Vegetables as Sources of Antioxidants

Article *in* Journal of Food & Nutritional Disorders · February 2013

DOI: 10.4172/2324-9323.1000104

Shetty et al., J Food Nutr Disor 2013, 2:1
http://dx.doi.org/10.4172/2324-9323.1000104

Journal of Food & Nutritional Disorders

Review Article

A SCITECHNOL JOURNAL

Vegetables as Sources of Antioxidants

Anoop A Shetty[1*], Santoshkumar Magadum[2] and Kalmesh Managanvi[3]

Abstract

Dietary plant antioxidants have been considered beneficial to human health. Antioxidants can eliminate free radicals and other reactive oxygen and nitrogen species, and these reactive species contribute to most chronic diseases. Dietary plants contain variable chemical families and amounts of antioxidants. Vegetables provide the body, an added source of antioxidants to fight against free radicals. Without the necessary intake of healthy vegetables, free radicals can spread and eventually lead to various types of cancer. This review discusses about vegetables as sources of antioxidants.

Keywords

Antioxidants; Vegetables; Anticancer

Introduction

The antioxidants contained in vegetables play an important role in the maintenance of health and prevention of disease [1]. A number of vitamins such as A, C, E, as well as carotene are excellent antioxidants, which also contribute to good health through other mechanisms, such as being co-factors for certain enzymes, involvement in oxidation-reduction reactions [2,3]. It has been estimated that every serving increase in vegetable consumption reduces the risk of cancer by 15%, cardiovascular disease by 30% and mortality by 20% [4,5], attributable to antioxidants such as ascorbic acid, vitamin E, carotenoids, lycopenes, polyphenols, and other phytochemicals [6]. A diet rich in fresh vegetables protects from the risk of most common epithelial cancers, including those of the digestive tract, and several non-digestive neoplasms. Selected antioxidants, β-carotene, vitamins C and E showed a significant inverse relation with the risk of oral, pharyngeal, oesophageal and breast cancers. Against colorectal cancer, the most consistent protective effects were provided by carotene, riboflavin and vitamin C, but inverse relations were observed for calcium and vitamin D [7]. Potentially anticarcinogenic agents found in vegetables also include numerous micronutrients, such as selenium, dietary fiber, glucosinolates and indoles, flavonoids, phenols, protease inhibitors and plant sterols.

The anti-cancer role of carotenoids may be related to their ability to quench singlet oxygen [8,9]. Yellow and orange vegetables and dark-green leafy vegetables contain carotenoids and flavonoids. Of the 22 species of vegetables investigated by Muller [10], kale, red paprika, leaf of parsley, spinach, Lamb's lettuce, carrot and tomato were very rich in carotenoids (over 10 mg/100 g edible portion). β-carotene is the most well-known carotenoid, and is found in most orange vegetables. Sweet potatoes and carrots are especially high in β-carotene. Green leafy vegetables such as spinach, kale, broccoli, Brussels sprouts and cabbage are moderately high in β-carotene. α- and β-carotene, and lycopene, are hydrocarbon carotenoids. Lycopene is found in tomatoes, but is scarce in other common vegetables. The predominant carotenoids in these vegetables are the oxygenated carotenoids (xanthophylls). Lutein is the major oxygenated carotenoid in kale, spinach, parsley and mustard greens. Carotenoids are destroyed to some extent by cooking vegetables, and among different carotenoids, the oxygenated carotenoids are destroyed to a greater extent than β-carotene.

Flavonoids are a large group of natural phenolic compounds contained at high concentrations in vegetables. Flavonoids like catechin, quercetin, dihydroquercetin and rutin possess antioxidant properties [11]. Many vegetables supply different types of flavonoids in varying quantities. Quercetin, part of a subclass of flavonoids called flavonols, forms the main antioxidant component in vegetables [12]. Quercetin is supplied by vegetables like broccoli, onions, parsley and green leafy vegetables.

Tomato

Tomatoes, one of the most produced and consumed vegetables worldwide, are a rich source of lycopene, β-carotene, folate, potassium, vitamin C (ascorbic acid), chlorogenic acid, flavonoids, rutin, plastoquinones, phenolics, tocopherol (vitamin E) and xanthophylls [13-16]. The average values obtained for antioxidant components in three fresh cultivars are ascorbic acid, 276 mg/100 g dry matter; total phenolics, 613 mg gallic acid equivalents/100 g dry matter, and lycopene 38 mg/100 g dry matter [17].

Vitamin C is considered an excellent antioxidant because it donates electrons for enzymes, or other compounds that are oxidants. Tomatoes are relatively low in beta-carotene, but high in lycopene, an active antioxidant agent with no vitamin A activity [18]. Lycopene is an interesting antioxidant because it is fairly stable to storage and cooking, and thus, is present in the cooked tomatoes that are consumed frequently, and account in part for the lower heart disease and cancer risk [12]. In addition, many epidemiological studies have suggested that the regular consumption of tomatoes may lead to a decreased incidence cardiovascular disease incidence [19,20], and reduced risk of breast, colon, lung, and prostate cancers [14,21]. Oleoresins obtained from non-commercial red tomato have high lycopene content with high antioxidant capacity and anti mutagenic activity, demonstrating that it is feasible to use this to obtain oleoresin rich in lycopene with high nutraceutical potential [22].

