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Antioxidant Potential of Bell Pepper (Capsicum annum L.)-A Review

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Abstract

The interests in the consumption of pepper fruits (Capsicum annum L.) is, to a large extent due to its content of bioactive compounds and their importance as dietary antioxidants. Peppers are used as a colourant, flavourant, and/or as a source of pungency. Peppers can be used fresh, dried, fermented, or as an oleoresin extract. It has both nutritional and nutraceutical importance. It contains an anticoagulant that helps prevent the blood clots that can cause heart attacks. Bell Pepper is good source of vitamin C. The benefits resulting from the use of natural products rich in bioactive substances has promoted the growing interest of food industries. Among the antioxidant phytochemicals, polyphenols deserve a special mention due to their free radical scavenging properties. Antioxidant compounds and their antioxidant activity in 4 different colored (green, yellow, orange, and red) sweet bellpeppers (Capsicum annuum L.) were investigated.The free radical scavenging abilities of peppers determined by the 2, 2~-diphenyl-1-picrylhydrazyl (DPPH) method. Natural antioxidants are preferred because synthetic antioxidants are considered carcinogenic. Antioxidants present in the (Capsicum annuum L.), protect the food or body from oxidative damage induced by free radicals and reactive oxygen.

Key words: Bell Pepper, Capsicum annum, Natural Antioxidants, Health benefits, dietary antioxidants

Introduction

Capsicum has its beginning since the beginning of civilizations. It is a part of human diet since 7500 BC. It was the ancient ancestors of the native peoples who took the wild chili Piquin and selected for the many various types known today. Native Americans had grown chili plants between 5200 and 3400 BC. This places chilies among the oldest cultivated crops of the Americas (Bosland, 1996). The genus Capsicum is one of the first plants being cultivated in the New World with beans (Phaseolus spp.), maize (Zea mays L.), and cucurbits (Cucurbitaceae) (Heiser, 1973). In the sixteenth century, Capsicum annuum and Capsicum frutescens were widely distributed from the New World to other continents via Spanish and Portuguese traders while the other species are little distributed outside South America (Andrews, 1995). Capsicum annuum is mostly used commercially.

Genus Capsicum is a member of family Solanaceae and has five species that are commonly recognized as domesticated: Capsicum annuum, Capsicum baccatum, Capsicum chinense, Capsicum frutescens, and Capsicum pubescens. However there are approximately 20 wild species that have been documented (Heiser, 1973). The classification system for this genus is somewhat confusing in the literature. In Spain, the Castilian word 'pimiento' refers to any Capsicum species, but in the USA, 'pimiento' or 'pimento' refers only to thick-walled, heart-shaped, non-pungent fruits from the species Capsicum annuum. The Hungarians call all Capasicum annuum fruits 'paprika', but paprika is defined in the world market as a ground, red powder derived from dried fruits with the desirable colour and flavour qualities. The word 'chile' is the common name for any Capsicum species in Mexico, Central America and the Southwestern USA. In Asia, the spelling 'chilli' is more common and is always associated with highly pungent varieties of Capsicum annuum and Capsicum frutescens, while the non-pungent sweet bell peppers are referred to as 'Capsicums' and it is native to Maxico. In American English, it is commonly known as the Chili Pepper or Bell Pepper. In British English, they are all called Peppers, whereas in Australian and Indian English, there is no commonly used name encompassing all its forms, the name Capsicum being commonly used for bell peppers exclusively. In Pakistan, it is locally known as Shimla Mirch (Grubben and Denton, 2004). Pungent fruits of all cultivated Capsicum species as a collective class are called 'chillies' in the Food and Agriculture Organization (FAO) Yearbook (Anon, 1997). Bird's eye chillies are grown primarily in East Africa, but they are merely small-fruited, highly pungent forms of Capsicum annuum or Capsicum frutescens. Different varieties of the genus Capsicum are widely grown for their fruits, which may be eaten fresh, cooked, as a dried powder, in a sauce, or processed into oleoresin (Poulos, 1993). Three major products traded on the world market for use in food processing are paprika, oleoresin, and dried chilli (both whole and in powdered form).

