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Antioxidant Potential and Nutritional Values of Vegetables: A Review

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ABSTRACT

More than 70% people in developing countries depend on vegetables and fruits further regular dietary needs. Vegetables prevents human from several sever and chronic diseases. It is necessary to consume daily at least 400 g of vegetables including pulses, nuts and seeds. Since vegetables have antioxidant properties they prevents human from cancer, cardio vascular diseases, diabetes, hyper tension, leprosy, rheumatism, epilepsy, liver and urinary disorder, stroke, paralysis etc. The vegetables contain several phytochemicals possessing antioxidant activity. The major groups of phytochemicals include vitamin A, C, E and K, carotenpoid, terpenoid, flavonoids, polyphenols, saponins, enzymes and minerals. The present paper describes the relationship between phytochemicals and antioxidant activity. More than 50 vegetables and leafy vegetables are identified for their antioxidant activity in terms of DPPH, FRAR, IC_{50}, ORAC values. Correlation between antioxidant activities was both positive and negative in vegetables. The present review emphasizes on vegetables as a strong source of antioxidants and a power house of nutrition. The many uncommon vegetables used by the tribals of under developed countries need to be studied for their antioxidant activity and medicinal properties.

Key words: Vegetables, antioxidant properties, phytochemicals, minerals

INTRODUCTION

Recent researches have identified a vast majority of antioxidants from vegetables and fruits. Antioxidants like vitamin A, C, E, ß-carotene, glutathione precursors like selenium, vitamin B2 (Riboflavin), B3 (Niacin), B6 (Pyridoxin), B9 (Folic acid), B12 (Cynacobalmin), Bioflavanoids which are very rich all seasonal fruits and vegetables with vivid colors stand as prophylactic (Godber, 1990). Selective intake of the foods containing the above antioxidants can prevent the onset of the degenerative diseases like particularly cardiovascular diseases cancers and diabetes. Some very important micronutrients like Chromium and Venadium which improve insulin sensitivity, magnesium preventing retinopathy and vitamin E improving antioxidant defence and insulin sensitivity have become deficient in diabetics. A number of dietary antioxidants exist beyond the traditional vitamins collectively known as phytonutrients or phytochemicals which are being increasingly appreciated for their antioxidant activity. Regular consumption of fruit and vegetables is associated with reduced risks of cancer, cardiovascular disease, stroke, alzheimer disease, cataracts and some of the functional declines associated with aging. Prevention is a more effective strategy than is treatment of chronic diseases. Functional foods that contain significant amounts of bioactive components may provide desirable health benefits beyond basic nutrition and play important roles in the prevention of chronic diseases.

ETHNO-MEDICINAL USES OF VEGETABLES

It is well known that many plants and foods have been and continue to be ingested because of their perceived medicinal and health-benefiting characteristics. Providing modern healthcare to rural people in India is still a far reaching goal due to economic constraints (Grover *et al*., 2002). Hence, people mainly depend on the locally available plant materials to cure various health disorders (Chopra *et al*., 1956; Grover and Vats, 2001). Plants possess components, which render beneficial properties (Tanabe *et al*., 2002). Hence, currently attention is being drawn towards exploring plant sources for substances that provide nutritional and pharmaceutical advantages to humans. Green leafy vegetables (GLVs) are a good source of minerals and vitamins. The ethno-botanical reports offer information on medicinal properties of GLVs like antidiabetic (Kesari *et al*., 2005) anti-histaminic (Yamamura *et al*., 1998), anti-carcinogenic (Rajeshkumar *et al*., 2002), hypolipidemic (Khanna *et al*., 2002) and anti-bacterial activity (Kubo *et al*., 2004) (Table 1).

Table 1: Traditional uses of some vegetables

Family names	Botanical names (common name)	Traditional uses
Amaryllidaceae	*Allium sativum* Garlic	Heart diseases (including atherosclerosis, high cholesterol, high blood pressure) and cancer
Araceae	*Colocasia esculenta* Schott. Kachalu	Atrophy, bronchial disorders, cough, cuts, injuries as haemost burns, stings of bees, wounds
Zingiberaceae	*Zinger officinale* Ginger	Dyspepsia, gastroparesis, rheumatoid arthritis, osteoarthritis, or joint, muscle injury, short-term relief of pregnancy-related nausea and vomiting
Solanaceae	*Lycopersicon esculentum* Tomato	Cervix, stomach, mouth, colon and even rectal cancer, heart diseases, premature aging protective against neurodegenerative diseases
Apiaceae	*Daucus carota* Carrot	Dropsy, retention of urin, gravel, bladder problems, flatulence, nephritic complaints, ulcer, amenorrhea, eczema, itching, liver disorders, cancer, painful urination (strangury), dysmenorrheal, abcesses, bad wounds and colic
Solanaceae	*Capsicum annuum* Green pepper	Atonic gout, dyspepsia, tympanitis, paralysis etc
Cucurbitaceae	*Cucumis sativus* Cucumber	Anticancer (breast cancer, ovarian cancer, uterine cancer) and prostate cancer also for weight loss, aiding digestion and chronic constipation
Polygonaceae	*Rumex vesicarius* Linn. Bladder-Dock	Purgative, colic, to relieve headaches and alleviate body pain
Cucurbitaceae	*Lagenaria siceraria* Bottle Gourd	Insomnia, insanity, epilepsy, stomach acidity, indigestion and ulcers, constipation and other nervous diseases
Malvaceae	*Hibiscus sabdariffa* Linn. Roselle	Antihypertensive, stomachic, emollient diuretic, mild laxative, treatment for cardiac, nerve diseases and cancer
Labiatae	*Ocimum sanctum* Tulsi	Controlling blood glucose levels and cholesterol levels, headaches, common colds, stomach disorders, inflammation, heart diseases, various poisoning, malaria and even for periods of women
Meliaceae	*Azadirachta indica* Neem	Anti-bacterial, anti-viral, anti-fungal, anti-helmintic, anti-diabetic, measles, chicken-pox, malaria, diabetes. Contraceptive and sedative
Cucurbitaceae	*Momordica charantia* L. Bitter gourd	Hypoglycemic, blood purifier, preventing constipation, for weight loss, for eye caring, useful for medication in early stages of cholera, strengthening immune systems and treating HIV infection
Cucurbitaceae	*Luffa cylindrical* L. Vietnamese gourd	Bitter tonic, emetic, diuretic and purgative and useful in asthma, skin diseases, splenic enlargement, rheumatism, backache, internal hemorrhage, anthelmentic, carminative, laxative, depurative, emollient, expectorant, tonic, chest pains as well as hemorrhoids

Table 1: Continue

Family names	Botanical names (common name)	Traditional uses
Cucurbitaceae	*Luffa acutangula* (L.) Roxb. Silk Gourd	Fever, restlessness and thirst during the course of febrile diseases, dyspnea, cough profuse leukorrhea, strangury (a slow and painful spasmodic discharge of urine drop by drop) with blood, furuncle, galactostasis, carbuncle and swelling
Cucurbitaceae	*Trichosanthes dioica* Roxb. Pointed gourd	Antipyretic, diuretic, cardiotonic, laxative, antiulcer, etc.
Cucurbitaceae	*Luffa cylindrical* (L.) Roem. Towel gourd/ Sponge guard	Diuresis, promoting blood circulation, dredge main and collateral channels, detoxification effect, hemostasis, diminish inflammation, regulate menstruation, eliminating phlegm cough effect, skin aging effects
Solanaceae	*Solanum tuberosom* L. Potato	Appetite, antibacterial, arthritis, infections, boils, burns and sore eyes
Solanaceae	*Solanum melongena* L. Egg plant	Blood circulation, preventing arteriosclerosis, wound healing, preventing cough and rheumatism
Musaceae	*Musa paradisica* L. (unripe) Banana	Bronchitis, cold, snakebite, reducing hyperglycemia in normal and diabetic, protected the gastric mucosa from aspirin-induced erosion, stimulating gastric and colonic mucosa
Caricaceae	*Carica papaya* L. Papaya	Skin blemishes, treating stomach ulcers, diphtheria andconstipation, kidney failure and anticancer
Solanaceae	*Capsicum frutescens* L. Chili pepper	Skin diseases, headache and night blindness, tuberculosis, stomach-ache, backache, cough and chest pain
Solanaceae	*Capsicum annuum* Linn. *Var. grossam* (Willd.) Sendt. Capsicum	Lethargic affections, atonic gout,dyspepsia, tympanitis, paralysis, malignent scarlet fever etc.
Solanaceae	*Nicotiana tabacum* Linn. Tambacco	Eczema, itch, food poison, haemost, snake bite, toothache, spongy gums and wounds
Fabaceae	*Bauhinia variegate* Orchid tree	Antidysentery, antidiarrhea laxative, to cure leucorrhoea and mumps and piles
Mimosaceae	*Parkia roxburghii* G. Don. Kedaung	Chronic dysentery, piles and as laxative. Its most sought after property is as anti-bacteria and is applied in traditional medicine for infections and stomach disorders
Poaceae	*Zea mays* L. Corn	Diuretic, heart disease, hypertension and kidney stone and for lowering blood pressure
Convolvulaceae	*Ipomeae batatas* Sweet potato	Diarrhea, constipation and a good source of vitamin A and C
Moraceae	*Artocarpus heterophyllus Lamk* Jack fruit	Skin diseases and asthma and for healing stomach ulcers, diuretic.
Poaceae	*Bambusa tulda* Roxb. Jati	Chicken pox and other skin diseases; the paste of shoot is used haemostatic and antidote
Elaeagnaceae	*Elaegnus latifolia* Silverberry	Syphilis and blackfoot children
Myricaceae	*Myrica nagi* Bayberry	Diarrhea, jaundice, scrofula, astringent, chronic inflammation of throat, leucorrhoea, uterine haemorrhage
Fabaceae	*Glycine max* L. Merr. Soyabean	Allergies diabetes, skin, eye diseases and dandruff problems
Fabaceae	*Cicer arietinum* Linn. Chickpea	Lowering blood sugar levels, stomach disorders like dyspepsia, vomiting, indigestion, costiveness, diarrhea and dysentery, skin and scalp cleaning and moisturizing agent
Fabaceae	*Phaseolus vulgaris* Linn. Kidney Bean	Bean-diuretic, hypotensive, resolvent, regulates blood sugar, water retention; albuminuria, especially of pregnancy; premenstrual tension

