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**REVIEW PAPER**

# Health Promoting Phytochemicals in Vegetables: A Mini Review

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**ABSTRACT**

Phytochemicals are naturally occurring chemical compounds found in plants that provide health benefits for humans. Generally the phytochemicals are produced as a result of various metabolic reactions in the plants. They play an important role in protecting plants from environmental hazards such as stress, drought and pathogenic attack etc. They also contribute to plant colour, aroma and flavour. Phytochemicals are broadly described as polyphenols, flavonoids, isoflavonoids, anthocyanidins, phytoestrogens, terpenoids, carotenoids, limonoids, phytosterols, glucosinolates and fibers. Majority of foods, such as whole grains, beans, fruits, vegetables and herbs contain varied types and amounts of phytochemicals. Among these, fruits and vegetables contribute to the significant sources of phytochemicals. Phytochemicals have tremendous impact on the health care system and may provide medical health benefits including the prevention and treatment of diseases and physiological disorders. Foods containing these phytochemicals are known as functional foods which play an increasingly important role in the treatment of various chronic diseases. Hence, phytochemicals are potentially involved as protective compounds for a number of chronic diseases and also used as good health food.

**Keywords:** Phytochemicals, Nutraceuticals, Polyphenols, Flavonoids, Disease management

From the ancient time, plants have provided a source of inspiration for novel drug compounds, as plant derived medicines have made large contributions to human health and well being. Humans consume a wide range of foods, drugs, and dietary supplements that are derived from plants and which modify the functioning of the central nervous system (CNS). The psychoactive properties of these substances are attributable to the presence of plant secondary metabolites / chemicals that are not required for the immediate survival of the plant but are synthesized to increase the fitness of the plant to survive by allowing it to interact with its environment, including pathogens and herbivorous, and symbiotic insects (Liu and Hotchkiss, 1995). These compounds are called as photochemicals. These phytochemicals, as plant components with discrete bio-activities towards animal biochemistry and metabolism are being widely examined for their ability to provide health benefits. The major classes of phytochemicals with disease preventing functions are phenolics, terpenoids, glucosinolates, polyacetylene, phytosterols and phytostanols. Each class of these functional agents consists of a wide range of chemicals with differing potency (Wattenberg, 1992; Vinson *et al.* 2001). A large number of the plants are claimed to possess the antibiotic properties in the traditional system and are also used extensively by the tribal people worldwide for various remedies (Ames and Gold, 1991). *Let food be thy medicine and medicine be thy food*, quoted

by Hippocrates about 2,500 years ago is certainly the tenet of today which is receiving overwhelming interest. In this industrialized world, there has been an explosion of consumer interest in the active role of specific foods in the well being and life promotion as well as in the prevention of diseases (Mulvihill and Huff, 2010).

Nowadays, the food industry is directing new product development towards the area of nutraceutical/functional foods and health food due to the consumers' demand for healthier foods (Das *et al*. 2011). Nutraceuticals can be referred to as "*any substance that is a food or a part of a food which provides medical or health benefits including the prevention and treatment of disease*" (De Felice, 1995). *Nutraceutical is a product isolated or purified from foods that is generally sold in medicinal forms not usually associated with foods*. The phytochemicals are therefore also known as phytonutraceuticals or phytoceuticals. There is an extremely wide range of functional ingredients or nutraceutical or bioactive compounds which are present in vegetables and are associated with beneficial effects on human health (Steinmetz and Potter, 1991; Hasler, 2002; Sharma *et al.* 2012). Keeping this in view, the present article has been compiled to provide an overview of different types of the phytochemicals present in vegetables and their health-promoting effects that have the potential of being incorporated into foods or food supplements for making it a functional food.