- Oleoresin: A viscous liquid derived by polar solvent extraction from ground powder of any Capsicum species; there are three types of oleoresin: paprika (used for colour), red pepper (used for colour and pungency), and Capsicum (used for pungency).
- Paprika: A ground, bright red, usually non-pungent powder used primarily for its colour and flavour in processed foods; all paprika varieties are C. annuum; paprika fruits are used to produce paprika oleoresin.

• Chilli: Any pungent variety of any Capsicum species, but primarily C. annuum; chilli varieties may be used to produce red pepper oleoresin or Capsicum oleoresin.

• Pepper(s): Generic term describing the fruits of any Capsicum species, both pungent and non-pungent.

Peppers are used as a colourant, flavourant, and/or as a source of pungency. Peppers can be used fresh, dried, fermented, or as an oleoresin extract. They can be used whole, chopped, coarsely ground, or finely ground, with or without seeds. Various types of processed products containing primarily peppers include pickled fruits, chilli sauce, chilli powder (also known as cayenne powder), crushed red pepper flakes, fermented mash, paprika, and three types of oleoresin. Other processed products that contain a significant proportion of peppers include fresh and processed salsas, curry powders, barbecue seasonings, chili powder (a mixture of chilli powder, oregano, cumin, and garlic powder), and many other foods (Govindarajan, 1986).

The main source of pungency in peppers is the chemical group of alkaloid compounds called capsaicinoids (CAPS), which are produced in the fruit. The atomic structure of CAPS is similar to piperine (the active component of white and black pepper, Piper nigrum) and zingerone (the active component of ginger, Zingiber officinale). Capsaicin (C18H27NO3), trans-8-methyl-N-vanillyl-6-nonenamide), is the most abundant CAPS, followed by dihydrocapsaicin, with minor amounts of nordihydrocapsaicin, homocapsaicin, homodihydrocapsaicin, and others. Capsaicin is a white crystalline, fat-soluble compound formed from homovanillic acid that is insoluble in water, odourless, and tasteless (Andrews, 1995). Varieties of chilli differ widely in CAPS content. The amount of CAPS in a given variety can vary depending on the light intensity and temperature at which the plant is grown, the age of the fruit, and the position of the fruit on the plant. The first test developed to measure pungency was the Scoville test, first developed in 1912 by Wilbur Scoville. It measures 'heat' as Scoville heat units (SHU) in a given dry weight of fruit tissue. Sweet peppers have 0 SHU, chillies with a slight bite may have 100 to 500 SHU, and the blistering habaneros have between 200,000 and 300,000. The red colour of mature pepper fruits is due to several related carotenoid pigments, including capsanthin, shown in Figure, capsorubin, cryptoxanthin, and zeaxanthin, which are present as fatty acid esters. The most important pigments are capsanthin and its isomer capsorubin, which make up 30–60% and 6–18% respectively, of the total carotenoids in the fruit. The intensity of the red color is primarily a function of the amount of these two pigments; the Hungarian and Spanish varieties used for paprika have very high amounts of capsanthin and capsorubin compared to other varieties (Govindarajan, 1985).

CAPS in oleoresins are very stable compounds and generally do not break down, even during processing at high temperatures and during long storage periods. CAPS in dry products (fruits, powder, etc.) are not as stable as in oleoresins. The temperature at which the fruits are dried affects the CAPS content. For example, drying ripe fruits at 60ºC to a final moisture content of 8% decreases CAPS content approximately 10%. If the fruits are held for extended periods of time at 60ºC after reaching 8% moisture content as much as 50% of the CAPS may be lost. Once the fruits are dried, they typically lose 1–2% CAPS/month under cold (~16ºC) storage, and even more when stored under ambient conditions. Ground powder can lose as much as 5% CAPS/month depending on the fineness of the grind and the storage temperature (Bensinger, 2000). The red colour of paprika and chilli powder, on the other hand, is not as stable as oleoresin and CAPS, and much work has been done to optimize the processing and storage conditions for dried chillies and paprika to maximize the colour intensity for the longest period of time (Garcia-Mompean *et al*., 1999).

