for human being, therefore the use of these synthetic antioxidant has started to be restricted and substituted by natural antioxidants (Bronen, 1975; Ito *et al.*, 1983; Grice, 1986; Imida *et al.*, 1983). Recently, various studies and research articles showed that some secondary metabolites such as flavonoids, phenolics and polyphenolics (condensed and hydrolysable tannins) demonstrate the potent antioxidative effectivity (Hagerman *et al.*, 1998). Ascorbic acid (vitamin C), tocopherols and tocotrienols (vitamin E), melatonin and glutathione (Fig. 2) which are widely found in plant kingdom possess potent antioxidant properties. These plant materials may provide safe replacement for harmful and toxic synthetic antioxidants. Various studies indicated that there is an inverse relationship between the dietary intake of antioxidant rich foods and the incidence of human diseases (Sies, 1993; Halliwell, 1997). There are many epidemiological results revealing an association between people who have a diet rich in fresh fruits and vegetables and a decrease in the risk of cardiovascular diseases and certain forms of cancer. The natural antioxidants are beneficial for our health without any side effect and scavenge the free radical immediately after intake through metabolic activities. Thus, natural anti-oxidants are suitable substitute for synthetic ones. Pathology and mechanism of action of some representative group of antioxidant compounds is summarized in Table 2 and structure of some natural antioxidants are shown in Fig. 2.

Objective of the Review

Medicinal plants, as a group, comprise approximately 8000 species and account for about 50% of all the higher flowering plant species of India. India is one of the richest with vast resource of medicinal and aromatic plants. It constitutes 11% of total known world flora having medicinal property. Ayurveda has been in practice in India for more than 3500 years and the first recorded book on Ayurvedic medicine was Charaka Samhita dates back to 600 BC. The traditional healers have used this resource since time immemorial for the benefit of mankind. In this review article, we have summarized the plant species showing potent antioxidant activity with their family, active principles and traditional medicinal uses on the basis of the survey of literature (Table 3).

Table 2: Mechanism of action of various natural antioxidants

Compound	Pathology	Mechanism of action
Alkaloids	Cancer, Neurodegenerative diseases, chronic inflammation	Shown a variety of biological activities such as inhibition of topoisomerase I and II; cytotoxicity against different tumor cell lines (Radisky <i>et al.</i> , 1993; Gunasekera <i>et al.</i> , 2003)
Catechins	Neurodegenerative diseases	Enhance activity of SOD and catalase (Levites <i>et al.</i> , 2001).
Carotenoids	Cancer, diabetic retinopathy, chronic	Mainly act as physical quenchers of reactive oxygen (Sundquist <i>et al.</i> , 1994)
α -tocopherol	Cancer, neurodegenerative diseases, chronic inflammation	Scavenges lipid peroxy radicals (LOO) through hydrogen atom transfer (Burton and Ingold, 1981)
Phenolics	Cancer, diabetic retinopathy, chronic inflammation	Inhibit the oxidation of lipids, fats and proteins (RH) by donation of a phenolic hydrogen atom to the free radical (Aruoma <i>et al.</i> , 1993)
Tannins	Cardiovascular disorders	Tannins are known to enhance synthesis of nitric oxide and relax vascular segments precontracted with norepinephrine (Dwivedi, 2007)

Table 3: Plant species showing potent antioxidant activity with their family, traditional medicinal uses and active principles