**Phytochemicals**

Phytochemicals exist as long as plants exist but we only know about hundred years about their existence. The Chinese have the oldest medicine system. The earliest records about herbal medicine dates back to 2800 BC when the Chinese emperor Shen Nong wrote the text, *The Great Native Herbal*. Phytochemicals are basically categorized as primary or secondary constituents, depending on their role in plant metabolism. Primary constituents include the common sugars, amino acids, proteins, purines and pyrimidines of nucleic acids, chlorophyll's etc. Whereas, the secondary constituents are the remaining plant chemicals such as alkaloids, terpenes, flavonoids, lignans, plant steroids, curcumines, saponins, phenolics, flavonoids and glucosides (Saxena *et al*. 2013; Thakur *et al*. 2018). The main classes of the phytochemicals are shown in Fig. 1.

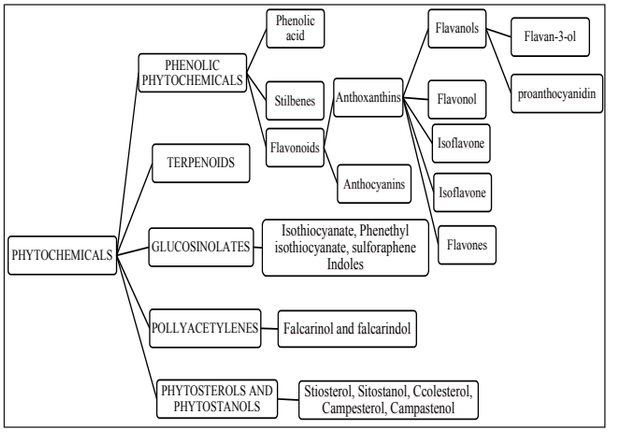


**Fig. 1:** Classification of phytochemicals

**Source:** Marta and Casado, 2011.

Further, based on their chemical structure, phytochemicals are classified into the categories but basically they are subdivided into three main categories i.e. phenolic acids, flavonoids and stilbenes or ligans.

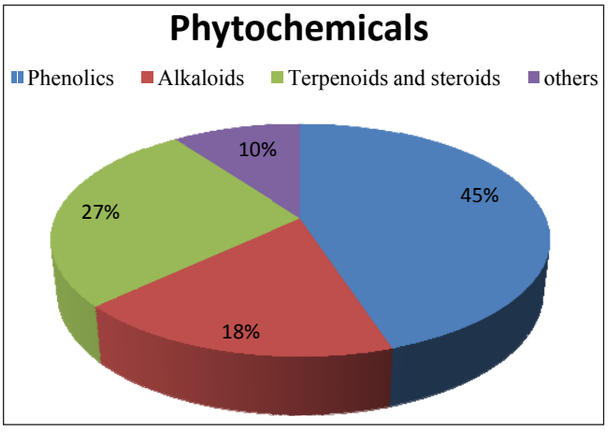


**Fig. 2.** Pie chart representing the major percentage of different phytochemicals

These flavonoids are further subdivided into anthocyanins, flavones, flavanones, isoflavones

as well as flavonols and flavanols (Wen and Walle, 2006). The percent share of main phytochemicals present in plants especially fruits and vegetables are represented in Fig. 2.

**Phytochemicals and Bioactive compounds of Vegetables**

Vegetables are essential for well-balanced diets since they supply phytonutrients and pytochemicals. About 3 billion people in the world are malnourished due to imbalanced diets. Regular consumption of a vegetable rich diet has undeniable effects on health since they have been strongly associated with improvement of gastrointestinal health, good vision and reduced risk of heart disease, stroke, chronic diseases such as diabetes and some forms of cancer (Ren *et al*. 2003). However, the mechanism by which vegetables decrease risk of disease is complex and largely unknown. Some phytochemicals of vegetables are strong antioxidants and are thought to reduce the risk of chronic disease by protecting against free radical damage (Corder *et al*. 2006). The dietary fiber content and type of different vegetables may also contribute to the overall health benefit. Each vegetable contains a unique combination of phytonutriceuticals. A great diversity of vegetables should be eaten to ensure that individual's diet includes a combination of phytonutriceuticals and to get all the health benefits. Majority of the vegetable originated nutraceuticals are claimed to possess multiple therapeutic benefits; though substantial evidence for their benefits as well as unwanted effects is lacking (Rao and Rao, 2007). Vegetables are rich sources of bioactive compounds such as flavonoids, carotenoids, anthocyanins, vitamins and other polyphenolics. Such compounds play a role in disease prevention/reduce disease risk factors through antioxidant activity. Researchers have identified hundreds of compounds in vegetable crops with functional qualities and they continue to make new discoveries surrounding the complex benefits of phytochemicals such as lycopene in tomatoes, cucumin in turmeric, gingerol in ginger, organosulphur compounds in allium species, omega-3 fatty acids in cucurbitaceous vegetable seeds and momordicin in bitter gourd (Sharma *et al*., 2016). The vegetable breeders have been able to boost the nutritional content of certain vegetable crops like vitamin enhanced broccoli and essential amino acids enriched potatoes (Ostlund, 2002).