Table 1: Continue

Family names	Botanical names (common name)	Traditional uses
Fabaceae	*Lens culinaris* Medik. Masari	Diuretic, tonic, laxative and astringent to the bowels; useful in constipation and other intestinal affections
Fabaceae	*Pisum sativum* Linn. Mattar	Refrigerant, appetizer, fattening, laxative, alleviative of bile, phlegm and burning of the skin
Moringaceae	*Moringa oleifera* Lam. Drumstick tree	Cardiac, antitumor, antipyretic, antiepileptic, antiinflammatory, antiulcer, antispasmodic, diuretic, antihypertensive, cholesterol lowering, antioxidant, antidiabetic, hepatoprotective, antibacterial and antifungal activities
Brassicaceae	*Raphanus sativus* Linn. Radish	Hypoglycemic potential coupled with antidiabetic efficacy, gastrointestinal (GI) prokinetic effects and strong antioxidant activity
Brassicaceae	*Brassica campestris* Linn. Mustard	Boils, migraine, muscular pain, skin disorder, bronchial disorder, cough, leprosy, pneumonia, scabies, syphilis
Brassicaceae	*Brassica nigra* Koch Rai	Rheumatism
Brassicaceae	*Brassica oleracea* Linn. Var. White cabbage	Diuretic, laxative, stomachic and antihelminthic, digestive, tonic cholesterol-lowering, anticancer, antifungal
Brassicaceae	*Brassica rapa* Linn. Cruciferous vegetables	Antiviral, antibacterial, anticancer activity and suppress thyroid function
Brassicaceae	*Eruca sativa* Mill. Rocket salads	Astringent, diuretic, digestive, emollient, tonic, depurative, laxative, rubefacient and stimulant
Brassicaceae	*Raphanus sativus* Linn. Rat-Tail Radish	Intestinal parasites, carminative, diuretic, expectorant, laxative and stomachic, asthma and other chest complaints
Chenopodiaceae	*Chenopodium album* Linn. White goosefoot	Apetite oleaginous, anthelmintic, laxative, diuretic, aphrodisiac, tonic,useful in biliousness, abdominal pains, eye diseases, throat troubles, piles, diseases of the blood, the heart, the spleen, laxative, anthelmintic and cardiotonic
Campanulaceae	*Pratia begonifolia* Round leaf star creeper	Urinary diseases, dissolving kidney and gall bladder stones
Amaranthaceae	*Celosia cristatae* L. Cock's comb	Diarrhea, urinary tract infection and excessive menstrual problem; leaf extract is used in cuts and injuries
Brassicaceae	*Brassica oleracea* Broccoli	Anti-cancer, especially in the prevention and treatment of gastric cancer, breast cancer effect is the best
Brassicaceae	*Brassica oleraceae* Linn. Var. *capitat* Brussels sprouts	Asgoitrogens, anticancer and thyroid hormone production
Brassicaceae	*Brassica oleracea* Cauliflower	Cancer prevention, particularly with respect to the following types of cancer: bladder cancer, breast cancer, colon cancer, prostate cancer and ovarian cancer
Cucurbitaceae	*Cucurbita pepo* Pumpkin	Antirheumatic, demulcent, laxative, diuretic, nervine, taenifuge, good immune booster also to treat kidney problems, prostate hyperplasia and intestinal parasites
Amaryllidaceae	*Allium cepa* Red Onion	Colds, fever, allergy bacterial infection, congestion and sore throat, effectively treats an earache
Moraceae	*Ficus hispida* L. Creeping figs	Urinary bladder complains also applied on skin diseases and leprosy
Malvaceae	*Abelmoschus esculenus* (Linn.) Lady's Finger	Diuretic, demulcent, stomachic, stimulant, cooling, tonic, carminative, aphrodisiac, nerve tonic, stomachic, sweetens the breath and antiseptic properties
Leguminosae	*Trigona foenum-graecum* Linn. Fenugreek	Aromatic, cooling, laxative, skin and mucous membranes, relieve irritation of the skin, and alleviate swelling and pain
Chenopodiaceae	*Spinacia oleraceae* Linn. Spinach	Anti-oxidant, antiproliferative, antiinfammatory, antihistaminic, CNS depressant, protection against gamma radiation, hepatoprotective etc
Cucurbitaceae	*Cucumis sativus* Linn. Khira	Antihelminthic, cooling, diuretic and strengthening

Table 1: Continue

Family names	Botanical names (common name)	Traditional uses
Cucurbitaceae	*Cucurbita maxima Duch. ex* Lam. Red Gourd	Burns, scalds, inflammations, abscesses, boils and is remedy for migraine,neuralgia, haemoptysis and hemorrhages
Cucurbitaceae	*L. acutangula* M. Roem Kali tori	Convulsion, cramps, fever, jaundice, madness, scabies, syphilis, tetanus, snake bite
Apiaceae	*Coriandrum sativum* Linn. Coriander	Carminative, expectorant, aromatic, narcotic, stimulant and stomachic properties and the raw ones are chewed to stimulate the flow of gastric juices and sweeten the breath
Apiaceae	*Foeniculum vulgare* Fennel	Primarydysmenorrhea and carminative
	Cyamopsis tetragonoloba Linn. Cluser bean	Laxative, regular healthy digestive tract healthy Irritable Bowel syndrome (IBS), Crohn's disease and colitis and also in reducing cholesterol
Apiaceae	*Anethum graveolens* Linn. Dill	Mucosal protective, antimicrobial, antioxidant, antigastric irrition, stimulate milk production and change the estrous cycles, affects hypothalamo-gonadal axis in females and also affect male reproductive organ for enhancing male sexual behaviors
Amaranthaceae	*Chenopodium album* White Goosefoot	Antiinflammatory, antispasmodic, antiallergic, antibacterial and antifungal remedies
Apiaceae	*Centella asiatica* Centella	Asthma, ulcers, lepsory, lupus, vein diseases memory improvement, antidepressant, antibacterial, antifungal, psoriasis and anti-cancer agent
Cucurbitaceae	*Momordica balsamina* African cucumber	Liver deficiencies, blood cleanser, ulcers of the stomach and duodenum, disorders. Used as a purgative, emetic, bitter stomachic and as a wash for fever
Amaranthaceae	*Amaranthus spinosus* Spiny amaranth	Astringent, diaphoretic, diuretic, emollient, febrifuge, purgative. Used to treat snake bites, ulcerated mouths, vaginal discharges, nosebleeds, wounds
Amaranthaceae	*Amaranthus hybridus* Smooth amaranth	Intestinal bleeding, diarrhea, excessive menstruation
Amaranthaceae	*Amaranthus dubius* Spleen amaranth	Alleviate stomach pains
Acanthaceae	*Justicia flava* Yellow justice	Stomach ache, diarrhea, fevers, yaws, emetics and eye lotions
Polygonaceae	*Emex australis* Spiny emex	Gastrointestinal disorders, colic, biliousness and dyspepsia
Asteraceae	*Galinsoga parviflora* Gallant soldier	Treating nettle stings
Portulacaceae	*Portulaca oleracea* Pigweed	Dysentery, diarrhoea, haemorrhoids and enterorrhagia, antibacterial, antiscorbutic, depurative, diuretic, febrifuge
Fabaceae	*Senna occidentalis* Coffeeweed	Stomach pains, biliousness, fevers, jaundice, ringworms, sore throats and edemas, abscesses and skin diseases
Chenopodiaceae	*Chenopodium album* Lamb's-quarters	Anthelmintic, antiphlogistic, antirheumatic, mildly laxative, odontalgic, bug bites, sunstroke and rheumatic joints
Pedaliaceae	*Ceratotheca triloba* African foxglove	Stomach cramps, nausea, fever and diarrhea
Mackinlayaceae	*Centella asiatica* Pennywort	Inflammations, fevers, improves healing, immunity, improves the memory, wounds, chronic skin conditions, venereal diseases, malaria, varicose veins, ulcers and nervous disorders and senility
Cleomaceae	*Cleome monophylla* Spindle pod	Coughs, swellings and anthelmintic

Table 1: Continue

Family names	Botanical names (common name)	Traditional uses
Commelinaceae	*Commelina nudiflora* Linn. Climbing dayflower	Febrifuge, rubefacient, diuretic, good blood coagulant, antifebrile and antidote, tonic for the heart, antifungal and antibacterial
Caesalpinaceae	*Cassia tora* The Sickle Senna	Ageing, atherosclerosis, cancer, inflammatory, joint disease, asthma, diabetes and degenerative eye diseases
Fabaceae	*Bauhinia purpurea* Butterfly tree	Febrifugal, antidiarrhoeal, antidysenteric remedy and astringent
Solanaceae	*Solanum nigrum* Black Nightshade	Antitumorigenic, antioxidant, anti-inflammatory, hepatoprotective, diuretic and antipyretic sedative, narcotic, tonic, laxative and appetite stimulant
Solanaceae	*Physalis viscose* Gooseberry	Antioxidants, anti-inflammatory and anticancer
Portulacaceae	*Portulaca oleracea* Purslane	Antitumorigenic, antioxidant, anti-infammatory, anti-rheumatic, anti-dibetic, diuretic and wound healing

Table 2: Antioxidant defence system

Antioxidant defense system	
Endogenous antioxidants enzymatic antioxidants	Exogenous antioxidants, Principal dietary antioxidants from fruits, vegetables and grains
Superoxide dismutase (SOD)	**Vitamins:** Vitamin C, Vitamin E
Enzyme detoxifying superoxide radical (O_2*-)	Trace elements-zinc, selenium
Catalase (CAT) and glutathione peroxidase (GPx)	**Carotenoids:** β-carotenoid, lycopene, lutein, zeaxanthin
Enzymes involved in the H_2O_2 and GPx against both H_2O_2 and ROOH)	**Phenolic acids:** Chlorogenic acids, gallic acids, cafeic acids etc.
	Flavonoids: Quercetin, kaempferol, myricetin
Glutathione reductase	**Flavanols:** Ptoanthocyanidin and pelagonidin
Enzyme involved in the regeneration of glutathione	**Isoflavones:** Genistein, daidzein and glycitein
Thioredoxin reductase	**Flavanones:** Naringenin, eriodictyol and hesperetin
Enzyme involved in the protection against protein oxidation	**Flavones:** Lutin and apigenin
Glucose-6-phosphate dehydrogenase	
Enzyme involved in the regeneration of NADPH	
Non-enzymatic antioxidants	
(principal intracellular reducing agents)	
Glutathione (GSH), uric acid, lipoic acid, NADPH, coenzyme Q, albumin, bilirubin	

PROTECTIVE ACTION OF ANTIOXIDANTS

Increased consumption of fruits and vegetables has been associated with protection against various age-related diseases (Ames *et al.*, 1993; Steinberg, 1991). What dietary constituents are responsible for this association is not known, but well-characterized antioxidants, including vitamins C and E, or **β**-carotene, are often assumed to contribute to the observed protection (Ames, 1983; Buring and Hennekens, 1997; Gey *et al.*, 1991; Stahelin *et al.*, 1991; Steinberg, 1991; Willett, 1994). However, the results from intervention trials have not been conclusive regarding the protection following supplementation with such antioxidants (Hennekens *et al.*, 1996; Omenn *et al.*, 1996; Prieme *et al.*, 1997; Van Poppel *et al.*, 1995). Recent epidemiological evidence indicates that the putative beneficial effects of a high intake of fruits and vegetables on the risk of diseases of aging may not be exclusively due to these antioxidants (Hertog *et al.*, 1992; Knekt *et al.*, 1997), but other antioxidant phytochemicals contained in fruits and vegetables may be equally important (Table 2 and 3).