It has been reported that thermal treatment can decrease the antioxidant capacity of vegetables, as in tomatoes [23], while high hydrostatic pressure treatments can maintain the water-soluble antioxidant capacity of tomato puree [24]. In tomato, forced air-drying at 42°C for 48 hrs decreases ascorbic acid, total phenolics and total antioxidant activity, but increases extractable lycopene contents

***Corresponding author:** Anoop A Shetty, Department of Vegetable Science, G.B. Pant University of Agriculture and Technology, Pantnagar-263145, Uttarakhand, India, E-mail: anoopshettyforyou@gmail.com

Received: December 10, 2012 **Accepted:** February 20, 2013 **Published:** February 25, 2013

doi:http://dx.doi.org/10.4172/2324-9323.1000104

[17]. Typical home processing of tomatoes leads to loss of some antioxidant properties and change of colour. It has been reported that boiling and baking have a relatively small effect on ascorbic acid, total phenolics, lycopene and total antioxidant activity, while frying significantly reduces these important nutrients [14].

Chilli and Sweet Pepper

Pepper is an important source of nutrients in the human diet, and an excellent source of vitamins A, C and E, as well as neutral and acidic phenolic antioxidants important in plant defense responses [25-28]. Two fractions of phenolics, flavonoids (with phenolic acids) and capsaicinoids isolated from the pericarp of pepper fruit showed antioxidant activity [29].

Levels of these compounds can vary by genotype and maturity, and are influenced by growing conditions and losses after processing. Generally, the concentration of carotenoids, ascorbic acid, flavonoids, phenolic acids, and other chemical constituent increases as the peppers reach maturity, whereas the level of lutein declines [28]. Provitamin A increases as colour develops in most cultivars, except for yellow varieties, and brown peppers have the highest provitamin A activity compared to other coloured peppers [30]. Coloured pepper varieties seem to be good sources of antioxidant, with the high carotenoid content found in mature stages [31].

Ripening and harvest period influences the antioxidants and the development of oxidative processes in sweet pepper. Each sweet pepper cultivar studied showed differences in antioxidant compounds, depending on the harvest period, but May was the optimal time, if all cultivars have to be harvested at the same time [32].

The nutritive value of chilli is largely determined by ascorbic acid content. A study revealed that ascorbic acid content gradually increased from green to red, and subsequently declined in the later stages (red partially dried and red fully dried fruits). The variability of ascorbic acid content in the genotypes suggests that these selected genotypes may be useful as parents in hybridization programmes, to produce fruits with good nutritional values [33]. Ascorbic acid content of sweet pepper also increases with fruit ripening, while decreases during post harvest handling [34].

Potato

Ascorbic acid contained in potato tubers attracts attention, as a significant source of vitamin C in human nutrition. Marabel variety of potato has the highest ascorbic content (207.2 mg/kg), and exceeded other seven varieties by 15-49% [35]. Ascorbic acid concentrations varied between 11 and 30 mg per 100 g fresh weight in North American varieties and breeding lines of potato [36].

A negative effect on ascorbic acid content in potato tubers was observed in case of an increased intensity of nitrogen fertilization (at 180 kg N/ha ascorbic acid decrease was lower by 6.1% compared to dose 100 kg N/ha). On the contrary, a favourable effect was determined at increased levels of potassium and magnesium fertilization (at 166 kg K/ha and 60 kg Mg/ha ascorbic acid increase was 6.2% higher compared to the levels of 108 kg K/ha and 30 kg Mg/ha) [35]. After the harvest, ascorbic acid concentration decreases during storage, and is further degraded by cooking, and by potato processing into food products [37].

Bulb and Root Crops

Aerial parts (leaves and stem) of radish (*Raphanus sativus*), which are usually discarded, possesses potent antioxidant and radical scavenging activity, as measured by standard antioxidant assays. HPLC identification of polyphenolics indicated the presence of catechin, protocatechuic acid, syringic acid, vanillic acid, ferulic acid, sinapic acid, o-coumaric acid, myricetin and quercetin in leaves and stem. Leaves and stem of radish had total polyphenolic content of 86.16 and 78.77 mg/g dry extract, respectively. Often under-utilized part of this vegetable thus possesses considerable amount of polyphenolics. Hence, it should be regarded as a potential source of natural antioxidants, and could be effectively employed as an ingredient in health, or in functional food [38].

Carrots are high in fibers, carotenoids, vitamins C and E, and phenolics such as coumaric, chlorogenic and caffeic acids [39]. Water-soluble anthocyanin obtained from the carrot also possesses antioxidant properties. Drinking carrot juice may protect the cardiovascular system by increasing total antioxidant status, and by decreasing lipid peroxidation [40]. Water soluble antioxidant capacities of carrot juices can be increased by thermal treatment and maintained by high pressure treatment [41].