**Classification of vegetables and phytochemicals present**

The term vegetable is used to describe the tender edible shoot, leaves, fruits and roots of plants that are consumed whole or in part, raw or cooked as a food supplement. Vegetables may be classified on the basis of life cycle, edible parts of the plant, adaptation and botanical features (Fig. 3). On the basis of part used they can be classified as: (i) Root vegetables (carrots, beets, turnips), (ii) Tuber vegetables (potatoes, taro, sweet potatoes), (iii) Bulbous vegetables (onions, garlic, leeks), (iv) Leafy vegetables (cabbage, spinach, lettuce, grape leaves, chard, dill, mint, parsley), (v) Flowery vegetables (cauliflower, broccoli, globe artichoke), (vi) Fruit vegetables (tomato, egg plant, squash, okra, chillies, cucumber), (vii) Stem vegetables (asparagus, celery, kohlrabi), (viii) Seed vegetables (black-eyed peas, peas, kidney beans, beans, moongra, drumstick beans, guar beans, lentils, soybean).

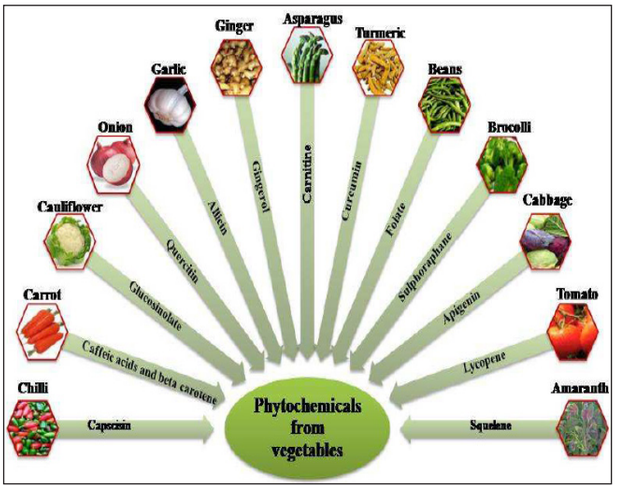


**Fig. 3:** Different phytochemicals derived from vegetables used as nutraceutical

Major phytochemicals present in vegetables have been classified into ten different classes based on

their biological activities including: (1) Carotenoids (α- and β- carotene, β- cryptoxanthin, lutein, lycopene, and zeaxanthin), (2) Glucosinolates (sulforaphane, indole-3 carbinol), (3) Phenols (flavanoids), (4) Cyclic phenolics (chlorogenic acid, ellagic acid, and coumarins) (5) Saponins, (6) Phytosterols (campestrol, β- sitsterol, and stigmasterol), (7) Sulfides and thiols (8) Phyto-estrogens (isotlavones, daidzenin, genistein, and lignans), (9) Protease inhibitors and (10) Inositol phosphates (phytate, inositol tetra and penta phosphates). Vegetables have been shown to protect against specific types of cancer for example, the crucifers (Brassicaceae) including Broccoli, Brussels sprouts, Kale and Cabbage have been shown to protect against lung and chemically induced cancers (Table 1).

