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Vegetables as Functional Foods

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Abstract

The adequate nutrition is essential for good health and physical and cognitive development of human body. It requires a diverse diet including staple foods, vegetables, fruits, animal-source foods. Over 60% of the world's under nourished people live in Asia, and a quarter in Africa. Surprisingly, nearly 60-80% of the Indian population is deficient in Vitamin D. Dietary calcium intake among Indians remains significantly low, mainly in those who have vitamin D deficiency, as its absorption is dependent on adequate levels of vitamin D. The most common B12 deficiency was not thought to be prevalent in India but recent studies have shown 47-49% prevalence. Adequate levels of vitamin B12 are required for conversion of inactive folate to its active form. Naturally, those without adequate levels of B12 are likely to suffer from folic acid deficiency. Vitamin A deficiency still remains a major public health nutritional problem in rural pre-school children of India. It also makes children more susceptible to iron deficiency because of its crucial role in mobilising iron from the site where it is stored. More than 75% of toddlers in India suffer from iron-deficiency anemia and about 52 % of young girls are severely anemic. Deficiency of zinc is common in pregnant and lactating women, forming a predominant cause of death in children from rural areas.

India faces the human and economic threat posed by non communicable diseases (NCDs). Cardiovascular diseases, cancers, chronic respiratory diseases, diabetes, and other NCDs are estimated to account for 60% of all deaths in India, making them the leading cause of death – ahead of injuries and communicable, maternal, prenatal, and nutritional conditions. At present, almost every third person in the society is under stress and having chronic disorders like diabetes, arthritis, allergy, cardiovascular disease, fatigue and even cancer. The growing incidence of NCDs causes great individual hardship and places enormous burden on society, untenable in the long run for any country or economy. Recently, there is decline in the physical and mental capabilities along with the social values. The modern synthetic diet, formulated to appeal to our inherent attraction to sugar, salt, fats, and calories at the expense of nutrition, leaves us over-fed and under-nourished. A considerable portion of chronic human diseases, including diabetes and heart disease, appear to be related largely to a diet that is inadequate in the essential vitamins, minerals, phytonutrients, and other constituents found in natural, unprocessed foods. The vegetables are rich in vitamin and mineral content, flavonoid, isoflavone, and carotenoid which are essential to maintain health and fight disease.

Vegetable are an immense store of active chemical compounds and considered as the cheapest and most easily available sources of these essential nutrients.

Keyword: Vitamins; Minerals; Phytonutrients; Flavonoid; Isoflavone; carotenoid.

Vegetables as Functional Foods

The concept of nutraceuticals is not entirely new, although it has evolved considerably over the years. In the early 1900s, food manufacturers in the United States began adding iodine to salt in an effort to prevent goiter (an enlargement of the thyroid gland), representing one of the first attempts at creating a functional component through fortification. A nutraceutical is a food with a medical-health benefit, including the prevention and treatment of disease. Such foods also commonly are referred to as functional foods, signifying they and/or their components may provide a health benefit beyond basic nutrition. While all foods are functional in that they provide nutrients, nutraceuticals contain health-promoting ingredients or natural components that

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have a potential health benefit for the body. Among these foods vegetables (leaves, shoots, buds, flowers, roots, tubers etc) are rich sources of essential vitamins, minerals and phytochemicals (Figure 1) having functional properties.

Fruits, vegetables, and other plant-based foods are rich in bioactive phytochemicals that may provide desirable health benefits beyond basic nutrition to reduce the risk of the development of chronic diseases and also have been hypothesized to reduce the risk of major chronic diseases (Liu, 2004). The intake of green and leafy vegetables lowers the risk of chronic diseases, cardiovascular diseases, anemia, cancer, oxidative stress, diabetes, weight gain etc (Anu *et al.,* 2014).

Numerous nutraceuticals currently are on the market. The Table 2 represents available nutraceuticals / active principles and their potential human health benefits.

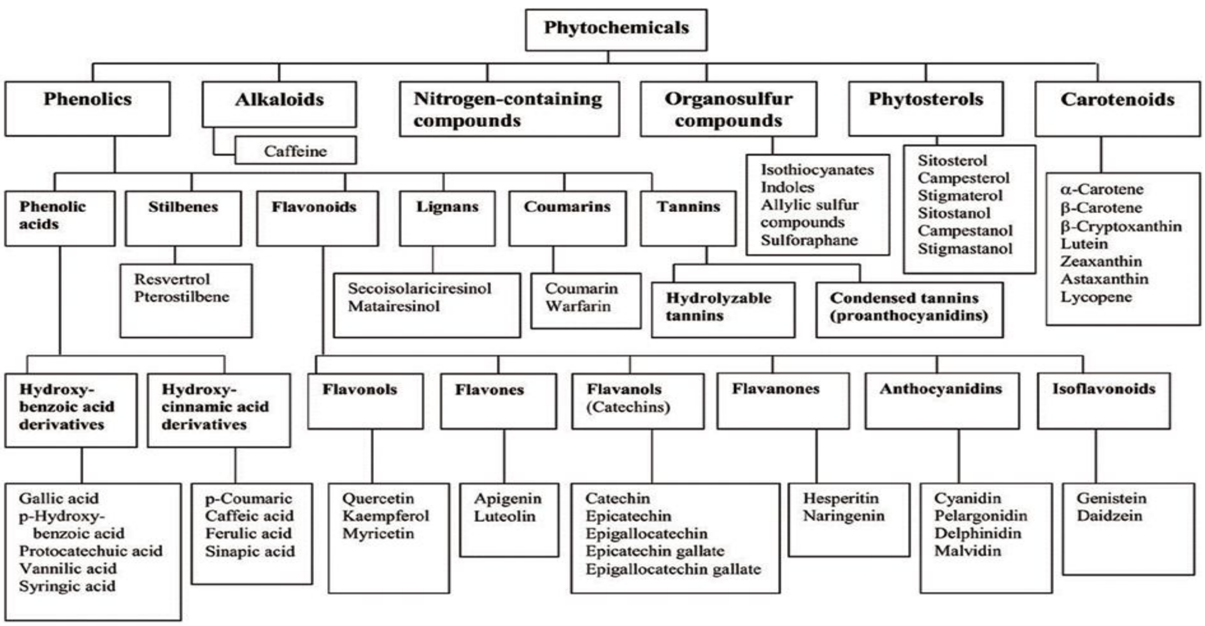

Fig. 1: List of various phytochemicals (Liu, 2004)
(Source: Mahima *et al.,* 2013)

Vegetables : Phytonutrients and Natural Antioxidants

Steinmetz and Potter (1991a) identified more than a dozen classes of these biologically active plant chemicals, now known as phytochemicals. Some of dark green leafy vegetables like arugula, broccoli, spinach, kale and cabbage; dandelion greens; swiss chard and watercress etc., provide a variety of nutrients like vitamin A and B complex, vitamin E, major minerals (calcium and phosphorous) and trace minerals (manganese and potassium) etc. Root vegetables like beets are rich in vitamin B complex, Vitamin C, manganese, magnesium, iron, copper and phosphorus. A close relative of Indian drumstick (*Moringa oleifera)* has highly nutritious leaves, edible flowers, edible pods, antibiotic properties in seeds and the bark is used as a hot condiment with one of the highest calcium levels and highest Vitamin C levels. Young plantain leaves, consumed raw in salad in Asia, are rich source in vitamin B1 and riboflavin.