Peppers in food processing are used as food colorant, as source of pungency in food, as source of flavour, as source of pain relief for pharmaceutical use and as repellent. In many cases two or more of these properties are included in the same product; for example, paprika may be a source of color, pungency, and flavor.

People whose diets are largely colourless starches, such as rice or maize, use peppers to add color to their bland, achromatic diets. In various processed products paprika, paprika oleoresin, red pepper oleoresin, and dried chilli may all serve as a source of red color, but paprika and paprika oleoresins are the primary source of red color. Paprika is used in many products where no pungency is desired, but only the color, flavor, and texture of a finely ground powder is desired. These include processed lunchmeats, sausages, cheeses and other dairy products, soups, sauces, and snacks such as potato chips. Paprika oleoresin is used as a color and flavor additive in many products where the texture is important and small particles of paprika powder would be undesirable (Govindarajan, 1986).

Paprika is also important for its flavor in many products in addition to its color. Dried chilli is also valued for its contribution to flavor in chilli sauces and chilli powders. The flavoring principle is associated with volatile aromatic compounds and color. As a general rule, when the color of paprika or chilli powder fades, the flavor also disappears.

Peppers are well-known for their health benefits. Herbalists have long promoted peppers for their health-enhancing effects. These include clearing the lungs and sinuses, protecting the stomach by increasing the flow of digestive juices, triggering the brain to release endorphins (natural painkillers), making your mouth water, which helps to neutralize cavity-causing acids, and helping protect the body against cancer through antioxidant activity (Andrews, 1995).

CAPS stimulate sensory neurons in the skin and mouth cavity, creating a sensation of warmth that increases to severe pain (type C nociceptive fibre pain) with higher doses. The neurons produce the neuropeptide Substance P (SP), which delivers the message of pain. Repeated exposure of a neuron to capsaicin depletes SP, reducing or eliminating the pain sensation in many people (Caterina *et al*., 1997). Thus the use of CAPS in pain relief has two modes of action: the sensation of heat, which may help sore muscles and arthritic joints feel better, and the depletion of SP, which reduces the pain sensation in the exposed area. Peppers have been reported to contain an anticoagulant that helps prevent the blood clots that can cause heart attacks (Andrews, 1995). Foods containing CAPS increase the thermic effects of food (TEF). The TEF is the slight increase in the body's metabolic rate after consumption of a meal. A meal containing foods with CAPS can increase the body's TEF up to 25% for three hours (Andrews, 1995). The role of CAPS in triggering the brain to release endorphins (natural painkillers) is well-known. As more CAPS are consumed, the body releases more endorphins, causing one to feel a mild euphoria – a natural high. Regular consumption has only a slight desensitizing effect. The Hungarian scientist Albert Szent-Gyorgyi won the 1937 Nobel Prize for isolating ascorbic acid, better known as vitamin C, from peppers. Peppers are also high in vitamin A, vitamin E, and potassium, and low in sodium. One hundred grams of fresh red chilli pepper has 240 mg of vitamin C (five times higher than an orange), 11,000 IU of vitamin A, and 0.7 mg of vitamin E. Vitamin C is sensitive to heat and drying but vitamin A is very stable, and paprika and dried chilli both contain relatively high amounts of this important nutrient (Govindarajan, 1986).

The chemical composition of foods is highly complex and comprises both volatile and non-volatile substances. Some of these substances contribute to the flavour of foods. Since the aroma component (volatile flavour) is usually responsible for the characteristic flavour of foods, the volatile compounds have received most attention (van Ruth *et al*., 2003). In the bell pepper 63 compounds were identified and included alcohols, aldehydes, ketones, acids, esters and sulphur- and nitrogen-containing compounds. The five most abundant compounds were 3-methylbutanal, 2-methylbutanal, 3-methylbutyric acid, acetone and hexanal (Chitwood *et al*., 1983).