## HEALTH PROMOTING PHYTONUTRICEUTICALS IN VEGETABLES

Phytonutriceuticals are the chemical compounds derived from plants that have health-promoting properties. Most of them are found in relatively small quantities in vegetables. However, when consumed in sufficient quantities, they contribute significantly toward protecting living cells against chronic diseases. The most important phytonutriceuticals in vegetables that have biological activity against chronic diseases are discussed here.

**Table 1:** Classification of vegetables on the basis of colour and corresponding phytochemical

| Colour | Contents | Benefits | Examples |
|---|---|---|---|
| **Green Vegetables** | Chlorophyll, fiber, lutein, zeaxanthin, calcium, folate, vitamin C, calcium and beta-carotene. | Reduce cancer risks, lower blood pressure and LDL cholesterol levels, normalize digestion time, support retinal health and vision, fight harmful free-radicals, boost immune system activity. | Asparagus, Broccoli, Brussel sprouts, Celery, Chinese cabbage, Cucumber, Green beans, Green cabbage, Green onion, Green peppers, Lettuce, Okra, Peas, Spinach. |
| **White Vegetables** | Beta-glucans, EGCG, SDG and lignans. | Provide powerful immune boosting activity. These nutrients also activate natural killer B and T cells, reduce the risk of colon, breast, and prostate cancers and balance hormone levels thus reducing the risk of hormone-related cancers. | Cauliflower, Garlic, Ginger, Mushrooms, Onions, Potato, Shallots, Turnip, Radish. |
| **Red Vegetables** | Lycopene, ellagic acid, quercetin and hesperidin. | Reduce the risk of prostate cancer, lower blood pressure, reduce tumor growth, lower LDL cholesterol levels, scavenge harmful free-radicals, and support joint tissue in arthritis cases. | Beets, Red apple, Red bell peppers, Red chilli peppers, Red onion, Red potato, Tomato, Red Carrot. |
| **Yellow/ Orange Vegetables** | Beta-carotene, zeaxanthin, flavonoids, lycopene, potassium and vitamin C. | Reduce age-related degeneration and the risk of prostate cancer, lower LDL cholesterol and blood pressure, promote collagen formation and healthy joints, fight harmful free radicals, encourage alkaline balance. | Carrot, Papaya, Pumpkin, Sweet potato, Yellow peppers, Yellow potato, Yellow summer squash, Yellow bell peppers, Yellow tomato, Yellow winter squash. |
| **Blue/ Purple Vegetables** | Lutein, zeaxanthin, resveratrol, vitamin C, fiber, flavonoids, ellagic acid and quercetin. | Support retinal health, lower LDL cholesterol, boost immune system activity, fight inflammation, reduce tumor growth, act as an anti-carcinogen in the digestive tract, and limit the activity of cancer cells. | Egg plant, Purple Belgian endive, Purple Potato, Purple asparagus, Purple cabbage, Purple carrot, Purple bell peppers, Purple onion, Purple broccoli, Purple cauliflower, Purple kollrabi, Purple broad beans. |

**Source:** Ren *et al.* 2003; Rao and Rao, 2007.

**(I) TERPENOIDS**

Terpenoids form a group of naturally occurring compounds majority of which occur in plants, a few of them have also been obtained from other sources. Terpenoids are volatile substances which give plants and flowers their fragrance. They occur widely in the leaves and fruits of higher plants, conifers, citrus and eucalyptus (Breitmaier, 2008). The term 'terpene' was given to the compounds isolated from terpentine, a volatile liquid isolated from pine trees. The simpler mono and sesquiterpene is chief constituent of the essential oils obtained from sap and tissues of certain plant and trees (Croteau *et al*., 2000). The di and tri terpenoids are not steam volatile. They are obtained from plant and tree gums and resins. Tertraterpenoids form a separate group of compounds called 'Carotenoids'. The term 'terpene' was originally employed to describe a mixture of isomeric hydrocarbons of the molecular formula $C_{10}H_{16}$ occurring in the essential oils obtained from sap and tissue of plants, and trees. But there is a tendency to use more general term 'terpenoids' which include hydrocarbons and their oxygenated derivatives. However the term terpene is being used these days by some authors to represent terpenoids. By the modern definition: "Terpenoids are the hydrocarbons of plant origin of the general formula $(C_5H_8)_n$ as well as their oxygenated, hydrogenated and dehydrogenated derivatives" (Maggi *et al*. 2009). In addition, a large number of structurally diverse plant terpenoids are known or assumed to have specialized functions associated with interactions of sessile plants with other organisms in the context of reproduction, defence or symbiosis (Gershenzon and Dudareva, 2007).