Vegetables can provide phytonutrients as well as nutritional components, such as vitamins, minerals and fiber (Mattoo *et al*., 2007; Orech *et al*., 2007; Murphy *et al*., 2012; Bumgarner *et al.*, 2012) and amazing source of antioxidants (Kiefer *et al*., 2004; Odukoya *et al*., 2007; Thompson *et al*., 2010) and vitamins (β-carotene, vitamins C and E (Esfahani *et al*., 2011; Mahima *et al*., 2011). Vegetables like carrots, pumpkins, acorn squash, butternut squash, Hubbard squash and sweet potatoes, also known as orange vegetables, are a rich source of carotenoids, which act as antioxidants. Due to presence of antioxidants, higher intake of green leafy vegetables and cruciferous vegetables reduces homocysteine and markers of oxidative stress (Singh *et al*., 2009; Esfahani *et al*., 2011) leading to lower risk of bladder cancer (Michaud *et al*., 1999), non-Hodgkin's lymphoma (NHL) and particularly follicular lymphoma (Thompson *et al*., 2010; Chiu *et al*., 2011). Increased consumption of vegetables has also been found to improve the Pneumovax II vaccination antibody response in older people, leading to improved immunity (Gibson *et al*., 2012). The antioxidants are

Table 2: Vegetables their scientific name, active principle and health benefits

Vegetable	Scientific name	Family name	Active principles	Beneficial health effects
Ladies finger	*Abelmoschus esculentus*	*Malvaceae*	Mucilage	Have blood sugar stabilizing property by regulating sugar absorption from intestine. Have anti ulcer property. Have hypoglycaemic effect. Lower cholesterol in blood and prevent cancer as it blinds to bile acids.
Tamarind	*Tamarindus indica*	*Leguminosae*	Cardiac glycosides, tartaric acid	Have anti microbial effect, anti-inflammatory properties, hypolipomi c and antioxidant activities
Coconut	*Cocas nucifera*	Areaceae	Phytohormones, peroxidase, RN Apolymerases	Coconut juice has estrogenic effect. Have both anti bacterial and anti viral properties, antidote effect, antithrombotic effect.
Egg plant	*Solanum melongena*	Solanaceae	Rich source of iron, calcium, potassium, phosphorus, vitamin B complex	Lowers blood cholesterol level
Drum stick	*Moringa oleifera*	Morigaceae	Its leaves are particularly rich in potassium, calcium, phos-phorous, iron, vitamins A & D	Can be used for diabetes, hypertension, or HIV / AIDS
Cabbage	*Brassica oleracea*	Brassicaceae	Beta carotene	Have anticancer, antioxidant, antiasthmatic, analgesis properties. Improve digestion, circulation and remove constipation
Broccoli	*Brassica deracea*	Brassicaceae	Quercetin, sulphoraphane, polyphenols, glucosinolates	Potent anticancer, artery protecting, immune-modulating infection-fighting, antioxidant properties;promote reproductive potential;relive constipation;decrease cholesterol
Cucumber	*Cucumis sativus*	Cucurbitaceae		Have cooling effect, helpful in fevers, acidosis constipation, high blood pressure, rheumatism, obesity
Radish	*Raphanus sativus*	Brassicaceae	Raphanin	Anti-microbial, antiviral and secretolytic property; helpful in uterine involution,bronchitis, hyperlipidemia
Beet	*Beta vulgaris*	Amranthaceae	Betacyanin	Beneficial effect in tuberculosis, constipation, poor appetite, obesity, gout, pimples and tumors, hepatic disorders
Chilli	*Capsicum*	Solanaceae	Capsaicinoids, Lignan	Antioxidant and anti-inflammatory properties; helps in uterine involution
Tomato	*Solanum lycopersicum*	Solanaceae	Lycopene, Betacarotene	Potent antioxidant, helpful in prevention of arterial diseases and cancer

also helpful in combating the oxidative stress induced by the environmental pollutants such as heavy metals and pesticides (Singh *et al*., 2007; Kumar *et al*., 2012).

Out of more than 600 carotenoids present in plants, only few like alphacarotene, betacarotene, lycopene, zeaxanthine, lutein and betacryptoxanthine are utilized by human beings. The high level of α-carotene, β-carotene, lutein, zeaxanthin, lycopene and total carotenoids in blood circulation is helpful in reduced risk of breast cancer in women (Eliassen *et al*., 2012). Phytoene and phytofluene, precursors of higher unsaturated carotenoids are responsible for photoprotective effects (Stahl and Sies, 2012). Green leafy vegetables are rich in iron content required for synthesis of haemoglobin, hence suggested in iron deficiency anaemia. Various minerals including the trace minerals are also co-enzymes in certain biochemical reactions in the body (Mahima *et al*., 2012), which adds to the importance of leafy vegetables in metabolic reactions.