Table 3: Vegetables containing nutrients

Nutrients	Functions in the body/benefits	Vegetable sources
Vitamins		
Vitamin A	Helps maintain good vision (Necessary for night vision), resistance to infections and supports growth and repair of body tissues. Also maintains integrity of white and red blood cells, assists in immune reactions, helps maintain the stability of cell membranes	Dark-green vegetables (such as spinach and turnip greens), orange vegetables (such as carrots, pumpkin and sweet potato), orange-flesh fruits (such as apricot, mango, orange, papaya, peach and pineapple) and tomato
Vitamin C	Essential element in collagen formation (strengthens blood vessels, forms scar tissue, is a matrix for bone growth); an antioxidant; strengthens resistance to infections and improves absorption of iron	Citrus fruits and their juices, berries, dark green vegetables (spinach, asparagus, green peppers, brussel sprouts, broccoli, watercress, other greens), red and yellow peppers, tomatoes and tomato juice, pineapple, cantaloupe, mangos, papaya and guava
Vitamin E	Helps maintain cell membrane, red blood cell integrity, protects vitamin A and fatty acids from oxidation	Vegetable oils such as olive, soybean, corn, cottonseed and safflower, nuts and nut butters, seeds, whole grains, wheat, wheat germ, brown rice, oatmeal, soybeans, sweet potatoes, legumes (beans, lentils, split peas) and dark leafy green vegetables
Vitamin K	Helps make factors that promote blood clotting	Nuts, lentils, green onions, crucifers (cabbage, broccoli) baked potato or sweet potato, banana and plantain, cooked dry beans and leafy greens
Folic acid	Part of coenzymes used in new cell synthesis Essential for blood cell formation, protein metabolism and prevention of neural tube defects	Dark-green leafy vegetables (such as spinach, mustard greens and romaine lettuce), legumes (cooked dry beans and peas, green peas and seeds
Fiber	Diabetes, heart disease	Most fresh fruits and vegetables, nuts, beans and peas
Selected minerals		
Magnesium	Involved in bone mineralization, the building of protein, enzyme action, normal muscular contraction and transmission of nerve impulses	Spinach, lentils, potato, banana, nuts, corn, cashews
Calcium	Osteoporosis, muscular/skeletal, teeth, blood pressure	Cooked vegetables (such as beans, tomatoes) peas, papaya, raisins, orange, pumpkin and cauliflower
Potassium	Hypertension (blood pressure) stroke, Arteriosclerosis	Baked potato or sweet potato, banana, cooked dry beans, cooked greens, dried fruits (such as apricots and prunes)
Manganese	Involved in the formation of bone, as well as in enzymes involved in amino acid, cholesterol and carbohydrate metabolism	Nuts, whole grain cereals, beans, rice, dried fruits, green leafy vegetables
Molybdenum	Important in a variety of enzyme systems	Legumes and grains
Copper	Supports healthy bones, muscles and blood vessels. Assists in iron absorption	Legumes, nuts, seeds, raisins, whole grains
Boron	Bone health, prevention of osteoporosis	Non-citrus fruits, leafy vegetables
Calcium	The principal mineral of bones and teeth, also involved in normal muscle contraction (including heart muscle)	Broccoli, chard and legumes
Chromium	With insulin helps to convert carbohydrates and fats into energy	Broccoli, radish, onion, cabbage, cauliflower, garden pea, kale and celery
Selenium	It is responsible for boosting the immunity of cancer patients and plays an important role in cellular function as it forms the integral part of an important antioxidant enzyme	Crimini mushrooms, mustard seeds, broccoli, garlic, spinach and sunflower seeds

Table 3: Continue

Nutrients	Functions in the body/benefits	Vegetable sources
Zinc	Necessary to synthesize DNA, for wound healing, healthy growth and development of the body during adolescence, childhood and pregnancy	Nuts, whole grains and legumes
Polyphenols		
Anthocyanins	Act as antioxidants, the association between anthocyanins and oxidative stress appears to relate to the ability of anthocyanins to reduce excitation pressure and, hence, the potential for oxidative damage	Red cabbage, red onion, apricot, kale, broccoli etc.
Catechins		
Isoflavones	Isoflavones have an influence on the women's health during menopause and it is necessary to reduce the risk of fibroids and andomertriosis	Soy-beans, garbanzo beans, chick peas, red clover and legumes
Rutin	Ascular degeneration, vascular bleeding (bruising/ capillary fragility, nose bleeds, periodontal bleeding, varicose veins, hemorrhoids and aneurism	Green and yellow peppers, tomatoes, onions, broccoli and parsley
Hesperidin	Hesperidin is effectively used as a supplemental agent in the treatment protocols of complementary settings and also helps in reducing oedema or excess swelling in the legs due to fluid accumulation. Its deficiency has been linked to abnormal capillary leakiness as well as pain in the extremities causing aches, weakness and night leg cramps	Leafy vegetables such as swiss chard, spinach, beets/beet greens, parsley, lemon and rhubarb
Quercetin	Quercetin has been found to be an effective hyperthermia sensitizer, making it a potential adjunct therapeutic agent in the treatment of various cancers that are sensitive to heat stress (colon adenocarcinoma, prostate, ovarian, uterine or cervical cancer, leukemia, melanoma and others)	Vegetables, spices, seeds, nuts, mushrooms, celery, parsley and herbs
Tannins	Tannins have also been reported to anticarcinogenic and antimutagenic potentials of tannins may be related to their antioxidative property, also help to accelerate blood clotting, reduce blood pressure, decrease the serum lipid level, produce liver necrosis and modulate immunoresponses	Black beans, red beans, white beans, Egg plant, Unripe banana etc.
Lycopene	Act as strong antioxidant powers, with some studies showing a reduced risk of cancer, cardiovascular disease and macular degeneration	Tomato, dried parsley, basil, Asparagus, red cabbage and red chilli
Lutein	Consuming lutein as part of the dietmight help to prevent AMD (Age-related macular degeneration), Reducing the risk of developing eye cataracts, reduced risk of developing breast cancer	Dark green leafy vegetables like spinach and kale, corn, Broccoli, Papaya, green peas, Carrot, Brussels sprouts, Turnip greens, zucchini etc
Cryptoxanthins	Cryptoxanthin is an antioxidant and may help prevent free radical damage to cells and DNA, as well as stimulate the repair of oxidative damage to DNA	Petals and flowers of plants in the genus Physalis, orange rind, papaya
Ellagic acid	Ellagic acid has antiproliferative and antioxidant properties, chemoprotective effect in cellular models by reducing oxidative stress	Freeze-dried berries, pears, peaches, plums, grapes, apples, kiwi and several nuts

Over the years, consumers have been paying more and more attention to the health and nutritional aspect of horticultural products. Having a diet rich in fruits and vegetables will be able to provide some protection against the common diseases such as cardiovascular diseases, cancers and other agerelated degenerative diseases (Scalzo *et al.*, 2005). Evidence shows that free radicals are responsible for the damage of lipids, proteins and nucleic acid in cells could lead to these common diseases (Alothman *et al.*, 2009). Recent studies showed that frequent consumption of fruits and vegetables can reduce the risk of stroke and cancer which is related to the antioxidant microconstituents contained on the plant parts. Different vegetables may exhibit different capacities due to the presence of different dietary antioxidants, such as vitamin C and E, carotenoids, flavanoids and other phenolic compounds (Saura-Calixto and Goni, 2006).

ANTIOXIDANT METABOLITES IN VEGETABLES

Antioxidants 'Antioxidants' are substances that neutralize free radicals or their actions (Sies, 1996). Nature has endowed each cell with adequate protective mechanisms against any harmful effects of free radicals: Superoxide Dismutase (SOD), glutathione peroxidase, glutathione reductase, thioredoxin, thiols and disulfide bonding are buffering systems in every cell. α-Tocopherol (vitamin E) is an essential nutrient which functions as a chain-breaking antioxidant which prevents the propagation of free radical reactions in all cell membranes in the human body. Ascorbic acid (vitamin C) is also part of the normal protecting mechanism. Other non-enzymatic antioxidants include carotenoids, flavonoids and related polyphenols, α-lipoic acid, glutathione etc., (Sies, 1996; Cadenas and Packer, 1996; Halliwell and Aruoma, 1993). Antioxidant compounds like phenolic acids, polyphenols and flavonoids scavenge free radicals such as peroxide, hydroperoxide or lipid peroxyl and thus inhibit the oxidative mechanisms that lead to degenerative diseases. There are a number of clinical studies suggesting that the antioxidants in fruits, vegetables, tea and red wine are the main factors for the observed efficacy of these foods in reducing the incidence of chronic diseases including heart diseases and some cancers (Table 2 and 3).

Vitamin C: Ascorbic acid (vitamin C), a powerful, water-soluble antioxidant as scavenger of ROS (Smirnoff, 2000). To prevent or at least alleviate deleterious effects caused by ROS. It has the abitlity to donate electrons in a number of enzymatic and non-enzymatic reactions. As a directly scavenge $^1O_2$, O_2^{*-} and $^{\cdot}OH^-$ and regenerate tocopherol from tocopheroxyl radical, thus, providing membrane protection (Thomas *et al.*, 1992). Ascorbic acid also acts as co-factor of violaxanthin de-epoxidase, thus, sustaining dissipation of excess excitation energy (Smirnoff, 2000). Ascorbic acid plays an important role in minimizing the damage caused by oxidative process. This is performed by its synergistic action with other antioxidants (Smirnoff, 2005; Athar *et al.*, 2008). Ascorbate-Glutathione cycle, it plays a role in preserving the activities of enzymes that contain prostheritic transition metal ions (Noctor and Foyer, 1998). Both vitamins C and E show very apparent effects protecting the human body from free radicals and disease. These super vitamins have been shown to have positive effects on tumors activated by ultraviolet light (Table 3).