**Potential health benefits**

Terpenoids are vital for the growth and survival of photosynthetic organisms, since they play an essential role in conversion of light into chemical energy and for assembly and function of photosynthetic reaction centers (chlorophylls, bacteriochlorophylls, rhodopsins and carotenoids) (Manach *et al*. 2005). Other known functions of plant terpenoids include important roles in stress response or in defense mechanisms (Tholl, 2006). With such wide range of biological functions, terpenoids have extensive applications in the fields of functional foods, pharmaceuticals, cosmetics, colorants, disinfectants, fragrances, flavorings and agrichemicals. Several terpenoids have also been used as drugs to benefit human health, such as artemisinin used as an antimalarial drug (Van *et al.* 1999). Many of the terpenoids are commercially interesting because of their use as flavours and fragrances in foods and cosmetics examples menthol and sclareol or because they are important for the quality of agricultural products, such as the flavour of fruits and the fragrance of flowers like linalool (Harbourne *et al*. 2013). Terpenes have a unique antioxidant activity they react with free radicals by partitioning themselves into fatty membranes by virtue of their long carbon side chain. Perhaps the most studied of the terpene antioxidants are the tocotrienols and tocopherols (Dillard and German, 2000).

**Classification of Terpenoids**

Most natural terpenoid hydrocarbon have the general formula $(C_5H_8)n$. They can be classified on the basis of value of n or number of carbon atoms present in the structure as shown in Table 2.

**Table 2:** Different classes of terpenoids occurring in nature

| Sl. No. | Number of carbon atoms | Value of n | Class |
|---|---|---|---|
| 1 | 10 | 2 | Monoterpenoids ($C_{10}H_{16}$) |
| 2 | 15 | 3 | Sesquiterpenoinds ($C_{15}H_{24}$) |
| 3 | 20 | 4 | Diterpenoids ($C_{20}H_{32}$) |
| 4 | 25 | 5 | Sesterpenoids ($C_{25}H_{40}$) |
| 5 | 30 | 6 | Troterpenoids ($C_{30}H_{48}$) |
| 6 | 40 | 8 | Tetraterpenoids($C_{40}H_{64}$) |
| 7 | >40 | >8 | Polyterpenoids $(C_5H_8)n$ |

**Source:** Yadav *et al.* 2014.

**General properties of terpenoids**

Most of the terpenoids are colourless, fragrant liquids which are lighter than water and volatile with

steam. A few of them are solids e.g. camphor. All are soluble in organic solvent and usually insoluble in water. Most of the terpenoids are optically active. They undergo polymerization and dehydrogenation. Teroenoids are easily oxidized nearly by all the oxidizing agents and thermal decomposition, most of the terpenoids yields isoprene as one of the product.

**(II) CAROTENOIDS**

Carotenoids are fat soluble pigments found throughout nature. Carotenoids were discovered during the 19th century. Carotenoids are red, yellow and orange organic pigments, found in Chloroplast and Chromoplast of Plants. Carotenoids are the precursor of Vitamin A and are powerful antioxidants that helps in preventing some form of cancer and heart diseases. Carotenoids are a class of hydrocarbon compounds consisting of 40 carbon atoms (tetraterpenes) and extensive conjugated double-bond system that determines the color. As the number of conjugated double-bond increases, color changes from pale yellow, to orange or to red. Carotenoids are biosynthesized by bacteria, algae, fungi, and plants (Armstrong and Hearst, 1996), but not by animals, which must obtain them from their food. Not only plants, for example, vegetables, fruits, cereals etc., carotenoids also produced by microorganisms are lycopene, b-carotene, astaxanthin, lutein, zeaxanthin (Bhosale, 2004), b-cryptoxanthin and canthaxanthin (Bhosale and Bernstein, 2005). Lycopene, a-carotene, β carotene, lutein, zeaxanthin, and β-cryptoxanthin (Fig. 4) are the most abundant in human plasma (Aizawa and Inakuma, 2007).