The fiber content of vegetables provides a bulk in the diet. This helps to reduce the intake of starchy foods, enhances gastrointestinal function, prevents constipation and may thus reduce the incidence of metabolic diseases like maturity onset, diabetes mellitus and hypercholesterolemia. The fibre cleanses the gut by removing the various carcinogens from the body and prevents the absorption of excess cholesterol. It also prevents the intake of excess starchy food and therefore protect against metabolic disorders (hypercholesterolemia and diabetes mellitus). Fibre from the seed coat and the cell walls of the cotyledon of peas is beneficial for gastrointestinal function and health (Dahl *et al*., 2012) and also phytochemicals like polyphenolics and saponins present in coloured seed coat of peas have potent antioxidant and anticarcinogenic properties. Polyphenols play critical role in prevention of various diseases including cardiovascular, neurodegenerative disorders, diabetes mellitus, osteoporosis and even cancer (Hafidh *et al*., 2009; Mudgal *et al*., 2010), hepatic damage (Salawu and Akindahunsi, 2006), inhibit angiogenesis (Sahib *et al*., 2010) and obesity (El-Shebini *et al*., 2007). Green and yellow vegetables decrease the risk of chronic disease and inhibit the development of atherosclerosis (Wolfenden *et al*., 2012). Therefore, it may lead to a reduction in the risk of coronary heart disease (Samman *et al*., 2003; Adams *et al*., 2006; Esfahani *et al*., 2011), diabetes (Imai *et al*., 2012), stroke, markers of inflammation and oxidative stress (Holt *et al*., 2009) viz., serum homocysteine and markers of protein, lipid and DNA oxidation (Esfahani *et al*., 2011). Such consumptions could also mitigate contaminant exposure and/or their adverse health effects (Gagne *et al*., 2013).

Major mineral components of the leaves include calcium (1.22-4.13 mg 100 g^{-1}), potassium (0.08-6.10 mg 100 g^{-1}), sodium (0.03-6.84 mg 100 g^{-1}) and iron (0.01-0.12 mg 100 g^{-1}). Calcium is a major component giving strong bones, muscle contraction and relaxation, synaptic transmission, blood clotting and absorption of Vitamin especially B_{12}. The relatively high content of calcium in *Gryllotalpa africana* (4.13 mg 100 g^{-1}), *T. triangulare* (7.44 mg 100 g^{-1}), potassium and magnesium are known to decrease blood pressure. Potassium plays a crucial role in skeletal muscle contraction and transmission of nerve impulses. Therefore, the persons having the soft bone are usually advised to have the vegetables rich in calcium and potassium.

Phytoconstituents of vegetables are also very effective stimulants for the nervous system of the body. The bitter leaf contains an alkaloid, vernomine, which is capable of reducing headaches associated with hypertension (Ayitey-Smith, 1989). Broccoli is as excellent source of sulphoraphane, which has a powerful anticancerous effect. Spinach retards central nervous system and cognitive behavioral deficits. *Ocimum* species are rich in alkaloids that are useful in cold, cough, chronic catarrh and migraine. The medicinal importance of tannins, saponins and inulins which are components of traditional herbal preparations are highly useful in managing various common ailments. Lesser medication and more natural foods need to be have a priority place in our life but to get maximum health benefits sufficient knowledge and understanding a necessity.

Diets rich in vegetables and fruit have been linked with lower rates of cancer and coronary heart disease (Craig, 1997; Beecher, 1993; Potter, 1997; Steinmetz and Potter, 1996). Plant-based phenols, flavonoids, isoflavones, terpenes, glucosinolates, and other compounds that are present in the everyday diet are reported to have antioxidant and anticarcinogenic properties and a wide spectrum of tumor-blocking activities (Craig, 1997; Potter, 1997; Rhodes, 1996; Zhang *et al.*, 1992). The search for the mechanisms of chemoprotection has focused on the biological activity of compounds found in cruciferous and green leafy vegetables, citrus fruit, green tea, and red wine (Rhodes, 1996; Chung *et al.*, 1998; Verhoeven *et al.*, 1997). Plant flavonoids may protect against LDL oxidation through a reduction of free radicals, chelation of metal ions, or protection or regeneration of á-tocopherol (Hertog *et al.*, 1992 Bravo,1998; Wattenberg, 1993).

Glucosinolates and isothiocyanates are also regarded as dietary protectors against cancer (Zhang *et al.*, 1992). Isothiocyanates inhibit the activation of carcinogens by cytochrome P-450 (phase 1) enzymes and promote detoxification of activator carcinogens by inducing phase 2 enzymes. Phase 2 enzymes inactivate carcinogens by neutralizing their toxic properties and speeding their elimination from the body (Fahey *et al.*, 1997). Some phase 2 enzymes function as inhibitors of cytochrome P-450 (Zhang *et al*., 1992).

Lutein is a yellow-to-orange pigment or phytochemical found mostly in plants. It works as an antioxidant to reduce the damage done by free radicals. Lutein is a carotenoid and is related to vitamin A. Other carotenoids include beta carotene, alpha carotene and zeaxanthin. Orange and yellow vegetables, including carrots, spinach, pumpkins, winter squash, cantaloupes, and red peppers, are rich sources of β-carotene. Dark green leafy vegetables, including spinach, kale, turnip greens, broccoli, Brussels sprouts, and collards, are rich sources of lutein and zeaxanthin. Tomatoes, is the most common source of lycopene. It has been estimated that 85% of lycopene intake in the United States is from processed tomato products such as ketchup, tomato paste, and tomato soup. The most abundant carotenoids in potatoes are lutein and zeaxanthin, followed by β-carotene and β-cryptoxanthin (Andre, 2007).

Dietary glutathione occurs in moderate amounts in some fruits and vegetables, whereas it is absent or found only in small amounts in grains and dairy products (Jones *et al.,* 1992). Dietary glutathione content of fresh asparagus is 28.3 mg/100 g and fresh avocado 27.7 mg/100 g (Jones *et al.,* 1992). Glutathione may protect cells from carcinogenic processes through functioning as an antioxidant (Jones *et al.,* 1989; Mannervik *et al.,* 1989), binding with mutagenic chemical compounds (Wattenberg, 1985; Frei *et al.,*1989) directly or indirectly acting to maintain functional levels of other antioxidants such as vitamins C and E and beta-carotene (Frei *et al.,* 1989; Frei *et al*., 1988), involvement in the DNA synthesis and repair (Oleinick *et al*., 1988; Fuchs,1989) and enhancing the immune response (Buhl *et al.,* 1989).

Antioxidants

Several epidemiological studies have indicated that a high intake of plant products is associated with a reduced risk of a number of chronic diseases, such as atherosclerosis and cancer (Gosslau and Chen, 2004; Gundgaard *et al.*, 2003; Hashimoto *et al.*, 2002; Kris-Etherton *et al.*, 2002; Law and Morris, 1998; Temple, 2000). These beneficial effects have been partly attributed to the compounds which possess antioxidant activity. The major antioxidants of vegetables are vitamins C and E, carotenoids, and phenolic compounds, especially flavonoids. These antioxidants scavenge radicals and inhibit the chain initiation or break the chain propagation (the second defense line). Vitamin E and carotenoids also contribute to the first defense line against oxidative stress, because they quench singlet oxygen (Krinsky, 2001; Shi *et al.*, 2001). Flavonoids as well as vitamin C showed a protective activity to α-tocopherol in human LDL, and they can also regenerate vitamin E, from the α-chromanoxy radical (Davey *et al.*, 2000; Zhu and Huang, 2000).