Vitamin E: Tocochromanols, known as vitamin E, are essential components of biological membranes, exclusively located in the plastid or thylakoid membranes (Munne-Bosch, 2005), where they have both antioxidant and non-antioxidant functions (Kagan, 1989). They occur in four different types or isomers, namely, α, β, γ and δ-tocopherols. All four types of tocopherols structurally consist of a chromanol head group attached to the phytyl tail, which together giving vitamin E compounds amphipathic character (Kamal-Eldin and Appelqvist, 1996). Among others, α-tocopherol with its three methyl substituents has the highest antioxidant activity of tocopherols (Kamal-Eldin and Appelqvist, 1996) and relative antioxidant activity of the tocopherol isomers *in vivo* is α>β>γ>δ, due to the methylation pattern and the amount of methyl groups attached to the phenolic ring (Blokhina *et al.*, 2003). α-tocopherols prevent the chain propagation step in lipid auto-oxidation and this makes it an effective free radical trap. α-tocopherols found in green parts of plants scavenge lipid peroxy radicals through the concerted action of other antioxidants (Kiffin *et al.*, 2006; Hare *et al.*, 1998). Further, tocopherols are also known to protect lipids and other membrane components by physically quenching and chemically reacting with oxygen in chloroplasts, thus, protecting the structure and function of PSII (Igamberdiev and Hill, 2004). The main function of tocopherol lies in its fatty acyl chain-breaking activity, which scavenges Reactive Oxygen Species (ROS) resulting from photosynthesis, thus protecting polyunsaturated fatty acid chains (PUFAs) from lipid peroxidation. Increasing evidence suggests that in higher plants, vitamin E may play a protective role in cell membrane systems, thus maintaining the integrity and normal function of the photosynthetic apparatus (Havaux *et al.*, 2005; Collin *et al.*, 2008) (Table 3).

Vitamin K: This is a group of structurally similar, fat-soluble vitamins that the human body needs for posttranslational modification of certain proteins required for blood coagulation and in metabolic pathways in bone and other tissue. They are 2-methyl-1,4-naphthoquinone (3-) derivatives (Stafford, 2005). This group of vitamins includes two natural vitamers:vitamin K_1 and vitamin K_2. Vitamin K_1, also known as phylloquinone, phytomenadione, or phytonadione, is synthesized by plants and is found in highest amounts in green leafy vegetables because it is directly involved in photosynthesis (Newman *et al.*, 2008). It may be thought of as the "plant form" of vitamin K. It is active in animals and may perform the classic functions of vitamin K in animals, including its activity in the production of blood clotting proteins. Animals may also convert it to vitamin K_2. Vitamin K_2, the main storage form in animals, has several subtypes, which differ in isoprenoid chain length. These vitamin K_2 homologs are called menaquinones and are characterized by the number of isoprenoid residues in their side chains. Vitamin K_1 is found chiefly in leafy green vegetables such as dandelion greens, spinach, swiss chard and *Brassica* (e.g., cabbage, kale, cauliflower, broccoli and brussels sprouts) and often the absorption is greater when accompanied by fats such as butter or oils (Table 3). Some vegetable oils, notably soybean, contain vitamin K, but at levels that would require relatively large calorific consumption to meet the USDA recommended levels (Weber, 2001).

Folate: Folic acid (also known as folate, vitamin M, vitamin B_9, vitamin B_c (orfolacin), pteroyl-L-glutamic acid and pteroyl-L-glutamate are forms of thewater-soluble vitamin B_9. Folate is composed of the aromatic pteridine ring linked to para-aminobenzoic acid and one or more glutamate residues. Folic acid is itself not biologically active, but its biological importance is due to tetrahydrofolate and other derivatives after its conversion to dihydrofolic acid in the liver (Bailey and Ayling, 2009). It is present in a wide variety of foods, such as green-leafy vegetables and fruits (Table 3). They very rich in Leafy vegetables such as beets, corn, tomato, broccoli, brussels sprouts, romaine lettuce and bok choy and some of Asian vegetables (Houlihan *et al.*, 2011; Hoffbrand and Weir, 2001). Folate is important for the synthesis of DNA, transfer RNA and the amino acids cysteine and methionine. DNA synthesis plays an important role in germ cell development and therefore, it is obvious that folate is important for reproduction. It has also been reported that folic acid, the synthetic form of folate, effectively scavenges oxidizing free radicals and as such can be regarded as an antioxidant (Joshi *et al.*, 2001). Despite its water-soluble character, folic acid inhibits lipid peroxidation (LPO). Therefore, folic acid can protect bio-constituents such as cellular membranes or DNA from free radical damage (Joshi *et al.*, 2001). Only limited knowledge is available on the impact of dietary folate and synthetic folic acid on (sub) fertility.

Fibers: Dietary fiber is largely composed of complex carbohydrates that are somewhat resistant to digestion. One major component of soluble fibers is pectin, which is largely composed of uronic acid residues such as galacturonic acid. Pectin and other soluble polysaccharides may undergo some metabolism in the small intestine and especially in the large intestine through bacterial enzymes, converting it to products that contribute to maintaining the colonic microflora, which is beneficial to digestion (Weisburger *et al.*, 1993; Cummings *et al.*, 1979; Holloway *et al.*, 1983). Insoluble fiber like cellulose, found in plant cell walls, can aid in waste and toxin removal through several mechanisms (Weisburger *et al.*, 1993). Dietary fibers in foods are also beneficial for good health. Physiological impacts of insufficient dietary fiber intake are constipation, increased risk of coronary heart disease and increased fluctuation of blood glucose and insulin levels (AACC, 2001; Jenkins *et al.*, 1998). Including fruits and vegetables in the human diet may be beneficial, based on their dietary fiber content, with regard to some cancers (Weisburger *et al.*, 1993; Harris and Ferguson, 1993) (Table 3).

SECONDARY METABOLITES IN VEGETABLES IN FREE RADICAL SCAVENGING ACTIVITY

Secondary constituents are the remaining plant chemicals such as alkaloids (derived from amino acids), terpenes (a group of lipids) and phenolics (derived from carbohydrates). Antioxidants are secondary constituents or metabolites found naturally in the body and in plants such as fruits and vegetables. Plants produce a very impressive array of antioxidant compounds that includes carotenoids, flavonoids, cinnamic acids, benzoic acids, folic acid, ascorbic acid, tocopherols and tocotrienols to prevent oxidation of the susceptible substrate (Hollman, 2001). Common antioxidants include vitamin A, vitamin C, vitamin E and certain compounds called carotenoids (like lutein and beta-carotene) (Hayek, 2000). These plant-based dietary antioxidants are believed to have an important role in the maintenance of human health because our endogenous antioxidants provide insufficient protection against the constant and unavoidable challenge of reactive oxygen species (ROS; oxidants) (Fridovich, 1998).

PHENOLIC COMPOUNDS

Phenolic compounds comprise a large group of organic substances and flavonoids are an important subgroup. This group constitutes the majority of dietary antioxidants. There are four major groups of flavonoids, i.e., anthocyanins, flavones, flavonols and the isoflavonols. Anthocyanins, which are coloured flavonoids responsible for a wide range of colours in plants, can scavenge free radicals, particularly singlet oxygen due to their reversible oxidation-reduction properties. Flavonoids, mainly present as colouring pigments in plants also function as potent antioxidants at various levels (Sies, 1996; Cadenas and Packer, 1996). Flavonols include quercetin found in onion and to a lesser extent in French beans and broad beans. The isoflavonoids (isoflavones) are a group of flavonoids in which the position of one aromatic ring is shifted. Isoflavoids may also be responsible for the anticancer benefits of food prepared from soybeans. Food sources that are especially rich in polyphenols include, among others, potato, plums, leafy vegetables, whole grain products and coffee (Souci *et al.*, 2000) (Table 3). Polyphenols scavenge free radicals (R*) possessing an unpaired electron either by donation of hydrogens or electrons, resulting in comparatively stable phenoxyl (PhO*) radicals (neutral (PhO*) or cationic (PhO^{+}*) molecules, respectively), which are stabilized by delocalization of unpaired electrons around the aromatic ring (Rice-Evans *et al.*, 1996; Bouayed *et al.*, 2011a, b). Polyphenols have been reported to be more efficient than vitamin C, vitamin E and carotenoids (concentration ranges between high micromolar and low millimolar in human plasma and organs) against oxidative stress at tissue levels (Scalbert *et al.*, 2002; Manach *et al.*, 2004; Yang *et al.*, 2008; Pandey and Rizvi, 2009; Bouayed and Bohn, 2010; Bouayed *et al.*, 2011b, c).

Carotenoids: Among the various natural pigments, carotenoids comprise a large family of more than 700 structures (Britton *et al.*, 2004) and are synthesized in plants and other photosynthetic organisms, as well as in some non-photosynthetic bacteria, fungi, algae, yeasts and moulds (Stahl and Sies, 2003, 2005). Most carotenoids can be derived from a 40-carbon basal structure, which includes a polyene chain contains 3 to 15 conjugated double bonds. The pattern of conjugated double bonds in the polyene backbone of carotenoids determines their light absorbing properties and influences the antioxidant activity of carotenoids (Goodwin, 1980; Britton *et al.*, 1998). The best documented antioxidant action of carotenoids is their ability to quench singlet oxygen (Paiva and Russell, 1999) via physical or chemical quenching (Stahl and Sies, 2003). Food items rich in carotenoids includes: corn, yellow pepper, apricots, spinach, pumpkin and sweet potato, tomatoes and carrots (Biehler *et al.* 2012). According to their chemical composition carotenoids are categorized as either carotenes or xanthophylls (oxocarotenoids) (Olson and Krinsky, 1995). While the carotene group, such as β-carotene, α-carotene and lycopene, composed only of carbon and hydrogen atoms, xanthophylls, such as zeaxanthin, lutein, α and β-cryptoxanthin, carry at least one oxygen atom (Stahl and Sies, 2005; Chaudhary *et al.*, 2010).