Plant species	Family	Traditional medicinal uses	Extract/active constituents
<i>Acacia catechu</i> (L. f.) Willd.	Mimosaceae	Diarrhoea, cough, skin eruption, asthma, check nasal bleeding	Catechin and quercetrine (Cartron <i>et al.</i> , 2001)
<i>Aerva perisa</i>	Amaranthaceae	dysentery, bronchitis Headache, dysentery, gonorrhoea, kidney disorders and cutaneous affections	Flavonoidal constituents; methyl grevillate; 5,4'-Dihydroxy-3,6,7-trimethoxyflavone; 5-Hydroxy-3,6,7,4'-tetramethoxyflavone; Apigenin-7-O- β -D-glucopyranoside; β -Sitosteryl acetate; Lupeol, Lupeol acetate; 4-Ethoxy benzoic acid; 2',3,5',6,7-Pentamethoxyflavone and 3,3',5'-Trihydroxy-4'-methoxyflavone 7-O- β -D-glucopyranoside (Ahmed <i>et al.</i> , 2006)
<i>Alternanthera purgens</i>	Amaranthaceae	Diuretic and used in gonorrhoea	Flavone C-biosides; α - and β -spinasterols and choline (Petrus and Seetharaman, 2005).
<i>Anadenanthera macrocarpa</i> (Benth.) Brenan	Fabaceae	Extract of bark is taken for liver problems, upper respiratory infections, angina pectoris and gonorrhoea	Thiobarbituric acid (Lamarque <i>et al.</i> , 1998)
<i>Anemopaegma arvense</i>	Bignoniaceae	Anticancer properties and widely used as a stimulant in traditional medicine	Flavan-3-ol-phenylpropanoid conjugates; cinchonain Ia, cinchonain IIa and kandelin (Tabanca <i>et al.</i> , 2007)
<i>Angelica dahurica</i>	Umbelliferae	Analgesic, antibacterial, antidote, carminative, diaphoretic, Poultice, stimulant, contraindicated for pregnant women, fever, rheumatism, leucorrhoea and antistaphylococcal	9-Hydroxy-4-methoxy psorlen and all oisimperatorin (Piao <i>et al.</i> , 2004; Lechner <i>et al.</i> , 2004)
<i>Anogeissus latifolia</i>	Combretaceae	Puerperal fever, cancer, diarrhoea, stomachache, cholera, dysentery, Kapha and pitta	Gallic acid and 3,3'-Di-O-methylellagic acid-4'- β -D-xyloside (Carton <i>et al.</i> , 2001; Govindarajan <i>et al.</i> , 2004a, b)

Table 3: Continued

Plant species	Family	Traditional medicinal uses	Extract/active constituents
<i>Artemesia</i> spp.	Asteraceae	Anthelmintic, antiseptic, deobstruent, antimalarial, emmenagogue, febrifuge and tonic	Flavonoids; acetylenic compounds and ascorbic acid (Mangathayaru <i>et al.</i> , 2007; Valecha <i>et al.</i> , 1994)
<i>Asparagus</i> spp.	Liliaceae	Aphrodisiac, antiseptic, abortifacient, antispasmodic, leucorrhoea, cytotoxic and molluscicides activity	Ascorbic acid; Steroidal Saponins and glycosides (Velavan <i>et al.</i> , 2007; Sharma <i>et al.</i> , 1982, 1983; Sati <i>et al.</i> , 1984; Sati and Pant, 1985a, b; Sati and Sharma, 1985; Sati <i>et al.</i> , 1985)
<i>Bauhinia forticote</i>	Caesalpinaceae	Hypoglycemic, blood purifier and diuretic	Kempferol-3,7-O-dihmannoside (De Sousa <i>et al.</i> , 2004)
<i>Calliandra haematocephala</i>	Leguminosae	Antimicrobial and diuretic	Galloylated flavonol glycosides (Moharram <i>et al.</i> , 2006)