Nutrient antioxidants may act together to reduce reactive oxygen spieces level more effectively than single dietary antioxidants, because they can function as synergists (Eberhardt *et al.*, 2000; Rossetto *et al.*, 2002; Trombino *et al.*, 2004). In addition, a mixture containing both water-soluble and lipid-soluble antioxidants is capable of quenching free radicals in both aqueous and lipid phases (Chen and Tappel, 1996). For example, with the liposome oxidation method, the activity of combination of quercetin or catechins plus α-tocopherol was significantly higher than the sum of the individual activities (Murakami *et al.*, 2003). Combinations of α-tocopherol or vitamin C plus phenolic compounds also provided synergistic effects in human erythrocyte membrane ghosts and phosphatidylcholine liposome systems (Liao and Yin, 2000).

Water-Soluble Antioxidants

Vitamin C

Vitamin C, which includes ascorbic acid and its oxidation product—dehydroascorbic acid, has many biological activities in human body. Block *et al.* (2004) have found that vitamin C can reduce levels of C-reactive protein (CRP), a marker of inflammation and possibly a predictor of heart disease. More than 85% of vitamin C in human diets is supplied by fruits and vegetables (Davey *et al.*, 2000 ; Lee and Kader, 2000). Biological function of L-ascorbic acid can be defined as an enzyme cofactor, a radical scavenger, and as a donor/acceptor in electron transport at the plasma membrane. Ascorbic acid is able to scavenge the superoxide and hydroxyl radicals, as well as regenerate α-tocopherol (Davey *et al.*, 2000). The content of vitamin C among Brassica vegetables varies significantly between and within their subspecies. Vitamin C levels varied over a 4-fold in broccoli and cauliflower, 2.5-fold in brussels sprouts and white cabbage, and twice in kale. The cause of reported variations in vitamin C content might be related to the differences in genotype (Kurilich *et al.*, 1999; Vallejo *et al.*, 2002).

Dehydroascorbic acid (DHA)—oxidation product of ascorbic acid is unstable at physiological pH and it is spontaneously and enzymatically converted to 2, 3-diketogulonic acid (Davey *et al.*, 2000). According to Gokmen *et al.* (2000), DHA was the dominant form of vitamin C in cabbage, with 4-fold higher level than ascorbic acid. In contrast to this report, Vanderslice *et al.* (1990) observed that the contribution of DHA to the total vitamin C contents was 14% or 8% in cauliflower and broccoli, respectively. Vallejo *et al.* (2003) reported the contribution of DHA to the total vitamin C contents was 11.3% in broccoli.

Potatoes are good sources of vitamin C (ascorbic acid). Andre *et al*. (2007) reported that the vitamin C content in potatoes ranged from 22 to 69 mg per 100 g dry weight depending on cultivars. One medium-size baked potato (173 g, fresh weight) provides 16.6 mg of vitamin C (USDA, 2012), which could meet 27.7% of daily value. Vitamin C is an essential nutrient and plays an important function in collagen synthesis to prevent scurvy, a vitamin C deficiency disease. Vitamin C is also an excellent antioxidant to scavenge free radicals and to prevent oxidative stress.

Lipid-Soluble Antioxidants

Carotenoids

Carotenoids are classified into hydrocarbons (carotenes) and their oxygenated derivatives (xanthophylls), with a 40-carbon skeleton of isoprene units (Liu, 2004). It is estimated that >600 distinct carotenoids have been isolated and identified with yellow, orange, and red colors and are present widely in fruits, vegetables, whole grains, and other plants. In terms of health benefits, carotenoids have received considerable attention because of their unique physiological functions as provitamins and antioxidant effects, especially in scavenging singlet oxygen.

Carotenoids (carotens and xanthophylls) are yellow, orange, and red pigments present in many fruits and vegetables. Several of them are precursors of vitamin A (i.e. β-carotene, γ-carotene, and β-cryptoxanthin), and due to conjugated double bonds they are both radical scavengers and quenchers of singlet oxygen. Lower serum β-carotene levels have been linked to higher rates of cancer and cardiovascular diseases, as well as to increased risk of myocardial infarction among smokers (Rice-Evans *et al.*.1997).

Carotenoids are especially powerful in scavenging singlet oxygen generated from light induced lipid oxidation or radiation. Astaxanthin, zeaxanthin, and lutein are excellent in scavenging free radicals because of the unique end functional groups.

Vitamin E

In addition to carotenoids, vitamin E also belongs to a group of lipid-soluble antioxidants. The biological activity of vitamin E exhibit tocopherols and tocotrienols, especially α-tocopherol. The predominant reaction responsible for tocopherol antioxidant activity is hydrogen atom donation, where a tocopheroxyl radical is formed (Lampi *et al.*, 2002). Vitamin E shows protective effects against the coronary heart disease due to inhibition of LDL oxidation (Stampfer and Rimm, 1995). Although vegetables in addition to fats, oils and cereal grains, constitute the major source of vitamin E in our diet, there are only few data of tocopherol content in vegetables. Piironen *et al.* (1986) reported that α-tocopherol was predominant tocopherol in all brassica vegetables, except in cauliflower, containing predominantly γ-tocopherol. In contrast, Kurilich *et al.* (1999) reported lower concentration of γ-tocopherol than α-tocopherol in cauliflower. In general, the best sources of lipid-soluble antioxidants are kale and broccoli. Brussels sprouts have moderate levels of the above-mentioned compounds, while cauliflower and cabbage are characterized by their relatively low amounts.

Lycopene

Lycopene is a carotenoid that is present in tomatoes, processed tomato products and other fruits. It is one of the most potent antioxidants among dietary carotenoids. Dietary intake of tomatoes and tomato products containing lycopene has been shown to be associated with a decreased risk of chronic diseases, such as cancer and cardiovascular disease. Serum and tissue lycopene levels have been found to be inversely related to the incidence of several types of cancer, including breast cancer and prostate cancer. Although the antioxidant properties of lycopene are thought to be primarily responsible for its beneficial effects, evidence is accumulating to suggest that other mechanisms may also be involved. Along with genetic factors and age, lifestyle and diet are also considered important risk factors. About 50% of all cancers have been attributed to diet (Williams *et al.*, 1999).