Minerals: Some minerals are essential for human nutrition (e.g., Fe, Cu, Se and Zn), others such as Cr, Cd, Ni, As and Pb (Hartwig, 1995; Valko *et al.*, 2006), possibly through the formation of Reactive Oxygen Species (ROS) (Rojas *et al.*, 1999; Linder, 2001). The trace elements essentially act as cofactors for antioxidant enzymes involved in the destruction of toxic free radicals produced in the body as a normal consequence of the metabolic processes. Three key trace elements whose roles in antioxidant defence are gradually gaining attention are zinc, selenium and iron. Apparently, Fe, Cu, Zn and Se are necessary to maintain genetic stability and nutritional well-being of humans and animals (Rojas *et al.*, 1999). Recent studies suggest that ultra-trace elements, such as As and Ni, may also play a role both in animal and human nutrition (Rojas *et al.*, 1999). In the last 20 years, a substantial body of evidence has been accumulated to support the role of zinc as a cellular antioxidant (Powell, 2000). Although zinc does not react directly with ROS, a number of indirect mechanisms have been described (Powell, 2000; DiSilvestro, 2000). One of the ways in which zinc acts as an antioxidant is through the induction of the metallothioneins, a group of low-molecular-weight amino acid residues, the production of which is induced by zinc in many tissues including the liver, gut and kidney. For instance, cadmium is present in spinach and cauliflower, while lead is found in Brussels sprouts and Chinese beets (3).

Table 4: ROS scavenging and detoxifying enzymes and reactions catalyzed

Enzymes	EC No.	Reaction catalysed	Localization (a)
Superoxide dismutase (SOD)	1.15.1.1	$O_2^{-}+O_2^{-}+2H^{+}\leftrightarrow 2H_2O_2+O_2$	Cyt, Chl, Mit, Per
Catalase (CAT)	1.11.1.6	$2H_2O_2\leftrightarrow O_2+2H_2O$	Mit, Per, Gly
Glutathione peroxidase(GPX)	1.11.1.12	2GSH+PUFA–OOH ↔GSSG+PUFA+$2H_2O$	Cyt, Chl, Mit, ER
Glutathione S-transferases (GST)	2.5.1.18	RX+GSH↔HX+R-S-GSH*	Apo, Cyt, Chl, Mit, Nuc
Phospholipid-hydroperoxide glutathione peroxidase	1.11.1.9	2GSH+PUFA-OOH (H_2O_2)↔GSSG+$2H_2O$†	Cyt, Chl, Mit, ER
Ascorbate peroxidase (APX)	1.11.1.11	AA+H_2O_2↔DHA+$2H_2O$	Cyt, Chl, Mit, Per
Guaiacol type peroxidase (POX)	1.11.1.7	Donor+H_2O_2↔oxidized donor+$2H_2O$†	CW, Cyt, Mit, Vac
Monodehydroascorbate reductase (MDHAR)	1.6.5.4	NADH+2MDHA ↔NAD^{+}+2AA	Cyt, Chl, Mit
Dehydroascorbate reductase (DHAR)	1.8.5.1	2GSH+DHA↔GSSG+AA	Cyt, Chl, Mit
Glutathione reductase (GR)	1.6.4.2	NADPH+GSSG↔$NADP^{+}$+2GSH	Cyt, Chl, Mit, Per

*R may be an aliphatic, aromatic or heterocyclic group, X may be a sulfate, nitrite or halide group; †Reaction with H_2O_2 is slow, (a) Gechev *et al*. (2006) is used as reference for localization of enzymes. The abbreviations are: Apo, apoplast, Cyt, cytosol; Chl, chloroplasts; CW, cell wall; ER, endoplasmatic reticulum; Gly, glyoxysomes; Mit, mitochondria; Nuc, nucleus; Per, peroxisomes; Vac, vacuole

ENZYMATIC ANTIOXIDANTS IN VEGTABLES

Detoxification constitutes the second line of defence against the maleficent effects of ROS. Therefore, once formed, the ROS must be detoxified as effectively as possible to minimize damage (Moller, 2001). Efficient destruction of ROS requires the action of several antioxidant enzymes acting in synchronicity with each other (Noctor and Foyer, 1998). Plants have also developed very efficient enzymatic antioxidant scavenging system to protect themselves against destructive ROS reactions (Mittler *et al*., 2004). In the cell, toxic effects of ROS are counteracted by several scavenging and detoxifying enzymes, such as superoxide dismutase (SOD), catalase (CAT), Ascorbate Peroxidase (APX), glutathione peroxidases (GPX), glutathione-*S*-transferases (GST), monodehydroascorbate reductases (MDHAR), dehydroascorbate reductases (DHAR) and Glutathione Reductases (GR) (4). While some of these enzymes are entirely dedicated to ROS homeostasis, others are involved also in other processes related to control of development, redox regulation of target proteins and detoxification reactions (Gechev *et al*., 2006). In cells, different scavenging enzymes encoded by the ROS network can be found in almost every subcellular compartment. Besides, each cellular compartment contains more than one enzymatic activity that detoxifies a particular ROS (Mittler *et al*., 2004). For example, the cytosol contains at least three different enzymatic activities that scavenge H_2O_2 (Suzuki and Mittler, 2006). It is clear that the presence of different enzymes in various cellular compartments disclosures their significant role in ROS detoxification for the survival of the plant (Mittler *et al*., 2004). In Table 4, ROS scavenging enzymes, their abbreviations, EC numbers, catalyzed reactions and cellular localizations are given.

MECHANISM OF ANTIOXIDANT ACTION

The harmful action of ROS and free radicals is normally blocked by antioxidant substances, which scavenge the free radicals and detoxify the organism (Kumaran and Karunakaran, 2006). Antioxidants are compounds that can delay or inhibit the oxidation of lipid or other molecules by inhibiting the initiation or propagation of oxidizing chain reactions (Cakir *et al*., 2006). All aerobic organisms have antioxidant defense systems (Cakir *et al*., 2006). These systems are able to scavenge free radicals and increase shelf life of processes foods by retarding the process of lipid peroxidation, the major cause of food and pharmaceutical deterioration (Halliwell, 1996; Gordon, 1996). Antioxidants can protect the human body from free radicals and ROS effects. They retard the progress of many chronic diseases as well as lipid peroxidation (Gulcin, 2007). Being enzymatic or non enzymatic species, antioxidant molecules are classified in different categories (Table 2). Both enzymatic (superoxide dismutase and catalase) and non-enzymatic (antocyanins and tochopherols) antioxidants are able to turn ROS into stable, harmless molecules. They are used in various applications such as pharmaceutical, food, cosmetic and chemical industries in order to act as preservative and extend efficiency and economical value of the products. Considering that antioxidant capacity of an organism is limited, excess production of various oxidizing compounds produces a condition called oxidative stress. Oxidative stress contributes to the pathogenesis of various diseases (e.g., cancers, neurodegenerative disorders and diabetes). Defense against oxidative stress through production of antioxidants and repair processes may constitute important allocations to somatic effort and is particularly relevant for species with low extrinsic mortality.

Antioxidants are major compounds that protect the quality of life by retarding the oxidation process through scavenging free radical produced during many natural events. Although their ultimate aim is removal of ROS, they may use different mechanism depending on their structure and site of action. Antioxidants are also able to act by up-regulating the expression of the genes encoding the antioxidant enzymes, repairing oxidative damage caused by radicals and increasing elimination of damaged molecules (Wood *et al.*, 2006). The use of antioxidants in food industry is inevitable as they can increase shelf life and prevent oxidation. Synthetic antioxidants such as butylated hydroxytoluene (BHT), sodium benzoate and butylated hydroxyanisole (BHA) are widely used in food products. However, their use must be controlled due to possible hazards such as carcinogenicity and toxicity (Ito *et al.*, 1983). Phenolic compounds from plant sources may act as antioxidants by scavenging lipid radicals. Over the last few years, an increasing interest in the search for naturally occurring antioxidants is ongoing. A large number of plants including fruits and vegetables are known as rich sources of antioxidant. The type of plant and its antioxidant activity depends entirely to the region that plant grows and natural vegetation present.

METHODS USED IN ANTIOXIDANT STUDIES: PRINCIPLE AND APPLICATIONS

A variety of *in-vitro* chemical methods are being used to determine the antioxidant activity of products and ingredients but questions regarding whether the results have any bearing on effectiveness in the human body are leading to development of additional methods that may be more appropriate for screening potential antioxidant ingredients. Several assays have been frequently used to estimate antioxidant capacities in fresh fruits and vegetables and their products and foods for clinical studies including 2,2-azinobis (3-ethyl-benzothiazoline-6-sulfonic acid) (ABTS) (Leong and Shui, 2002; Miller and Rice-Evans, 1997), 2,2-diphenyl-1-picrylhydrazyl (DPPH) (Brand-Williams *et al.*, 1995; Gil *et al.*, 2002), ferric reducing antioxidant power (FRAP) (Benzie and Strain, 1999; Guo *et al.*, 2003; Jimenez-Escrig *et al.*, 2001) and the oxygen radical absorption capacity (ORAC) (Cao *et al.*, 1993; Ou *et al.*, 2001; Prior *et al.*, 2003). The ORAC assay is said to be more relevant because it utilizes a biologically relevant radical source (Prior *et al.*, 2003). These techniques have shown different results among crop species and across laboratories. Ou *et al.* (2002) reported no correlation of antioxidant activity between the FRAP and ORAC techniques among most of the 927 freeze-dried vegetable samples, whereas these methods revealed high correlation in blueberry fruit (Connor *et al.*, 2002). Similarly, Awika *et al.* (2003) observed high correlation between ABTS, DPPH and ORAC among sorghum and its products.

Various methods have been developed and applied in different systems but many available methods result in inconsistent results. There is no simple universal method by which antioxidant capacity can be assessed accurately and quantitatively. In this review article, the available methods are critically reviewed on the basis of the mechanisms and dynamics of antioxidant action and the methods are proposed to assess the capacity of radical scavenging and inhibition of lipid peroxidation both *in vitro* and *in vivo*. It is emphasized that the prevailing competition methods such as Oxygen Radical Absorption Capacity (ORAC) using a reference probe may be useful for assessing the capacity for scavenging free radicals but that such methods do not evaluate the characteristics of antioxidants and do not necessarily show the capacity to suppress the oxidation, that is, antioxidation. It is recommended that the capacity of antioxidant compounds and their mixtures for antioxidation should be assessed from their effect on the levels of plasma lipid peroxidation *in vitro* and biomarkers of oxidative stress *in vivo*.

ANTIOXIDANT ACTIVITY OF VEGETABLES

In search for sources of novel antioxidants and other important nutrients, a large number of plants have been extensively studied (Dasgupta and De, 2007; Indrayan *et al.*, 2005; Iqbal *et al.*, 2006; Joyeux *et al.*, 1995; Odhav *et al.*, 2007; Xin *et al.*, 2004) during last few years.