<i>Carica papaya</i> L.	Caricaceae	Stomach trouble, urinary troubles, skin diseases, ring worm killer and gastric troubles	Ascorbic acid (Kondo <i>et al.</i> , 2005)
<i>Carlina acanthifolia</i> .	Asteraceae	Antimicrobial, anti-inflammatory and anti-ulcer	Essential oil (Dordevic <i>et al.</i> , 2007)
<i>Cassia siamea</i>	Fabaceae	Fruits and bark used as an antiseptic, antidote of snake and scorpion bite, fruits pulp in asthma, bronchitis and skin diseases	MeOH extract (Kaur <i>et al.</i> , 2006)
<i>Cratogeomys cochinchinense</i>	Clusiaceae	Cold and cytotoxic activity against the human lung cancer cell line (NCI-H187) with IC ₅₀ values	Xanthones (Phuwapraisrisan <i>et al.</i> , 2006; Laphookhieo <i>et al.</i> , 2006)
<i>Cuminum cyminum</i>	Apiaceae	Fruits used as a spice and medicinally used in cold, constipation, anorexia and diarrhea in hen	Volatile oil and acetone extract (Singh <i>et al.</i> , 2006)
<i>Curculigo crassifolia</i>	Amaryllidaceae	Asthma, coughs, cold, jaundice and stomach disorders	Phenolic compounds (Wang and Li, 2007)
<i>Delphinium linearilobum</i>	Renunculaceae	Root used as snake bite and as a stimulant, gives in toothache	Norditerpene alkaloids (Kolak <i>et al.</i> , 2006)
<i>Dolichos biflorus</i> Linn.	Fabaceae	Hypolipidemic effect	Flavonoids (Kottaimuthu <i>et al.</i> , 2007)
<i>Erythrina</i> sp.	Fabaceae	Bark used in skin diseases, insecticidal and leaf extract in gonorrheal diseases	Erylatissin A; erylatissin B; erylatissin C; (+)erysodin and (+)-11, α -hydroxy erysodine (Chacha <i>et al.</i> , 2005; Benard and Runner, 2004).
<i>Helichrysum compactum</i>	Asteraceae	Antibacterial activity	The flavonoids: apigenin; kaempferol; luteolin; naringenin; 3,5-dihydroxy-6,7,8-trimethoxyflavone; kaempferol-3-O-glucoside; luteolin-7-O-glucoside; luteolin-4',7-di-O-glucoside; apigenin-7-O-glucoside and quercetin-3-O-glucoside (Sevda <i>et al.</i> , 2005)
<i>Helminthostachys zeylanica</i> (L.) Hook.	Helminthostachyaceae	Diabetes and impotency	Ugonin J; ugonin K and ugonin L (Huang <i>et al.</i> , 2003)
<i>Heracleum persicum</i>	Apiaceae	Root paste applied in skin diseases, eczema and itches	Isopimpinellin; bergapten; pimpinellin and bakuchicin (Souri <i>et al.</i> , 2004)
<i>Hordium vulgare</i> L. Var. <i>nudum</i> Hook	Poaceae	Used for making beverages and edible purpose	Flavonoids 2''(3'')-O-glycosylisovitexin (Osawa <i>et al.</i> , 1992).
<i>Hunteria zeylanica</i>	Apocynaceae	Antinociceptive, antipyretic effects, diarrhea, gastrointestinal discomfort, ulcers and cytotoxic	Barakol, strictosidinic acid and alkaloid (eburnamine, isoeburnamine, eburnamine, yohimbol, eburnamonine and venoterpene) (Seazzocchio <i>et al.</i> , 2001; Gentry <i>et al.</i> , 1998; Lau <i>et al.</i> , 2001; Reanmongkol <i>et al.</i> , 1994)
<i>Hypericum perforatum</i>	Hypericaceae	Paste of leaves applied on cuts to check bleeding and infusion of leaves given in malarial fever	Caffeoylquinic acid (Lamarque <i>et al.</i> , 1998; Silva <i>et al.</i> , 2005)