Oxidative stress induced by reactive oxygen species is one of the main foci of recent research related to cancer and cardiovascular disease. Reactive oxygen species are highly reactive oxidant molecules that are generated endogenously through regular metabolic activity, lifestyle activity and diet. They react with cellular components, causing oxidative damage to such critical cellular biomolecules as lipids, proteins and DNA. There is strong evidence that this damage may play a significant role in the causation of several chronic diseases (Ames *et al.*,1995).

The antioxidants such as vitamin E, vitamin C, polyphenols and carotenoids are available from food. Current dietary guidelines to combat chronic diseases, including cancer and coronary artery disease, recommend increased intake of plant foods, including fruits and vegetables, which are rich sources of antioxidants. The role of dietary antioxidants, including vitamin C, vitamin E, carotenoids and polyphenols, in disease prevention has received much attention in recent years (Halliwell *et al.*, 1995). These antioxidants appear to have a wide range of anticancer and antiatherogenic properties. These observations may explain the epidemiological data indicating that diets rich in fruits and vegetables are associated with a reduced risk of numerous chronic diseases (Gaziano *et al.*, 1999).

Dietary antioxidant thought to be important in the defence against oxidation is lycopene, of which tomatoes are an important dietary source (Rao and Agarwal,1999). Lycopene is a natural pigment synthesized by plants and microorganisms but not by animals. It is a carotenoid, an acyclic isomer of ß-carotene. Lycopene is a highly unsaturated hydrocarbon containing 11 conjugated and 2 unconjugated double bonds. Lycopene from natural plant sources exists predominantly in an all-*trans* configuration, the most thermodynamically stable form. In human plasma, lycopene is present as an isomeric mixture, with 50% as *cis* isomers (Nguyen and Schwartz,1999).

Lycopene is one of the most potent antioxidants, with a singlet-oxygen-quenching ability twice as high as that of ß-carotene and 10 times higher than that of á-tocopherol (DiMascio *et al*.,1989). It is the most predominant carotenoid in human plasma. Its level is affected by several biological and lifestyle factors. Owing to their lipophilic nature, lycopene and other carotenoids are found to concentrate in low-density and very-low-density lipoprotein fractions of the serum. Lycopene is also found to concentrate in the adrenal gland, testes, liver and prostate gland, where it is the most prominent carotenoid. Tissue-specific lycopene distribution may be important in the role of this antioxidant. However, unlike other carotenoids, lycopene levels in serum or tissues do not correlate well with overall intake of fruits and vegetables (Michaud *et al.,* 1998).

The biological activities of carotenoids such as ß-carotene are related in general to their ability to form vitamin A within the body. Since lycopene lacks the ß-ionone ring structure, it cannot form vitamin A (Stahl and Sies, 1996). Its biological effects in humans have therefore been attributed to mechanisms other than vitamin A. Two major hypotheses have been proposed to explain the anticarcinogenic and antiatherogenic activities of lycopene: nonoxidative and oxidative mechanisms. Lycopene also has been shown to act as a hypocholesterolemic agent by inhibiting HMG-CoA (3-hydroxy-3-methylglutaryl-coenzyme A) reductase (Fuhramn *et al*., 1997).

Lycopene has been hypothesized to prevent carcinogenesis and atherogenesis by protecting critical cellular biomolecules, including lipids, lipoproteins, proteins and DNA. In healthy human subjects, lycopene- or tomato-free diets resulted in loss of lycopene and increased lipid oxidation, whereas dietary supplementation with lycopene for 1 week increased serum lycopene levels and reduced endogenous levels of oxidation of lipids, proteins, lipoproteins and DNA. Patients with prostate cancer were found to have low levels of lycopene and high levels of oxidation of serum lipids and proteins (Rao and Agrawal, 1999).

Red fruits and vegetables, including tomatoes, watermelons, pink grapefruits, apricots and pink guavas, contain lycopene. Processed tomato products, such as juice, ketchup, paste, sauce and soup, all are good dietary sources of lycopene. In a recent study in our laboratory, the average daily dietary intake of lycopene, assessed by means of a food-frequency questionnaire, was estimated to be 25 mg/d with processed tomato products, accounting for 50% of the total daily intake (Rao *et al.*, 1998).

Although comparative bioavailability values for lycopene from different tomato products are unknown, lycopene from processed tomato products appears to be more bioavailable than that from raw tomatoes (Gartner *et al.*, 1997). The release of lycopene from the food matrix due to processing, the presence of dietary lipids and heat-induced isomerization from all-*trans* to a *cis* conformation enhance lycopene bioavailability. The bioavailability of lycopene is also affected by the dosage and the presence of other carotenoids, such as ß-carotene. The bioavailability of lycopene was significantly higher when it was ingested along with ß-carotene than when ingested alone.

Phenolic Compounds

There are several thousand different flavonoids present in plants, and many of them have antioxidant activities. Such phenolic compounds have already been implicated as playing a role in the protection that fruits and vegetables have against chronic diseases (Nijveldt *et al.,* 2001). Phenolics are a group of compounds with ≥1 aromatic rings possessing ≥1 hydroxyl groups. Phenolics are generally are classified as subgroups of phenolic acids, flavonoids, stilbenes, coumarins, and tannins (Liu, 2004). Phenolic acids can be divided into 2 major subgroups: hydroxybenzoic acid and hydroxycinnamic acid derivatives. Hydroxybenzoic acid derivatives in plant foods include *p*-hydroxybenzoic, gallic acids, syringic, protocatechuic, and vanillic acids (Liu, 2004). They are usually present in the bound form in foods as components of complex structures such as lignins and hydrolyzable tannins or attached to cell walls and proteins. They can also be found as derivatives of sugar and organic acids in fruits, vegetables, and whole grains. Hydroxycinnamic acid derivatives in plant foods include *p*-coumaric, ferulic, caffeic, and sinapic acids. They are primarily present in the bound form, connected to cell wall structural components such as cellulose, lignin, and proteins through ester bonds (Liu, 2004).