DPPH FREE RADICAL SCAVENGING ACTIVITY

According to their reducing/antioxidantive power the antioxidantive effect of these vegetables and leafy vegetables can be divided into four groups: (a) low (0-20%), moderate (20-40%), good (40-80%) and very good (80-100%).

The results summarized in Table 1 indicate that the vegetable interact with DPPH radicals and there by stabilize their hyper activity. The lowest groups of vegetables exhibiting antioxidant activity in the range of 0-20% are as follows: *Allium sativum*, *Capsicum annuum* Linn. Var. grossam (Willd.) *Momordica balsamina* L., *Solanum tuberosom* L. and *Spinacia oleraceae* Linn.

The average groups of vegetables exhibiting antioxidant activity in the range of 20-40% are as follows: *Trigona foenum-graecum* Linn., *Lycopersicon esculentum*, *Rumex vesicarius* Linn., *Cucurbita pepo*, *Cucumis sativus*, *Rumex vesicarius* Linn., *Petroselinum crispum*, *Cucumis sativus* and *Raphanus sativus* Linn. (Table 5).

The good groups of vegetables exhibiting antioxidant activity in the range of 40-80% are as follows: *Brassica oleraceae* Linn. Var. capitat, *Anethum graveolens* Linn., *Brassica oleraceae* Linn. Var. botrytis, *Raphanus sativus* Linn., *Cucurbita maxima* Duch., *Lepidium meyenii*, *Cyamopsis tetragonoloba* Linn., *Lycopersicon esculentum*, *Capsicum annuum*, *Curcuma amada* Roxb., *Curcuma zedoaria*, *Macrolepiota mastoidea* and *Abelmoschus esculenus* (Linn.) (Table 5).

The very good groups of vegetables exhibiting antioxidant activity in the range of 80-100% are as follows: *Zinger officinale*, *Leucas aspera*, *Corchorus olitorius*, *Crotalaria ochroleuca*, *Solanum scabrum*, *Cleome gynandra*, *Achras sapota* Linn., *Amaranthus dubius*, *Asystasia gangetica*, *Amaranthus hybridus*, *Amaranthus spinosus*, *Leucas aspera*, *Corchorus olitorius*, *Crotalaria ochroleuca*, *Solanum scabrum*, *Cleome gynandra*, *Achras sapota* Linn., *Amaranthus dubius*, *Asystasia gangetica*, *Amaranthus hybridus*, *Amaranthus spinosus*, *Bidens pilosa*, *Chenopodium album*, *Centella asiatica*, *Cleome monophylla*, *Ceratotheca triloba*, *Justicia flava*, *Momordica balsamina*, *Oxygonum sinuatum*, *Portulaca oleracea*, *Physalis viscose*, *Solanum nigru*, *Senna occidentalis*, *Olax psittacorum*, *Cassia tora*, *Ipomoea cairica*, *Leucas aspera*, *Commelina benghalensis* (Table 5).

Vegetables with highest anticancer activity are *Allium cepa*, *Curcuma amada*, *Curcuma zedoaria*, *Citrus limon*, *Brassica oleraceae*, *Lycopersicon esculentum* etc. and the *Cucumis sativus* is with low level of anticancer activity (La Vecchia and Tavani, 1998; Nahak and Sahu, 2011; Kaur and Kapoor, 2004; Rao *et al*., 2004). Green leafy vegetables are rich sources of antioxidant vitamins (Gupta *et al*., 2005). The ascorbic acid, total carotene, β-carotene and total phenolic content of the green leafy vegetables, viz., *Amaranthus* sp., *Centella asiatica*, *Murraya koenigii* and *Trigonella foenum graecum* etc., are showing highest antioxidant activity among leafy vegetables (Gupta and Prakash, 2009). Spinach and kale are also rich sources of carotenoids and polyphenols. Spinach has an exceptionally high total polyphenol and flavonoid content. The high level of polyphenol acids and flavonoids in spinach leaves influences the high antioxidant activity (Ligor *et al*., 2012). Majority of leafy vegetables like Brassica, Coriandrum, Carrot, mint, Curry leaf, Radish, Methy contains phytochemicals which shows antioxidant activities include vitamins (A, C, E and K), carotenoid, terpinoid, flavonoid, polyphenols, saponins, enzymes and minerals. All these compounds prevent cancers and other diseases (Govind and Madhuri, 2011).

FRAR VALUE

The FRAP assay determines the capacity of antioxidants as reductants in a redox-linked colorimetric reaction of the reduction of Fe^{3+}-2,4,6-tripyridyl-S-triazine to a blue-coloured Fe^{2+} complex at low pH that is measured spectrophotometrically at 593 nm (Benzie and Strain, 1996). The extracts were incubated at room temperature with the FRAP reagent and the absorbance recorded after 1 h (Fasahat *et al*., 2012). The reducing power is expressed as μmol $FeSO_4$ g^{-1}. Here in this review some of the vegetables showing very good antioxidant activity in terms of FRAP (FRAR (Mg^{-1}) values and these are as follows: *Daucus carota* L. Var. sativa DC. (0.61), *Cucumis sativus* (1.69), *Cucumis melo* var. *flexuosus Lagenaria siceraria* (6.57), *Luffa cylindrical* L. (2.93), *Luffa acutangula* (L.) Roxb (2.58), *Trichosanthes dioica* Roxb. (3.78), *Carica papaya* L. (4.63), *Beta vulgaris* L. (5.45) *Citrus limon* L., *Aegle marmelos* Correa ex roxb. (6.36), *Solanum melongena* L. (3.69) and *Musa paradisica* L. (unripe) (13.18) (Table 5).

IC_{50} VALUE

IC_{50} value is defined as the concentration of substrate that 50% loss of DPPH* activity and was calculated by linear regression method of plots of the percentage of antiradical activity against the concentration of the tested compounds. The results summarized in Table 3 and 4 indicate that the IC_{50} values of *Brassica oleraceae* (Broccoli) with 7.53 mg mL^{-1}, *Musa canvendish* (10.93 mg mL^{-1}), *Zinger officinale* (1.8 mg mL^{-1}) and *Phoenix dactylifera* (1.65 mg mL^{-1}), *Apium nodiflorum* (0.07 mg mL^{-1}), *Foeniculum vulgare* (2.75 mg mL^{-1}), *Montia fontana* (1.49 mg mL^{-1}) and *Anethum graveolens* Linn. (3.31 mg mL^{-1}) showed significant lower IC_{50} values which refer the good antioxidant potential sources (Table 5).

Table 5: Antioxidant activity of some vegetables

Botanical names with common names family	Active components responsible for antioxidant activity	Antioxidant values	References
Daucus carota L. Var. sativa DC. carrot apiaceae	Proteins, amino acids, vitamin (A, B and C)	210(ORAC units 100 g^{-1}) 33.0%(DPPH) 42.2%(ABTS) 0.61(FRAR (Mg^{-1})	Chatatikun and Chiabchalard (2013), Chanda *et al*. (2013)
Coriandrum sativum Linn. Coriander apiaceae	Essential oil, vitamin C, carotene, borneal, limonene and α pinene	25.0 %(DPPH)	Gacche *et al*. (2010)
Anethum graveolens Linn.: dill apiaceae	Carvone, limonene, α-phellandrene, dill ether and myristicin	51.6 %(DPPH)	Gacche *et al*. (2010)
Caralluma tuberculata N.E. brown: chungah Asclepiadaceae	Luteolin 4'-beta-D-glucopyranosyl-(2-->1)-alpha-L-rhamnopyranoside	695.7(EC_{50})	Khanzadi (2011)
Brassica oleraceae Linn. Var. *capitat* Cabbage *brassicaceae*	Ascorbigen, vitamins (A,B and C), sulphoraphane, dithiolthiones, isothiocyanate	42.4 %(DPPH)	Gacche *et al*. (2010)
Brassica oleraceae Linn. Var. *botrytis* Cauliflower *Brassicaceae*	Ascorbigen, vitamins (A,B and C), sulphoraphane, dithiolthiones, isothiocyanate	67.2 %(DPPH)	Gacche *et al*. (2010)
Brassica oleracea: Broccoli *Brassicaceae*	Hydroxycinamic acid esters, 1,2-disinapoylgentiobiose and 1-sinapoyl-2-feruloylgentiobiose	880(ORAC units 100 g^{-1}) 8.9 (μmol of Trolox g^{-1}) 7.52 m mL^{-1} (IC_{50})	Sosnowska *et al*. (2006), Ou *et al*. (2002) and Piao *et al*. (2005)
Raphanus sativus Linn. *Brassicaceae*	Vitamin C, anthocyanin, glucosinolates	62.20%DPPH	Umamaheswari*et al*.(2012)
Cucurbita pepo: Zucchini Cucurbitaceae	Alkaloids momordicine I, momordicine II and cucurbitacine B	12.19%	Hamissou *et al*. (2013)
Cucumis sativus: Cucumber Cucurbitaceae	Luteolin-8-C-beta-D-glucopyranoside (orientin), luteolin-6-C-beta-Dglucopyranoside (isoorientin)	60 ORAC units 100 g^{-1}), 28.32% (DPPH) and 178.2 (IC_{50} mg mL^{-1}), 1.69 (FRAR (Mg^{-1})	Azeez *et al*. (2012)
Lactuca sativa: Lettuce Asteraceae	Vitamin (A,C, E, B1, B2, B3), β-carotene, malic acid, linoic acid, fiber, pectin, amino acids and minerals	92.62% (DPPH)	Azeez *et al*. (2012)
Cucumis melo var. flexuosus Snake Cucumber Cucurbitaceae	Vitamin A, thiamin, riboflavin, niacin, folate, ascorbic acid and proteins	22.23 (IC_{50} mg mL^{-1})	Qusti *et al*. (2010)
Lagenaria siceraria: Bottle Gourd *Cucurbitaceae*	Vitamin-B complex, choline, vitamin-C, β-carotene, Cucurbitacins, fibres and polyphenol	1770 (ORAC units 100 g^{-1}) 6.57 (FRAR (Mg^{-1})	Chanda *et al*. (2013)
Luffa cylindrical L. Chinese okra Cucurbitaceae	Luteolin-7-O-beta-D-glucuronide methyl ester	980 (ORAC units 100 g^{-1}) 2.93 (FRAR (Mg^{-1})	Chanda *et al*. (2013) Chanda *et al*. (2013)
Luffa acutangula (L.) Roxb: Silk Gourd Cucurbitaceae	Carotene, fat, protein, phytin, aminoacids, alanine, arginine, cystine, glutamicacid, glycine, hydroxyproline, leucine, lectin, serine, tryptophan, pipecolic acid	890 (ORAC units 100 g^{-1}) 2.58 (FRAR (Mg^{-1})	