Chemical constituents with antioxidant activity found in high concentration in plants (Velioglu *et al*., 1998) determine their considerable role in the prevention of various degenerative diseases (Diplock *et al*., 1998). Bell Pepper is good source of vitamin C and E, provitamin A, ascorbic acid and carotenoids (5.8 µgm/gm of fresh green wt.) (Materska and Perucka, 2005). Sweet peppers contain a very rich polyphenol pattern, which includes hydroxycianmates, flavonols and flavones (Marin *et al*., 2004). All these have great antioxidant activity. Natural antioxidants are preferred because synthetic antioxidants are considered carcinogenic (Branen, 1975).

Nutrition and health benefits

A wonderful combination of tangy taste and crunchy texture, bell peppers are the Christmas ornaments of the vegetable world with their beautifully shaped glossy exterior that comes in a wide array of vivid colors ranging from green, red, yellow, orange, purple, brown to black. Although peppers are available throughout the year, they are most abundant and tasty during the months of August and September (GMF, 2008).

Bell peppers offer a number of nutritional values. They are excellent sources of vitamin C and vitamin A. They also are a source of vitamin B6, folic acid, beta-carotene, and fiber. Red peppers also contain lycopene, believed important for reducing risk of certain cancers (GMF, 2008).

The proximate chemical composition of green bell pepper include dry mater (9.92%), total fat (0.33g), protein (0.99 g) , carbohydrate (10.63g), dietary fiber (2.73g) , vitamin C (133.00mg), calories (46.79cal), energy (195.58kj) (Durucasu and Tokusoglu, 2007).

Bell pepper have many health benefits like the protect us against free radicals, reduce risk of cardiovascular disease, promote optimal health, promote lung health, protect us against rheumatoid arthritis and seeing red may mean better eyesight (Ensminger and Esminger, 1986).

Essential oil functionality

The chemical composition of foods is highly complex and comprises both volatile and non-volatile substances. Some of these substances contribute to the flavor of foods. Since the aroma component (volatile flavor) is usually responsible for the characteristic flavor of foods, the volatile compounds have received most attention (Taylor *et al*., 2001). The fruits of Capsicum species have a relatively low volatile-oil content which has been reported to range from about 0.1 to 2.6% in paprika and similar large forms of C. annutn. The initial volatile-oil content of the freshly picked fruit is dependent largely upon the species and cultivar grown and the stage of maturity at harvest. The eventual volatile- oil content of the dried product, however, may be lower and is dependent upon the drying procedure, the duration and condition (whole or ground) of storage. Paprika powder, for example, usually contains less than 0.5% of volatile oil (van Ruth *et al*., 2003).

In the early stages of aroma research, most emphasis has been on development of methods to establish the chemical identity of the aroma constituents. The analytical task is rather complicated, as the fraction of aroma compounds of a simple food may be composed of 50–200 constituents, and these compounds are present in trace quantities. The large number of aroma chemicals complicates the task even further. Aroma science has benefited from the progress in the analysis techniques over the last decades, which led to long lists of volatiles (>6000) determined in foods (Maarse and Visscher, 1991).

Initially, the total volatile composition of a food was measured, for which extraction and distillation methods were employed, in combination with gas chromatography (GC). Later it appeared that the concentration of volatile compounds in a food does not necessarily reflect their concentration in air, as the concentration in air not only depends on the concentration in the food product but also on the interactions between the food matrix and the volatiles. The sensory perception of aroma is determined by the concentration of volatile compounds in the air phase. Therefore, headspace concentrations usually relate better to sensory properties than concentrations in the food product. Analysis methods, therefore, shifted from analysis of the compounds in the food to analysis of the volatile compounds in the air around the food (the headspace). Static and dynamic headspace measurements have become extensively used. This type of analysis developed further with the use of in-mouth analogues and in-mouth and in-nose measurements (van Ruth, 2001).

Indications that only a small fraction of the large number of volatiles occurring in food actually contributes to the aroma (Guth and Grosch, 1999) led to an interesting technique: gas chromatography–olfactometry (GC–O). The technique involves the sniffing of the gas chromatographic effluent by assessors in order to associate odour activity with eluting compounds, sometimes with a part of the effluent split to an instrumental detector. It is well known that many detectors are not as sensitive as the human nose for odour active compounds (Acree and Barnard, 1994)

The last few years have seen research groups developing methods to measure the change of the aroma profiles of foods during the time course of eating. Collection of air at the nostril(s) of subjects is the usual practice. Initially, these time–intensity measurements were conducted by trapping volatile compounds for short time intervals (e.g. 15 s). Absorbents and cryo-trapping have been used success-fully in combination with GC–mass spectrometry (GC–MS) (Taylorand and Linforth, 2000).