Phenolic compounds are a large group of the secondary metabolites categorized into classes depending on their structure and subcategorized within each class according to the number and position of hydroxyl group and the presence of other substituents. The most widespread and diverse group of the polyphenols are the flavonoids which are built upon C_6–C_3–C_6 flavone skeleton. In addition, other phenolic compounds such as benzoic acid or cinnamic acid derivatives have been identified in fruits and vegetables (Aherne and O'Brien, 2002). Phenolic compounds, especially flavonoids, possess different biological activities, but the most important are antioxidant activity, capillary protective effect, and inhibitory effect elicited in various stages of tumor (Cook and Samman, 1996; Czeczot, 2000; Hollman *et al.*,1996; Kuntz *et al.*,1999). Phenolics are able to scavenge reactive oxygen spieces due to their electron donating properties. Their antioxidant effectiveness depends on the stability in different systems, as well as number and location of hydroxyl groups. In many in vitro studies, phenolic compounds demonstrated higher antioxidant activity than antioxidant vitamins and carotenoids.

Flavonoids

Flavonoids are a major group of phenolic compounds that commonly have a generic structure consisting of 2 aromatic rings (A and B rings) connected by 3 carbons that are usually in an oxygenated heterocycle ring, or C ring (Liu, 2004). Fruits, vegetables, and other plant foods are rich sources of flavonoids, which have been linked to reducing the risk of major chronic diseases, such as heart disease, cancer, stroke, diabetes, Alzheimer's disease, cataracts, and age-related function decline (Liu, 2004). More than 5000 individual flavonoids have been isolated and identified. Structural differences in the heterocycle C ring categorize them as flavonols (quercetin, kaempferol, and myricetin), flavones (luteolin and apigenin), flavonols (catechin, epicatechin, epigallocatechin, epicatechin gallate, and epigallocatechin gallate), flavonones (naringenin), anthocyanidins (cyanidin and malvidin), and isoflavonoids (genistein and daidzein). These are common flavonoids in the diet. Dietary flavonoids are most commonly found in nature as conjugates in glycosylated or esterified forms, but can be present as aglycones, especially in cooked or processed plant foods. Many different glycosylated forms can be found in nature because >80 different sugars have been reported bound to flavonoids in plant foods (Hollman 2000). Anthocyanidins provide unique colors in some fruits, vegetables, and whole grains.

Thiols

Thiols comprises of sulfur-containing phytonutrients present in garlic and cruciferous vegetables (cabbage, turnips and members of the mustard family). Allylic Sulfides subclasses is abundantly found in garlic, onions, leeks, shallots and chives (Hofgen *et al.*, 2001) and are released when the plants are cut or smashed. These possess antimutagenic and anticarcinogenic properties as well as immune enhancing and cardiovascular protective properties (Vazquez-Preeto and Miatello, 2010).

Phytochemicals and Bitterness

Although present in very small amounts, antioxidant phytochemicals impart a perceptible bitter taste to foods. As documented below, some of these compounds are so aversive to the consumer (Drewnowski, 1996; Matsuura, 1989; Van Doorn, 1998) that they are selectively bred out of plants and routinely removed from processed foods (Rouseff, 1990; Roy, 1990). Indeed, the low amounts of bitter plant compounds in the current diet largely reflect the achievements of the agricultural and food industries (Roy, 1990). The debittering of plant foods has long been a major sensory concern for food science (Fenwick, 1990).

Cruciferous vegetables (broccoli, cauliflower, kale, turnips, collards, brussels sprouts, cabbage, kohlrabi, rutabaga, chinese cabbage, and bok choy) contain stable glucosinolates in the amounts of 0.5–1 g/g (Carlson *et al.*, 1987; Fenwick, 1990). Glucosinolates are natural pesticides, being toxic to insects (Fenwick, 1990). The major glucosinolates in cabbage and brussels sprouts—sinigrin, progoitrin, and glucobrassicin—are toxic to rats (Fenwick, 1990). Three-day-old broccoli sprouts contained higher concentrations of sulforaphane than did the mature plant (Fahey, 1997).

Diets high in vegetables and fruit have been associated with reduced cancer risk (Steinmetz and Potter, 1996). Many studies focused on the chemoprotective role of phytochemicals. Chemoprotective agents generally belong in 1 of 3 categories: those that block metabolic activation of carcinogens, those that prevent the formation of carcinogens from precursors, and those that suppress neoplasia in cells previously exposed to carcinogens (Wattenberg, 1993; Sharma *et al.*, 1994). Phytonutrients and their metabolites elicit a variety of biological activities, acting as antioxidants, phytoestrogens, or enzyme inducers (Dragsted *et al.*, 1993). Among the most promising compounds under study are bitter phenols and polyphenols, flavonoids, isoflavones, and glucosinolates.

Tomatoes

Tomatoes have received significant attention because of interest in lycopene, the primary carotenoid found in this fruit (Gerster, 1997), and its role in cancer risk reduction (Weisburger, 1998).The men, those who consumed tomato products had less than one-half the risk of developing advanced prostate cancer (Giovannucci *et al*., 1995). Interestingly, lycopene is the most abundant carotenoid in the prostate gland (Clinton *et al*., 1996). Other cancers whose risk have been inversely associated with serum or tissue levels of lycopene include breast, digestive tract, cervix, bladder, and skin (Clinton, 1998) and possibly lung (Li *et al*., 1997). Proposed mechanisms by which lycopene could influence cancer risk are related to its antioxidant function. Lycopene is the most efficient quencher of singlet oxygen in biological systems (Di Mascio *et al*., 1989). The antioxidant function of lycopene may also explain the recent observation in a multi-center European study that adipose tissue levels of carotenoids were inversely associated with risk for myocardial infarction (Kohlmeier *et al*., 1997).

Garlic

Garlic is likely the herb most widely quoted in the literature for medicinal properties (Nagourney, 1998). Thus, it's not surprising that garlic has ranked as the second best selling herb in the United States for the past two years (Anon., 1998). The purported health benefits of garlic are numerous, including cancer chemopreventive, antibiotic, anti-hypertensive, and cholesterol-lowering properties (Srivastava *et al*., 1995).