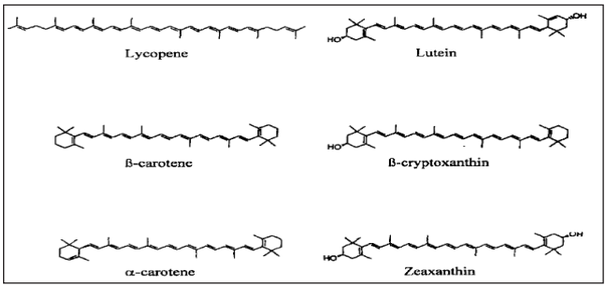


**Fig. 4:** Chemical structures of several selected carotenoids. *Source:* Jaswir and Noviendri, 2010

**Classification of Carotenoids**

**(a) Carotenes:** Oxygen free carotenoids which contains only carbon and Hydrogen are called carotenes. They are readily soluble in petroleum ether and hexane and found in carrots, Apricots and gives bright orange colour. e.g. Lycopene, β Carotene (Rao and Rao, 2007).

**(b) Xanthophylls:** It contains one or more $O_2$ atoms. It dissolves best in methanol and ethanol and found in spainch, maize and gives yellow colour. e.g. Lutein, Zeaxanthin (Basu *et al.* 2001). The commonly dietary sources of carotenoids are summarized in Table 3.

**Table 3:** Common dietary sources of carotenoids in regular consumed food (vegetables)

| Carotenoids | Food sources | Amount (mg/100g) |
|---|---|---|
| | **Carrots, cooked** | **9771** |
| β-Carotene | **Spinach** | 5400 |
| | cooked Canteloupe | 5300 |
| | Beet Green | 2560 |
| | Broccoli, cooked | 1300 |
| | Tomato, raw | 520 |
| α-Carotene | Carrots | 3723 |
| | **Tomatoes paste** | 36500 |
| | Tomatoes sauce | 13060 |
| Lycopene | Tomatoes ketchup | 12390 |
| | Tomatoes juice | 10000 |
| | **Tomatoes, raw** | **16300** |
| | Green collard | 3100 |
| | Spinach, cooked | 12475 |
| Lutein | **Beet root** | 7700 |
| | Broccoli, cooked | 1839 |
| | Green peas, cooked | 1690 |

**Source:** Rao and Rao, 2007; Basu *et al.* 2001.

**(III) PHYTOSTEROLS AND PHYTOSTENOLS**

Plants have a variety of sterols, which are collectively termed as 'phytosterols'. This term is derived from Greek word 'phyton means plant and 'stereos' means solid. More than 250 different phytosterols and related compounds have been identified in various plants and marine materials (Brufaua *et al.* 2008).

Phytosterols are natural components of human diets, largely derived from vegetable oils, cereals and fruits. Phytostanols have less abundance in nature than phytosterols and common dietary sources of phytostanols are corn, wheat, rye and rice. In all plant tissues, phytosterols occur in five common forms *viz*. (i) free alcohol (FS), (ii) fatty-acid esters (SE), (iii) steryl glycosides (SG), (iv) acylated steryl glycosides (ASG) and (v) phytosteryl hydroxycinnamic-acid esters (HSE) (Pascal and Segal, 2006). They have similar functions in plants as that of cholesterol in humans. Phytosterols and phytostanols are not synthesized in the human body and are completely derived from dietary sources and their content is especially high in vegetable oils (corn oil, rapeseed oil, soybean oil, and sunflower oil), nuts, seeds, and cereals (Harbourne *et al*. 2013). The most abundant phytosterols and phytostanols in human diet are sitosterol, campesterol, sitostanol, and campestanol (Kardong *et al*. 2013). Phytosterols and phytostanols do not provide any energy to the body but helps in lowering cholesterol (Brufaua *et al.* 2008), cancer protection (Bruce and Grattan, 2013), immuno-modulation and skin protection (Rahman *et al.* 2015; Cantrill and Kawamura, 2008). Some of the sources of important phytosterols are given in Fig. 5 along with their total phytosterols content.