Table 5: Continue

Botanical names with common names family	Active components responsible for antioxidant activity	Antioxidant values	References
Trichosanthes dioica Roxb: Pointed gourd Cucurbitaceae	Vitamin A, vitamin C, tannins, sapponin	840 (ORAC units 100 g^{-1}) 3.78 (FRAR (Mg^{-1})	Chanda *et al*. (2013)
Cucurbita maxima Duch.: Bottle gourd *Cucurbitaceae*	Vitamin C and Phenols	51.6% (DPPH)	Gacche *et al*. (2010)
Terminalia catappa L. *Combretaceae*	Alkaloid, Reducing sugar, Resins, Steroids, Tannins, Saponins	35.3% (DPPH)	Chyau *et al*. (2006)
Carica papaya L.: Papaya *Caricaceae*	α-tocopherol, ascorbic acid, beta carotene, fl avonoids, vitamin B1 and niacin	4.63 (FRAR (Mg^{-1})	Chanda *et al*. (2013)
Beta vulgaris L.: Beet *Chenopodiaceae*	Vitamins (A, B and C), iodine and betanin	5.45 (FRAR (Mg^{-1})	Chanda *et al*. (2013)
Spinacia oleraceae Linn.: Spinach *Chenopodiaceae*	Vitamin (A, E and C), folic acids and minerals	20.4% (DPPH)	Gacche *et al*. (2010)
Lepidium meyenii: Maca Cruciferae	Alkaloids, protein, quercitin, saponins, sitosterols, steroids, stigmasterol, tannins, uridine, vitamin (B1, B12, C, E and K) and zinc	71.38% (DPPH)	Sandoval *et al*. (2002)
Trigona foenum-graecum Linn.: Fenugreek Fabaceae	Choline, trigonelline, saponin, amino acids, vitamins and quercetin	25.7 %(DPPH)	Gacche *et al*. (2010)
Cyamopsis tetragonoloba Linn.: Cluserbean Fabaceae	Flavonoids, tannins, glutamic, arginine, aspartic and leucine	44.6% (DPPH)	Gacche *et al*. (2010)
Bauhinia variegata Linn. Mountain ebony Fabaceae	Protein, flavonoids, fatty oil-containing oleic acid, linoleic acid, palmitic acid and stearic acid, dihydroxy Kaempferol-3-glucoside, lupeol and beta-sitosterol	36.01% (DPPH)	Sharma *et al*. (2011)
Portulaca oleracea Linn.: Purslane Portulacaceae	Alkaloids, coumarins, flavonoids, cardiac glycosides, anthraquinone glycosides, alanine, catechol, saponins, tannins, organic acids, glutathione, glutamic acid and aspartic acid	950.3 (EC_{50})	Khattak (2011)
Citrus limon L. Rutaceae	Vitamin C, flavonoid, flavones, limonoid, limonene (terpenoid), nobiletin, tangeretin, glucarate	1.88 (FRAR (Mg^{-1})	Chanda *et al*. (2013)
Aegle marmelos Correa ex roxb. Rutaceae	Eugenol, lupeol, cineole, citronellal, aegenol, luvangetin, psoralen and cuminaldehyde	6.36 (FRAR (Mg^{-1})	Chanda *et al*. (2013)
Lycopersicon esculentum: Tomato (ripe) Solanaceae	Vitamins (A, B and C), essential amino acids and lycopene	195 (ORAC units 100 g^{-1}) 35.0% (DPPH)	Azeez *et al*. (2012)
Lycopersicon esculentum: Tomato (unripe) Solanaceae	Vitamins (A, B and C), essential amino acids and lycopene	41.10% (DPPH)	Azeez *et al*. (2012)
Capsicum annuum: Green pepper Solanaceae		42.92% (DPPH)	Azeez *et al*. (2012)
Solanum tuberosom L.: Potato Solanaceae	Solanine, solasodine, lutin, vitamin (A and C) and glucarate	300 (ORAC units 100 g^{-1}) 80.0 % (DPPH)	Velioglu *et al*. (1998)
Momordica charantia L. Cucurbitaceae	Linolenic and Palmitic acids, momrdin and vitamins	82.05%	Hamissou *et al*. (2013)

Table 5: Continue

Botanical names with common names family	Active components responsible for antioxidant activity	Antioxidant values	References
Momordica balsamina L. Cucurbitaceae	Alkaloids momordicine I, momordicine II and cucurbitacine B	8.60% (DPPH)	Chanda *et al*. (2013)
Solanum melongena L.: Egg plant Solanaceae	Solasodine and glucarate	400 (ORAC units 100 g^{-1}) 3.69(FRAR (Mg^{-1})	Chanda *et al*. (2013)
Capsicum frutescens (ripe) Solanaceae	Carotene, vitamin C, glutathione, flavonoids	67.85 %(DPPH)	Azeez *et al*. (2012)
Allium sativum: Garlic Liliaceae	Saponins, tannins, sulfurous compounds, prostaglandins, alkaloids, volatile oils and allicin	1939 (ORAC units 100 g^{-1}) 4.32%(DPPH) and 24.17 (IC50 mg mL^{-1})	Qusti *et al*. (2010)
Chenopodium album Linn. White goose foot Meliaceae	Amino acids (leucin, isoleucin, lycine), vitamin C	454.7(EC_{50})	Khattak (2011)
Musa paradisica L. (unripe): Banana Musaceae		380 (ORAC units 100 g^{-1}) 13.18 (FRAR (Mg^{-1})	Chanda *et al*. (2013)
Moringa oleifera Lam.: Drumstick Moringaceae	Alkaloids, flavonoids, anthocyanins, cosmetic oils Leaf: Quercetin-3-0-glucoside, quercetin-3-0-(6''-malonyl-glucoside), kaempferol-3-0(6''-malonyl-glucoside), 3-caffeoylquinic and 5-caffeoylquinic acid	1.75 (FRAR (Mg^{-1}), 376.0 (EC_{50})	Chanda *et al*. (2013) and Khattak (2011)
Rumex vesicarius Linn. Bladder-Dock Polygonaceae	Flavonoids (vitexin, isovitexin, orientin and isorientin), quinones, carotenoids, vitamins-C proteins, tannins, saponins, triterepenoids and organic acids and minerals	32.97% (DPPH)	El-Bakry *et al*. (2012)
Zinger officinale: Ginger Zingiberaceae	Camhene, gingerol, zingiberene, borneol, cineol, cucumins and proteins	1770 (ORAC units 100 g^{-1}) 88.29% (DPPH) and 1.8 (IC_{50} mg mL^{-1})	Azeez *et al*. (2012)
Curcuma amada Roxb.: Mango ginger Zingiberaceae	Curcumin, phytosterol and azulenogenic oil containing pinene, camphor, curcumene and ar-turmerone Caffeic, gentisic, ferulic, gallic, cinnamic	52.61% (DPPH)	Nahak and Sahu (2011)
Curcuma zedoaria Zingiberaceae	Vitamin C and curcumin	63.27% (DPPH)	Nahak and Sahu (2011)
Allium cepa: Onion Liliaceae	Diallyl disulphide, allicin, allin, quercetin antioxidant flavonoid, vitamin (C and E)	450 (ORAC units 100 g^{-1}) 90.2% DPPH	Velioglu *et al*. (1998)
Musa Cavendish: Banana *Musacea*	Vitamin C, vitamin E, β-carotene, gallocatechin and dopamine	10.93 ((IC_{50} mg mL^{-1})	Qusti *et al*. (2010)
Musa Cavendish: Banana peel *Musacea*	linoleic acid	75.3% DPPH	Mokbel and Hashinaga (2005)
Phoenix dactylifera Arecaceae	Phenolic compounds, essential minerals, fiber and proteins	1.65 (IC_{50} mg mL^{-1})	Qusti *et al*. (2010)
Abelmoschus esculenus (Linn.) Lady's finger Malvaceae	Carotene, vitamins (B and C) and amino acids	43.8% (DPPH)	Gacche *et al*. (2010)

Table 5: Continue

Botanical names with common names family	Active components responsible for antioxidant activity	Antioxidant values	References
Nelumbo nucifera Gaertn.: *Lotus* leaf	Alkaloids, vitamins, quercetin flavonoid, tannic acid and oligomeric procyanidines	92.8% (DPPH)	Choe *et al*. (2010)
Hordeum vulgare leaf	Protein, minerals and enzymes	79.5% (DPPH)	Choe *et al*. (2010)
Leucas aspera: Thumbai Lamiaceae	Alkaloids, flavonoids, terpenoids, steroids, tannins, phlobatannins, saponins, glycosides, diterpenes, tannins, saponins, sterols, oleic, linoleic, palmitic, stearic and oleanolic	83.67%(DPPH)	Das *et al*. (2011) and Rahman *et al*. (2008)
Petroselinum crispum: Parsley Umbelliferae	Flavonols, flavones, flavanones, catechins, anthocyanidins and isoflavones	40.1% (DPPH)	Kamel (2013), Fatemeh *et al*. (2011)
Anethum graveolens: Dill Umbelliferae	Tannins, terpenoids, cardiac glycosides and flavonoids	48.14% (DPPH)	Kamel (2013), Jana and Shekhawat (2010)
Macrolepiota mastoidea (fr.) Singer: Wild Mosroom	Flavonoids, phenolic acids, fiber tannins and minerals.	70.87% (DPPH)	Shirmila Jose and Radhamany (2013)
Quercus infectoria: Olivier Fagaceae	Gallic acid and ellagic acid	0.25 mg mL^{-1} (IC_{50}) 152.91 nmol g^{-1} (TAC)	Umachigi *et al*. (2013), Umachigi *et al*. (2008)
Bambusa arundinacea: Spiny bamboo Poaceae	Oxalic acid, amino acids, proteolytic enzyme, nuclease, urease	51.41% (DPPH))	Sandhiya *et al*. (2013)
Cassia sophera L.: Kasondi Caesalpiniaceae	Flavonoids, resins and phenols	15.42 IC_{50} (μg mL^{-1})	Rahman *et al*. (2008)
Corchorus olitorius: Jute mallow Oceanopapayeraceae	Vitamin (B1, B2, C), carotinoids, calcium, potassium, proteins and dietary fibers	90.4% (DPPH)	Elias *et al*. (2012)
Crotalaria ochroleuca: Slender leaf Fabaceae		86.9% (DPPH)	Elias *et al*. (2012)
Solanum scabrum: Black nightshade Solanaceae	Vitamin (A and C), riboflavin, folic acid, carotenes, protein, iron, Iodine, Zinc and Selenium	92.8% (DPPH)	Elias *et al*. (2012), Musyimi *et al*. (2012)
Cleome gynandra: Spider plant Capparaceae	Alkaloids, flavonoids, tannins, saponin, anthroquinons, phlobatanins and steroids	87.8% (DPPH)	Elias *et al*. (2012)
Amaranthus dubius: Bladder campion Amaranthaceae		78% (DPPH)	Odhav *et al*. (2007)
Asystasia gangetica: Chinese violet Acanthaceae	Alkaloids, tannins, steroidal aglycans, saponins, flavonoids, terpenoids and minerals.	84% (DPPH)	Odhav *et al*., 2007
Amaranthus hybridus: Red amaranth Amarantaceae	Polyphenols, carotenoids, flavonoids, phenolics, vitamins (C and E)	90% (DPPH)	Odhav *et al*. (2007)
Amaranthus spinosus: Spiny amaranth Amaranthaceae	Alkaloids, steroids, bita-steroids, quercetin, betanin, amarathin, beta-cyanin and bita-carotene	88% (DPPH)	Odhav *et al*. (2007)
Bidens pilosa: Spanish needle Asteraceae	Aliphatics, flavonoids, terpenoids, phenylpropanoids, aromatics, porphyrins and other compounds	88% (DPPH) Silva *et al*. (2011)	Odhav *et al*. (2007)