The characteristic flavor and pungency of garlic are due to an abundance of oil-and water-soluble, sulfur-containing elements, which are also likely responsible for the various medicinal effects ascribed to this plant. The intact garlic bulb contains an odorless amino acid, alliin, which is converted enzymatically by allinase into allicin when the garlic cloves are crushed (Block, 1992). Allicin then spontaneously decomposes to form numerous sulfur-containing compounds, some of which have been investigated for their chemopreventive activity. Considerable variation in the quantity of organosulfur compounds available in fresh and commercially available garlic products has been demonstrated (Lawson *et al*., 1991). Several epidemiologic studies show that the garlic may be effective in reducing human cancer risk (Dorant *et al.*, 1993). The investigation conducted in China showed a strong inverse relationship between stomach cancer risk and in-creasing allium intake (You *et al.*, 1988). More recently, in study postmenopausal women, garlic consumption was associated with nearly a 50% reduction in colon cancer risk (Steinmetz *et al.*, 1994). A more recent review of 20 epidemiological studies (Ernst, 1997) suggests that allium vegetables, including onions, may confer a protective effect on cancers of the gastrointestinal tract. Garlic has also been advocated for the prevention of CVD, possibly through antihypertensive properties. According to Silagy and Neil (1994a), however, there is still insufficient evidence to recommend it as a routine clinical therapy for the treatment of hypertensive subjects. The cardioprotective effects are more likely due to its cholesterol-lowering effect. In a meta-analysis, Warshafsky *et al.* (1993) showed that an average of 900 mg garlic / day could decrease total serum cholesterol levels by approximately 9%. Silagy and Neil (1994b) reported that 800 mg garlic / day reduced total cholesterol levels by 12%. It was reported that 12 weeks of garlic treatment was ineffective in lowering cholesterol levels in subjects with hypercholesterolemia (Isaacsohn *et al.*, 1998). It is currently unclear which component in garlic is responsible for its cholesterol-lowering effect.

Broccoli and other Cruciferous Vegetables

Epidemiological evidence has associated the frequent consumption of cruciferous vegetables with decreased cancer risk. Verhoeven *et al.* (1996) demonstrated an inverse association between consumption of total brassica vegetables like cabbage, broccoli, cauliflower, and brussels sprouts and cancer risk. Verhoeven *et al.* (1997) attributed the anticarcinogenic properties of cruciferous vegetables to their relatively high content of glucosinolates. Glucosinolates are a group of glycosides stored within cell vacuoles of all cruciferous vegetables. Myrosinase, an enzyme found in plant cells, catalyzes these compounds to a variety of hydrolysis products, including isothiocyanates and indoles. Indole-3 carbinol (I3C) is currently under investigation for its cancer chemopreventive properties, particularly of the mammary gland. Although a wide variety of naturally occurring and synthetic isothiocyanates have been shown to prevent cancer in animals (Hecht, 1995), attention has been focused on a particular isothiocyanate isolated from broccoli, known as sulforaphane. Sulforaphane has been shown to be the principal inducer of a particular type of Phase II enzyme, quinone reductase. Fahey *et al.* (1997) recently demonstrated that 3-day-old broccoli sprouts contained 10-100 times higher levels of glucoraphanin (the glucosinolate of sulforaphane) than did corresponding mature plants. However, in view of the importance of an overall dietary pattern in cancer risk reduction, the clinical implications of a single phytochemical in isolation has been questioned (Nestle, 1998).

These vegetables possess both antioxidant and anticarcinogenic vegetables (Cohen *et al.*, 2000; Verhoeven *et al*., 1997). In addition to antioxidant vitamins, carotenoids, and polyphenols, Brassica vegetables provide a large group of glucosinolates, which according to Plumb *et al.* (1996) possess rather low antioxidant activity, but the products of their hydrolysis can protect against cancer (Keum *et al.*, 2004; Paolini, 1998).

Broccoli is a source of flavonol and hydroxycinnamoyl derivatives. Price e*t al.* (1998) identified the main flavonol glycosides present in broccoli florets as quercetin and kaempferol 3-*O*-sophoroside. Three minor glucosides of these aglycones were also detected, namely isoquercitrin, kaempferol 3-*O*-glucoside and kaempferol diglucoside. The predominant hydroxycinnamoyl acids were identified as 1-sinapoyl-2-feruloylgentiobiose, 1,2-diferuloylgentiobiose, 1,2,2' -trisinapoylgentiobiose, and neochlorogenic acid (Vallejo *et al*., 2003). In addition, 1,2' -disinapoyl-2-feruloylgentiobiose and 1,2-disinapoylgentiobiose, 1-sinapoyl-2,2-diferuloyl gentiobiose, isomeric form of 1,2,2' -trisinapoylgentiobiose, and chlorogenic acids were found in broccoli (Price *et al*., 1997; Vallejo *et al.*, 2003). Total amounts of feruloylsinapoyl esters of gentiobiose and caffeic acid derivatives in 14 cultivars of broccoli varied from 0 to 8.25 mg/100 g, and from 0 to 3.82 mg/100 g, respectively.

Nielsen *et al.* (1993) showed that cabbage contains a mixture of more than 20 compounds of which seven have been identified as 3-*O*-sophoroside-7-*O*-glucosides of kaempferol and quercetin with and without further acylation with hydroxycinnamic acids. In addition, unmodified kaempferol tetraglucosides or their derivatives acylated with either sinapic, ferulic or caffeic acid were found in cabbage leaves (Nielsen *et al.*, 1998). Red pigmentation of red cabbage is caused by anthocyanins, which belong to flavonoids. Red cabbage contains more than 15 different anthocyanins which are acylglycosides of cyanidin (Dyrby *et al.*, 2001; Mazza and Miniati, 1993). Total anthocyanins content in red cabbage was 25 mg/100 g (Wang *et al.,* 1997) or 44.4–51.2 mg/100 g for anthocyanidins released after acid hydrolysis (Franke *et al.,* 2004).

Phenolics in vegetables exist in both free and conjugated forms. After hydrolysis, HPLC analysis showed that quercetin was the predominant flavonol aglycone in brassica vegetables Its level in Mauritian brassica vegetables varied from 3.9 mg/100 g in cauliflower to 39.0 mg/100 g in Chinese cabbage (Bahorun *et al.,* 2004). However, Chu *et al.* (2000) reported much lower contents of quercetin for brassica vegetables cultivated in Taiwan: 0.004 mg/100 g for white cabbage and 0.024 mg/100 g for Chinese cabbage. Kaempferol and myricetin derivatives were also present in Brassica vegetables, but myricetin was not present in broccoli, white cabbage, purple cabbage, and cauliflower. According to Bahorun *et al.* (2004), apigenin and luteolin were flavones detected in the hydrolysed extracts of different Brassica vegetables except for broccoli. Among four Taiwan Brassica vegetables studied by Chu *et al.* (2000), the levels of flavone were higher than those of flavonol in all tested vegetables. Apigenin was the predominant flavone aglycone in these vegetables except Chinese cabbage, where luteolin content was nearly 4-fold higher than apigenin content.