Table 3: Continued

Plant species	Family	Traditional medicinal uses	Extract/active constituents
<i>Justica adhatoda</i> L.	Acanthaceae	Cold, fever, cough, eye diseases, blood diseases, jaundice and antiseptic	Vasicine (Singh <i>et al.</i> , 2000)
<i>Leonurus japonicus</i>	Lamiaceae	The seed is aphrodisiac, diuretic, emmenagogue, ophthalmic and is also used in the treatment of various women's complaints. The aerial parts of the plant are alterative, antibacterial, antifungal, depurative, diuretic, emmenagogue, hypotensive, vasodilator and vulnerary	β -(3,4-dihydroxyphenyl)-ethyl-O-(2,6-dimethoxy-4-hydroxyphenyl)- β -D-glucopyranoside, named leonurisode A; β -(3,4-dihydroxyphenyl)-ethyl-O- α -L-arabinopyranosyl-(1 \rightarrow 2)- β -L-rhamnopyranosyl-(1 \rightarrow 3)-D-glucopyranoside, named leonurisode B; rutin; isoquercitrin; filiroside; isorhamnetin 3-O-rutinoside and iridoid glycoside leonuride (Qu <i>et al.</i> , 2006)
<i>Morus alba</i> L.	Moraceae	It is useful in treatment of vomiting, piles, bronchitis and inflammation	B-carotene and α -tocopherol (Yen <i>et al.</i> , 1996)
<i>Mucuna pruriens</i> (L.) DC.	Fabaceae	Nervine, tonic, cholera, diabetes, impotency and eye diseases	Bufotenine (Tripathi <i>et al.</i> , 2002)
<i>Pandanus odoratissimus</i> L. f.	Pandanaceae	Leprosy, scabies, skin diseases, rheumatism and snakebite	Pinoresinol, 3,4-bis(4-Hydroxy-3-methoxybenzyl)tetrahydrofuran (Jong and Chau, 1998)
<i>Perilla frutescens</i> (L.) Britt.	Lamiaceae	Leaves used as flavouring, plant extract or powder of dried parts used for cough, bronchitis, uterine ailments and leaf past applied on rheumatic arthritis	5-(3,4-dihydroxyphenylmethyl)oxazolidine-2, 4-dione and 3-(3,4-dihydroxyphenyl)lactamide (Nagatsu <i>et al.</i> , 1995)
<i>Phaseolus vulgaris</i> L.	Fabaceae	Used as pulse, paste of leaves used as antimicrobale	Cyanidin 3-O-p-D-glucoside and polyphenols (Suda <i>et al.</i> , 1994; Ranilla <i>et al.</i> , 2007; Cardador-Martinez <i>et al.</i> , 2006)
<i>Phellodendron amurense</i>	Rutaceae	Diabetes mellitus, meningitis, pneumonia, antistomachic, intestinal function control, anti-inflammatory, anti-psychic, hest relief, bacillary dysentery, diarrhea, tuberculosis and liver cirrhosis	Quercetin; quercetin-3-O- β -D-glucoside; quercetin-3-O- β -D-galactoside and kaempferol-3-O- β -D-glucoside (Gray <i>et al.</i> , 1988)
<i>Phyllostachys edulis</i>	Gramineae	Antiemetic, the leaves are used in the treatment of arthritic inflammations, the sheaths of the stem are used in the treatment of nausea and sour stomach	Phyllostadimers A (Suga <i>et al.</i> , 2003)
<i>Picea abies</i>	Pinaceae	Resin applied on cuts, sores and body pain	A-Tocopherol (Tegischer <i>et al.</i> , 2002)
<i>Piper crassinervium</i> Kunth.	Piperaceae	Cough, cold, and abdominal pain	Prenylated hydroquinone and benzoic acid derivatives (Yamaguchi <i>et al.</i> , 2006)
<i>Pleuropterus ciliinervis</i>	Polygonaceae	treat inflammation, bacterial infections, suppurative dermatitis and gonorrhoea	Piceid-2''-O-gallate; piceid-2''-O-coumarate; (2)-lyoniresinol 3a-O-b-D-glucopyranoside and (1)-lyoniresinol 3a-O-b-D-glucopyranoside (Lee <i>et al.</i> , 2003)
<i>Polygonum hydropiper</i> L.	Polygonaceae	Tonic, stimulant, cooling, astringent, piscicidal, urinary disorders and toothache	Galloyl kaempferol 3-glucoside and galloyquercetin (Pang <i>et al.</i> , 2003)
<i>Populus davidiana</i>	Salicaceae	Anti inflammation	Phenolic glycosides (Zhang <i>et al.</i> , 2006)
<i>Prunus domestica</i>	Rosaceae	The juice from the bark applied on body swellings and contusions and oil from kernels applied on neuralgic pains	Prunefin, genistein and quercetin (Jung <i>et al.</i> , 2002)
<i>Psoralea corylifolia</i>	Papilionaceae	Fruit is diuretic and causes biliousness. According to Unani system of medicine, its	Psoralen (Das <i>et al.</i> , 1999; Khanbabaee and Ree, 2001; Murthy <i>et al.</i> , 2002; Jung <i>et al.</i> , 2007)

Table 3: Continued

Plant species	Family	Traditional medicinal uses	Extract/active constituents
<i>Punica granatum</i> L.	Punicaceae	seed is purgative, stomachic, anthelmintic, vulnerary, stimulant, aphrodisiac and cures blood related troubles Fever, cough, pimples, boils, throat disorder, dysentery, diuretic, cardiac problems, vomiting and bronchitis	Punicalin (Das <i>et al.</i> , 1999; Khanabae and Ree, 2001; Murthy <i>et al.</i> , 2002)
<i>Rhododendron yedoense</i>	Ericaceae	Flowers and bark medicinal for digestive and respiratory disorders	Flavonoids (Jung <i>et al.</i> , 2007)

CONCLUSION

Forty four plants have been reviewed for their antioxidant properties. Flavanoids and tannins are potent antioxidants followed by ascorbic acid and alkaloids (Fig. 2). The mechanism of action of some of the identified natural antioxidants is known (Table 2) but as the active ingredients in many plants extract possessing antioxidant properties remains to be identified. The review clearly indicates that there is a great possibility of finding potent antioxidants of plant origin.

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