Color and pungency are the main quality parameters for assessing Capsicum varieties (Govindarajan *et al*., 1987). However, the majority of research has been focused on using aroma as an important parameter for assessing the quality of fresh fruits and vegetables (Guadayol *et al*., 1997). In the bell pepper 63 compounds were identified and included alcohols, aldehydes, ketones, acids, esters and sulphur- and nitrogen-containing compounds. The five most abundant compounds were 3-methylbutanal, 2-methylbutanal, 3-methylbutyric acid, acetone and hexanal (van Ruth *et al*., 2003). The volatile compound fractions of the pepper species have previously been isolated and more than 200 compounds were identified after hydro distillation and dynamic headspace sampling (purge and trap) procedures (Pino *et al*., 2006),

Later on characteristic volatile flavor compounds in healthy peppers (Capsicum annuum L.) were evaluated using a solvent-free solid injector coupled with a-gas chromatography-flame ionization detector (SFSI-GC-FID) and the results of evaluation were confirmed using GC–mass spectrometry (GC–MS). These compounds were compared with those obtained from peppers that were naturally infected or artificially inoculated with Colletotrichum spp. Parameters influencing the vaporization efficiency, including the injector temperature, pre-heating time and holding time, were optimized to improve the analytical efficiency. A total of 96 compounds (excluding eight capillary compounds), 17 of which were identified in healthy peppers, 49 of which were found in naturally infected peppers, and 61 of which were identified in artificially inoculated peppers, were separated and identified under the optimal conditions of an injector temperature of 250~C and 7-min preheating and holding times. Acetic acid and 2-furanmethanol were the major compounds detected in the volatiles of the healthy and diseased peppers. The major compound detected in both the healthy and naturally infected peppers was 3-hydroxypyridine, while hexadecanoic acid was the primary compound identified in the artificially inoculated peppers (In-Kyung Kim *et al*., 2007).

Antioxidants potential of Bell Pepper

Antioxidant means "against oxidation." Antioxidants work to protect lipids from peroxidation by radicals. They inhibit or delay the oxidation of other molecules by inhibiting the initiation or propagation of oxidizing chain reactions. Antioxidants are effective because they are willing to give up their own electrons to free radicals. When a free radical gains the electron from an antioxidant it no longer needs to attack the cell and the chain reaction of oxidation is broken (Dekkers *et al*., 1996). There are two basic categories of antioxidants, namely, synthetic and natural. In general, synthetic antioxidants are compounds with phenolic structures of various degrees of alkyl substitution, where as natural antioxidants of plant region are classified as vitamins, phenolic compounds, or flavinoids (El-Ghorab *et al*., 2007).

Antioxidants protect the food or body from oxidative damage induced by free radicals and reactive oxygen species by (1) suppressing their formation; (2) acting as scavengers; and (3) acting as their substrate. Synthetic antioxidants such as butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) have been used as antioxidants since the beginning of this century. Restrictions on the use of these compounds, however, are being imposed because of their carcinogenicity (Ito *et al*., 1983).

There are two lines of antioxidant defense within the cell. The first line, found in the fat-soluble cellular membrane consists of vitamin E, beta-carotene, and coenzyme (Kaczmarski *et al*., 1999). Of these, vitamin E is considered the most potent chain breaking antioxidant within the membrane of the cell. Inside the cell water soluble antioxidant scavengers are present. These include vitamin C, glutathione peroxidase, superoxide dismutase (SD), and catalase (Dekkers *et al*., 1996).

Natural antioxidants are extensively studied for their capacity to protect organism and cells from damage induced by oxidative stress (Dorman *et al*., 2008).

The supplementation of human diet with spices or herbs, containing especially high amounts of compounds capable of deactivating free radicals. The benefits resulting from the use of natural products rich in bioactive substances has promoted the growing interest of food industries (El-Ghorab *et al*., 2008).