Phenolic compounds in our diet may reduce the risk of chronic diseases such as cancer, heart disease, and diabetes. Fruits and vegetables are good sources of dietary phenolics. Among the common vegetables consumed in the United States, spinach had the highest phenolic content, followed by red pepper, beets, broccoli, Brussels sprouts, eggplant, asparagus, and green pepper, in order of phenolic content (Song *et al*., 2010; Chu *et al*., 2002). The rest of the vegetables in order of phenolic content were yellow onion, cauliflower, cabbage, radish, chili pepper, mushroom, sweet potato, carrot, sweet corn, potato, squash, white onion, green pea, tomato, green bean, celery, lettuce, romaine lettuce, and cucumber.

Bottle Gourd

Phytochemical screening on *L. siceraria* fruit flavonoids, cucurbitacins, saponins, polyphenolics, triterpenoids (Chen *et al.* 2008). Various extracts of fruit of *Lagenaria siceraria* were found to have anti-inflammatory, analgesic, hepatoprotective, anti-hyperlipidemic, diuretic and antibacterial activities (Gangwal *et al.* 2009).

Apart from above the bottle gourd also contents 1.6% choline on a dry weight basis; a precursor to acetylcholine, a chemical used to transfer nerve impulses and hence, it is believed to have neurological effects (Thomas, 2008). Bottle gourd contains cucurbitacins, polyphenols and two sterols namely; campesterol and sitosterol (Ghule *et al.* 2007). Bottle gourd is well known for their immunomodulatory, hepatoprotective, antioxidant, anti-stress, adaptogenic, analgesic, anti-inflammatory, cardio protective, cardio tonic, antihyperlipidemic, diuretic, aphrodisiac, alternative purgative, antidote to certain poisons and cooling properties (Ahmad *et al.* 2011; Deshpande *et al.* 2008; Mohale *et al.* 2008).

Beetroot

Beetroot predominately contains pigments called betalains, a class of betalamic acid derivatives which are composed of betacyanins and betaxanthins (Pitalua *et al.*, 2010). The betalain and phenolic composition of red beetroot has been studied in detail by Kujala *et al.* (2000) and Kujala *et al.* (2002). Beetroots are rich in valuable active compounds such as carotenoids (Dias *et al.,* 2009), glycine betaine (de Zwart *et al.,* 2003), saponins (Atamanova *et al.,* 2005), betacyanines (Patkai *et al.* 1997), folates (Jastrebova *et al.,* 2003), betanin, polyphenols and flavonoids (Vali *et al.*, 2007). The beetroot ingestion can be considered a factor in cancer prevention (Kapadia *et al.*1996).

Beetroot is one of the most potent vegetables with respect to antioxidant activity (Zitnanova *et al.,* 2006; Georgiev *et al.,* 2010). Betacyanins are a group of compounds exhibiting antioxidant and radical-scavenging activities (Pedreno and Escribano, 2000). They also inhibit cervical ovarian and bladder cancer cells in vitro (Zou *et al.,* 2005).).

Dietary Phytochemicals in the Prevention NCDs

Population-based studies (Hertog *et al.*, 1992 and Hertog *et al.*, 1993) showed that the risk of coronary heart disease was reduced at higher estimated intakes of flavonoids (apigenin, kaempferol, luteolin, myricetin, and quercetin). Data on diet and colon cancer (Trock *et al.*, 1990) also show a significant decline in risk with higher consumption of vegetables, green leafy vegetables, and cabbage. There is a general consensus that a diet higher in plant foods than is the current norm is associated with improved health and reduced disease risk. However, the most potent plant products are also likely to be the most bitter and therefore the most aversive to the consumer.

Risk of Cancer

The diet, which is rich in vegetables and fruits, including tomatoes, has been suggested to be responsible for the lower cancer rates. Dietary intake of tomatoes and tomato products has been found to be associated with a lower risk of a variety of cancers in several epidemiological studies. A high intake of tomatoes was linked to protective effects against digestive tract cancers in a case-control study http://www.cmaj.ca/content/163/6/739. and a 50% reduction in rates of death from cancers at all sites in an elderly US population. In recent studies serum and tissue levels of lycopene were shown to be inversely associated with the risk of breast cancer and prostate cancer; no significant association with other important carotenoids, including ß-carotene, was observed (Gann *et al.*, 1999). Overwhelming evidence from epidemiological, in vivo, in vitro, and clinical trial data indicates that diets high in fruits and vegetables can reduce the risk of chronic disease, particularly cancer (Block, 1992).

It is estimated that one third of all cancer deaths in the United States could be prevented through the dietary modification (Willett, 2002; Doll, 1981; Anand *et al*., 2008). Increasing bioactive compounds and antioxidant defenses through dietary phytochemicals, present in fruits, vegetables, whole grains, and other plant foods, may prevent, reduce, or delay the oxidation of DNA and affect cellular signal transduction pathways controlling cell proliferation and apoptosis (Liu, 2004). The high consumption of fruits and vegetables to reduce the risk of the development of cancer.

Most of the workers have investigated the effects of tomato or tomato product (lycopene) supplementation on oxidative damage to lipids, proteins and DNA. A preliminary report has indicated that tomato extract supplementation in the form of oleoresin capsules lowers the levels of prostate-specific antigen in patients with prostate cancer (Kucuk *et al.*, 1999).

Risk of Cardiovascular Disease

Antioxidant nutrients are believed to slow the progression of atherosclerosis because of their ability to inhibit damaging oxidative processes. Several controlled clinical trials and epidemiological studies have provided evidence for the protective effect of vitamin E, which has been ascribed to its antioxidant properties. The studies indicated that consuming tomatoes and tomato products containing lycopene reduced the risk of cardiovascular disease (Kohlmeier *et al.*, 1997).

Many epidemiological studies have examined the role of phytochemicals and increased dietary intake of fruits and vegetables in the prevention of cardiovascular disease (CVD). Consumption of flavonoids in humans was significantly inversely correlated with mortality from coronary heart disease (CHD) and with the incidence of myocardial infarction (Hertog *et al.*, 1993). Dietary flavonoid intake was also inversely associated with CHD mortality (Hertog *et al*., 1995). The total intake of flavonoids (quercetin, myricetin, kaempferol, luteolin, and ficetin) was inversely associated with the LDL cholesterol and plasma total cholesterol concentrations (Arai *et al*., 2000). As a single phytochemical, intake of quercetin was inversely correlated with LDL cholesterol and total cholesterol plasma levels. Intake of fruits and vegetables was inversely correlated with the incidence of stroke, stroke mortality, CVD mortality, CHD mortality, and all-cause mortality (Bazzano *et al*., 2002).

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