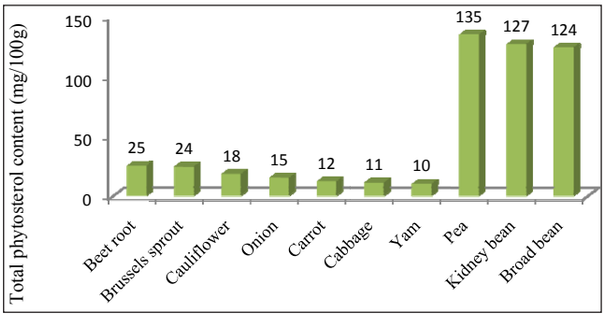


**Fig. 5:** Total phytosterols content of vegetables

**(IV) FLAVONOIDS**

Flavonoids are the largest group of plant phenols which are low molecular weight compounds with a wide spectrum of occurrence (Dai and Mumper, 2010). Recently much attention has been paid to their antioxidant properties and to their inhibitory role in various stages of tumour development in animal studies. Flavonoids are further grouped into two different categories viz. (a) anthocyanins and (b) anthoxanthins which are described below as:

**(a) Anthocyanins:** The anthocyanins are responsible for the red, blue and purple colours in vegetables (Cliffrod, 2000) and are reported to possess significant anti-inflammatory properties in obese adipose tissues (Tsuda, 2008) whereas, anti-obesity mechanism associated with anthocyanins has also been reported by Sasaki *et al.* (2007).

**(b) Anthoxanthins:** Anthoxanthins which are colorless or white to yellow molecules are classified into five major categories including flavonols, flavanone, flavones, flavanols and isoflavones. The major health benefits of flavoniods are listed in Table 4. Further, among different types of anthoxanthin, flavonoids, Flavonols and flavones are the most widely distributed in fruits and vegetables. The different types of vegetables varying in their content of flavonols and flavones as given in Table 5.

**Table 4:** Major health benefits of polyphenols (Flavonoids) intake

| Effect on the health | References |
|---|---|
| Reduce the risk of high blood cholesterol | Stensvold *et al.* 1992 |
| Protect against neurotoxic drugs | Katiyar *et al.* 1994 |
| Inhibition of non-heme iron absorption | Matsumoto *et al.* 1999 |
| Improve endothelial dysfunction | Schachinger *et al.* 2000 |
| Induce apoptosis of human oral tumor cell lines | Yoshida *et al.* 2000 |
| Reduce plasma lipid peroxidation | Torabian *et al*. 2000 |
| Prevention Neurodegenerative diseases | Yang *et al.* 2001 |
| Inhibit platelet aggregation | Russo *et al.* 2001 |
| Protect against inflammation | Halliwell and Gutteridge, 2001 |
| Treatment of diabetes | Pan, 2003 |
| Inhibit each stage of multistage carcinogenesis | Stewart *et al.* 2003 |

| | |
|---|---|
| Inhibit oxidation of LDL | Manach *et al.* 2005 |
| Treatment to prevent osteoporosis | Corder *et al.* 2006 |
| Reduce risk of myocardial infarction concentrations and anti-carcinogenic | Zunino *et al.* 2007 |
| Prevent dental caries | Hatcher *et al.* 2008 |
| Induce tumour cell death | Atmaca *et al.* 2010 |
| Prevented colon carcinogenesis | Davalli *et al.* 2012 |