Table 5: Continue

Botanical names with common names family	Active components responsible for antioxidant activity	Antioxidant values	References
Chenopodium album: White goosefoot Amaranthaceae	Flavonoids, lignins and tannins	82%(DPPH)	Odhav *et al*. (2007) and Vermerris and Nicholson (2006)
Centella asiatica: Centella Apiaceae	Asiatic acid, madecassic acid, asiaticoside and madecassoside	88%(DPPH)	Odhav *et al*. (2007), Ling (2004) and Ling *et al*. (2000)
Cleome monophylla: Spindle pod Capparidaceae	Flavonoids, alkaloids and triterpenoidal	84%(DPPH)	Odhav *et al*. (2007)
Ceratotheca triloba: Wild foxglove Pedaliaceae	Mucilage, phenolic compounds, lipids, flavonoids, tannins, saponins and fixed oils	84%(DPPH)	Odhav *et al*. (2007)
Emex australis: Double gee Polygonaceae	Flavonoids, alkaloids and terpenoids	78%(DPPH)	Odhav *et al*. (2007)
Galinsoga parviflora: Potato weed Asteraceae	Flavonoids, alkaloids steroids, terpenes and saponins	76%(DPPH)	Odhav *et al*. (2007)
Justicia flava: Yellow justicia Acanthaceae	Flavonoids, alkaloids and triterpenoidal	96%(DPPH)	Odhav *et al*. (2007)
Momordica balsamina: African cucumber Cucurbitaceae	Resins, alkaloids, flavonoids, glycosides, steroids, terpenes, cardiac glycoside and saponins	94%(DPPH)	Odhav *et al*. (2007)
Oxygonum sinuatum: Dubbeltjie Polygonaceae	Protein, dietary fibers and minerals.	92%(DPPH)	Odhav *et al*. (2007)
Portulaca oleracea: Purslane Portulacaceae	Vitamin (A, B and C), carotenoids, betalaine, betacyanin and minerals	96%(DPPH)	Odhav *et al*. (2007)
Physalis viscose: Gooseberry Solanaceae	Carotenoids, vitamin C, minerals, 28-hydroxywithanolide, withanolides, phygrine, kaempferol and quercetin	82%(DPPH)	Odhav *et al*. (2007)
Solanum nigrum: Black Nightshade Solanaceae	Gallic acid, catechin, protocatechuic acid (PCA), cafieic acid, epicatechin, rutin and naringenin	92%(DPPH)	Odhav *et al*. (2007)
Senna occidentalis: Negro coffee Fabaceae	Chrysarobin (1,8-dihydroxy-3-methyl-9-anthrone) and N-methylmorpholine	82%(DPPH)	Odhav *et al*. (2007)
Bauhinia purpurea: Butterfly tree Fabaceae	Linolenic acid, oleic fatty acid and myristic acid.	79.25%(DPPH)	Sahu *et al*. (2013)
Cassia tora: The Sickle Senna Caesalpinaceae	Chrysophanol, aloe-emodin, rhein, glucose, 1-stachydnine, amino acids, fatty acids, d-mannitol, β-sitosterol, myricyl alcohol, trigonelline, choline. Ononitol monohydrate	83.76%(DPPH)	Sahu *et al*. (2013), Vedpriya Arya and Vadav (2011)
Ipomoea cairica Palmate-leaved Morning Glory Convolvulaceae	Alkaloids, tannins, phenolic compounds, proteins and amino acid, terpinoids and sterols and saponins	88.21%(DPPH)	Sahu *et al*. (2013)
Raphanus sativus Linn.: Radish *Brassicaceae*	Triterpenes, alklaoids, flavanoids, tannins, saponins and coumarins	22.06%DPPH	Umamaheswari *et al*. (2012)

Table 5: Continue

Botanical names with common names family	Active components responsible for antioxidant activity	Antioxidant values	References
Commelina benghalensis: Day Flower Commelinaceae	Balsams, resin, tannins, flavonoids, phenols and volatile oils	86.47%(DPPH)	Sahu *et al*. (2013)
Leucas aspera: Thumba Lamiaceae	Triterpenoids, oleanolic acid, ursolic acid and b-sitosterol, nicotine	96.2%(DPPH)	Sahu *et al*. (2013)
Sauropus androgynus: Multi-vitamin Euphorbiaceae	Ascorbic acid, alpha-tocopherol (vitamin E) and beta-carotene (vitamin A)	54.36%(DPPH)	Nahak and Sahu (2010)
Azadirachta indica: Neem Meliaceae	Alkaloids, flavonoids, terpinoids, tannins, saponins and glycosides	50.48%(DPPH)	Nahak and Sahu (2010)
Ocimum basilicum: Sweet basil Lamiaceae	Alkaloids, phenols, steroids, eugenol, eugenal, carvaled, methyl chavicol, limatrol and Caryophylline	70.76%(DPPH)	Nahak *et al*. (2011)
Apium nodiflorum: Fool's-water-cress Apiaceae	Limonene, p-cymene, myristicine and β-pinene	0.07(mg mL^{-1} EC_{50})	Alpinar *et al*. (2009)
Foeniculum vulgare: Fennel Apiaceae	Caffeic acid, p-Coumaric, Ferulic acid-7-o glucoside, Quercetin-7-o glucoside, Ferulic acid 1,5 Dicaffeoylquinic acid, Hesperidin, Cinnamic acid, Rosmarenic acid, Quercetin and Apigenin	2.75(mg mL^{-1} EC_{50})	Alpinar *et al*. (2009)
Montia Fontana: Blinks Montiaceae	Vitamin C, macro and micro minerals and organic acids	1.49 (mg mL^{-1} EC_{50})	Alpinar *et al*. (2009)

ORAC VALUE

Based on widely reported rich antioxidant activities of vegetables, the scientists at United States Department of Agriculture (USDA) have developed a rating scale that measures the antioxidant content of various vegetables. The scale is called Oxygen Radical Absorbance Capacity (ORAC), which stands for oxygen radical absorbance capacity (Table 5). Ou *et al.* (2002) reported that green pepper, spinach, purple onion, broccoli, beet and cauliflower are the leading sources of antioxidant activities against the peroxyl radicals. Cao *et al.* (1996) reported that garlic had the highest antioxidant activity (μmol of Trolox equiv g^{-1}) against peroxyl radicals *Allium sativum* (1939) followed by kale (1770), spinach (1260), Brussels sprouts, alfalfa sprouts, broccoli flowers, beets, red bell pepper, onion, corn, eggplant (980-390), cauliflower, potato, sweet potato, cabbage, leaf lettuce, string bean, carrot, yellow squash, iceberg lettuce, celery and cucumber (380-50). Kale had the highest antioxidant activity against hydroxyl radicals followed by Brussels sprouts, alfalfa sprouts, beets, spinach, broccoli flowers and the others. Lee *et al.* (2007) reported that among various cruciferous vegetables studied, red cabbage had the highest radical scavenging activity followed by Chinese white cabbage, green cabbage and mustard cabbage (Table 5).

CORRELATION BETWEEN ANTIOXIDANT ACTIVITY AND TOTAL PHENOLIC CONTENT

It is generally believed that plants which are having more phenolic content show good antioxidant activity that is there is direct correlation between total phenol content and antioxidant activity (Qusti *et al.*, 2010; Zhou and Yu, 2006). Typically phenols that possess antioxidant activity are known to be phenolic acids and flavonoid, the major classes of phenolic compounds occurring widely in the kingdom especially in fruits and vegetables (Wojdylo *et al*., 2007). The amount of total phenols and antioxidanta are, by and large, with certain expections, within the range of values reported by several workers (Chu *et al*., 2000; Lee, 1992; Anese *et al*., 1999; Pellegrini *et al*., 2003) but they are lower than those reported by (Kaur and Kapoor, 2001, 2004; Kahkonen *et al*., 1999; Prior and Cao, 2000). It has been observed in some cases having no correlation between antioxidant activity and total phenolic content in extracts of some vegetables such as chick pea, drum stick, radish, mustard, purslane, white goose fruits, mountain abony, Caralluma, Carrot, *Terminalia cattapa*, Banana (unripe) determined by squared regression co-efficient (R2). These plants showed high phenol contents but comparatively low DPPH activity (Khattak, 2011; Chanda *et al*., 2013). Environmental factors such as differences in light, season, climate and temperature conditions on the one hand and production, optimal extraction factors and genotype on the other may have contributed to the differences in total phenols and antioxidant activities of various vegetables (Kalt, 2005; Rababah *et al*., 2010). It can be stated that phenolic content of the plant may be a good indicator of its antioxidant capacity (Govind and Madhuri, 2011).

CONCLUSION

Regardless of these advantages, unfortunately the majority of traditional vegetable plants are usually uncultivated and underutilized. It is critical to create awareness regarding diet related health benefits of these neglected precious crops. Further, with reference to food security there is a need to find out every potential source of safe and health-promoting nutrients. Findings of the study indicate that all the studied plants are excellent sources of micronutrients and free radical scavenging activity. The consumption of these traditional vegetables may have many beneficial health attributes. These data may also be helpful in allowing better food choices and improvement in nutritional and health status.

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