Cultivars and growing conditions seem to play an important role in affecting the metabolism of antioxidant components and antioxidant capacity. Red sweet pepper (Capsicum annuum L.) is a vegetable known for its rich antioxidant content. Fresh sweet peppers have exceptionally high ascorbic acid, a 100 g serving supplying 100% of the current RDA of 60 mg/ day (Simmone *et al*., 1997).

Bell peppers, among vegetables, have become extremely popular for the abundance and the kind of antioxidants they contain. Among the antioxidant phytochemicals, polyphenols deserve a special mention due to their free radical scavenging properties. These compounds whose levels vary strongly during growth and maturation are also important because of their contribution to pungency, bitterness, colour and flavour of fruits (Estrada *et al*., 2000).

The attractive red color is due to the various carotenoid pigments, which include β-carotene with pro-vitamin A activity and oxygenated carotenoids such as capsanthin, capsorubin and cryptocapsin, which are exclusive to this genus and are shown to be effective free radical scavengers (Matsufuji *et al*., 1998). Red peppers also contain moderate to high levels of neutral phenolics or flavonoids, namely quercetin, luteolin and capsaicinoids (Hasler, 1998).

Ten cultivars of red sweet peppers grown over two consecutive years were compared with regard to ascorbic acid, total reducing content, β-carotene, total antioxidant activity and free radical scavenging activity. Cultivar Flamingo had the highest ascorbic acid content followed by cultivars Bomby and Parker. All cultivars fulfilled 100% RDA requirement for vitamin C. Torkel and Mazurka excelled in terms of β-carotene. Flamingo had the highest total reducing content and antioxidant activity. There was no effect of harvest year on antioxidant activity; however, ascorbic acid, total reducing content (mainly phenolics) and β-carotene differed significantly. A weak correlation was observed between total reducing content and antioxidant activity as measured by ferric reducing antioxidant power (FRAP) and free radical (1,1-diphenyl-2-picrylhydrazyl, or DPPH) scavenging assays (Deepaa *et al*., 2006).

Changes in total phenolics, antioxidant activity (AOX), carotenoids, capsaicin and ascorbic acid were monitored during three maturity stages in 10 genotypes of sweet pepper (green, intermediate and red/ yellow). All the antioxidant constituents (phenolics, ascorbic acid and carotenoids) and AOX, when expressed on fresh weight basis in general, showed an overall increasing trend during maturity in all the genotypes studied. On dry weight basis, phenolic content declined in majority of the genotypes during maturity to red stage. With maturation, most of the cultivars showed a declining trend with regard to capsaicin content while total carotenoids and β-carotene content increased significantly (Deepaa *et al*., 2007).

Antioxidant compounds and their antioxidant activity in 4 different colored (green, yellow, orange, and red) sweet bellpeppers (Capsicum annuum L.) were investigated. The total phenolics content of green, yellow, orange, and red peppers determined by the Folin-Ciocalteau method were 2.4, 3.3,3.4, and 4.2 μmol catechin equivalent/g fresh weight, respectively. The red pepper had significantly higher total phenolics content than the green pepper. Among the 4 different colored peppers, red pepper contained a higher level of β-carotene (5.4 μg/g), capsanthin (8.0 μg/g), quercetin (34.0 μg/g), and luteolin (11.0 μg/g). The yellow pepper had the lowest β-carotene content (0.2 μg/g), while the green one had undetectable capsanthin and the lowest content of luteolin (2.0 μg/g). The free radical scavenging abilities of peppers determined by the 2,2~-diphenyl-1-picrylhydrazyl (DPPH) method were lowest for the green pepper (2.1 μmol Trolox equivalent/g) but not significantly different from the other 3 peppers (Sun *et al*., 2007).

Conclusion

Nutritionally, sweet peppers are good source of mixture of antioxidants including ascorbic acid, carotenoids, flavonoids and polyphenols it is essential that compositional studies in plant food be carried out to take into account various factors such as cultivars, seasons and pre- and post-harvest conditions that may affect the chemical composition of plant foods.

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