**Table 6:** Flavonol and fIavone contents of common vegetables

| Flavonol and flavone contents | Vegetables |
|---|---|
| (<l0mg/kg or < l0mg/litre) | Cabbage, spinach, carrots, peas, mushrooms |
| (<50mg/kg or < 50mg/litre) | Lettuce, broad beans, red pepper, tomato |
| (50mg/kg or 50mg/litre) | Tomato beverages, Broccoli, kale, French beans, celery, onions |

**Source:** Hertog *et al.* (1992, 1993).

**(V) GLUCOSINOLATES**

The glucosinolates (GLS) are sulphur-containing glucosides prevalent in the cell vacuoles of cruciferous family of vegetables, especially the *Brassica* spp. (e.g. cabbage, broccoli) and also present at relatively high levels in oilseeds such as rapeseed and in condiments such as mustard seed (Rodriguez *et al.* 2006). More than 120 different glucosinolates have so far been identified and the content as well as the composition of glucosinolates vary with plant species, agronomic practices and climatic conditions (Table 7) (Chen and Andreasson, 2001). The inverse association between consumption of brassica (cabbage, broccoli, cauliflower, and bsrussels sprouts) and cancer risk in case-control studies have been shown by Verhoeven *et al.* (1996 and 1997) which was attributed due to their relatively high content of glucosinolate. Though a wide variety of naturally occurring and synthetic isothiocyanates have been shown to prevent cancer in animals (Hecht, 1995) yet more attention has been given particularly for isothiocyanate isolated from broccoli, known as sulforaphane which has been reported to be the principal inducer of a particular type of Phase II enzyme having strong anticancerous activity. Fahey *et al.* (1997) have demonstrated that 3 day old broccoli sprouts contained 10-100 times higher levels of glucoraphanin (glucosinolate of sulforaphane) than did corresponding mature plants which signifies that the glucosinolates content keep on increasing even after harvest of the crop. However, in view of the importance of an overall dietary pattern in cancer risk reduction, the clinical implications of a single phytochemical in isolation have been questioned (Nestle, 1998).

**Table 7:** Glucosinolates (GLS) contents of crucifers vegatables

| Crucifers vegetables | Glucosinolates (GLS) contents (mg/100g) |
|---|---|
| White cabbage | 88.85 |
| Red cabbage | 98.34 |
| Brussels sprouts | 91.41 |
| Kale | 151.05 |
| Cauliflower | 42.58 |
| Turnip | 53.25 |
| Red radish | 63.52 |
| White radish | 126.42 |

**Source:** Ciska *et al.* 2000.

**Future prospects**

Many plants or products derived from plants are being used in different forms in ayurveda, homeopathy and unani medicine for prevention and treatments of different chronic health diseases since centuries. Nature is a unique and vast source of phytochemicals, many of which possess interesting biological activities and medicinal properties. But it is difficult to establish clear functionality and structural-activity relationships regarding the effects of phytochemicals in biological systems. This is largely due to the occurrence of vast number of phytochemicals with similar chemical structures, and to the complexity of physiological reactions. Moreover, given the number of phytochemicals isolated so far, nature might still have many more in store.

Therefore, the research opportunities in nutrition to explore the relationship between a food or a food

component and reduction of disease prevalence present the greatest challenge to the scientists now and in the future. Further, claims about health benefits of functional foods and their stability during preparation and storage for particular phytochemical must be based on sound and well established scientific research. Thus, more efforts are required to put these phytochemicals in direct use as functional food/nutraceutical with high retention in order to achieve specific functional health benefits associated with them.

## CONCLUSION

Foods containing these functional ingredients offer great potential to improve health and/or help to prevent certain diseases when taken as part of a balanced diet and healthy lifestyle. Health-conscious consumers are increasingly seeking for the phytochemicals in form of nutraceuticals and functional foods to control their own health and well-being. There are exciting opportunities for the food industry to create such novel food products as presently there is a huge gap in market demand and supply of such food products.

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