In addition, bulb crops such as onion and garlic contain antioxidants that provide additional nutritional elements in areas where such foods are consumed frequently, such as Eastern Europe, the Mediterranean region, and in parts of the western world [2]. Among the frequently consumed raw vegetables, the highest level of the antioxidant activity were found in the red onion, followed by white onion=yellow onion>garlic, in that order [42].

Cruciferous Vegetables

Vegetables belonging to the *Brassicaceae (Cruciferae)* family are rich in polyphenols, flavonoids and glucosinolates, and their hydrolysis products, which have antibacterial, antioxidant and anticancer properties [43]. Brassica vegetables provide a large group of glucosinolates, which according to Plumb et al. [44] possess rather low antioxidant activity, but the products of their hydrolysis can protect against cancer.

Generally, among Brassica vegetables, white cabbage is the poorest source of vitamin C. Red pigmentation of red cabbage is caused by anthocyanins, which belong to flavonoids. Total carotenoid contents of Brussels sprouts, broccoli, red cabbage and white cabbage are 6.1, 1.6, 0.43 and 0.26 mg/100 g, respectively. Lutein and β-carotene are the dominant carotenoids in cruciferous vegetables. Brassica vegetables also contain cryptoxanthin, neoxanthin and violaxanthin, but cryptoxanthin is present only in broccoli (0.024 mg/100 g) [45]. The descending order of total tocopherols and tocotrienols in Brassica vegetables is as follows: broccoli (0.82 mg/100 g)>Brussels sprouts (0.40 mg/100 g)>cauliflower (0.35 mg/100 g)>chinese cabbage (0.24 mg/100 g)>red cabbage (0.05 mg/100 g)>white cabbage (0.04 mg/100 g) [46].

A study on the variation in the antioxidant potential of green cabbage grown under nutritional soil supplements derived from agricultural and food processing sources found that the application of nutritional soil supplements results in increase in the antioxidant activity [47].

doi:http://dx.doi.org/10.4172/2324-9323.1000104

Broccoli is distinguished by the presence of numerous bioactive substances with health-promoting properties. Among these bioactive compounds, glucosinolates, phenolics, vitamins C, B_1, E, carotenoids and selenium deserve special attention. An additional advantage of broccoli is its tendency to accumulate heavy metals. Broccoli florets were characterized by particularly high glucoraphanin content (17.95 µmol/g of dry weight), which comprised about 50% of total glucosinolates [48]. Among different vegetable species, broccoli distinguishes itself by its high concentration of polyphenols, more than threefold higher than potatoes or lettuce [49,50]. The high level of ascorbic acid in fresh broccoli [51], as well as the composition of phenolic compounds, is favourable for neutralisation of free radicals. Development of broccoli heads is accompanied by losses of chlorophyll and ascorbic acid. At pre-florescence stage accumulation of soluble phenolics is observed [52]. Purple-sprouting broccoli contains higher amounts of antioxidant compounds compared with green broccoli, but tends to show higher sensitivity to cooking treatments. Cooking methods should be carefully considered in current dietary recommendations. Antioxidant components of cooked broccoli are quite different from uncooked broccoli. The antioxidant content of broccoli is retained or enhanced more after microwaving, than after boiling. Cooking in water causes a leaching effect of antioxidants, and this increases with the duration of cooking [53].

Green Leafy Vegetables

Green leafy vegetables are rich sources of antioxidant vitamins [54]. The ascorbic acid, total carotene, β-carotene and total phenolic content of the green leafy vegetables, *viz. Amaranthus* sp., *Centella asiatica*, *Murraya koenigii* and *Trigonella foenum graecum*, ranges from 15.18-101.36, 34.78-64.51, 4.23-8.84 and 150.0-387.50 mg/100 g, respectively, with antioxidant activity highest in *Murraya koenigii,* and least in *Centella asiatica* [55].

Lettuce has an effective antioxidant and other health-promoting properties. Among various types of lettuce commonly grown, leaf-type is most abundant in health-promoting phytochemicals [56]. Lettuce cultivar 'Red Sails', which has loose red foliage, is generally higher in total phenolic concentration and antioxidant capacity. 'Red Sails' also contains higher amount of major phenolic compound, chlorogenic acid [57].

Genotype along with growing and management conditions, can affect the content and the composition of antioxidants in plants. Growing conditions significantly affect the content of many phenolic compounds in lettuce. Growing lettuce under open field has a positive impact on its health-promoting qualities, compared to its cultivation in high tunnels [57].

Spinach and kale are also rich sources of carotenoids and polyphenols. Spinach has an exceptionally high total polyphenol and flavonoid content. The high level of polyphenol acids and flavonoids in spinach leaves influences the high antioxidant activity. Spinach and kale also contain lutein, which is known for its antioxidant activity. The concentrations of lutein measured 0.43 to 0.88 mg/g for frozen spinach, and 0.83 mg/g for fresh spinach [58].

Drumstick

Drumstick (*Moringa oleifera*) is used in Indian traditional medicine for a wide range of ailments. Both mature and tender leaves of *Moringa oleifera* have potent antioxidant activity against free radicals, to prevent oxidative damage to major biomolecules, and afford significant protection against oxidative damage [59].

Leguminous Vegetables

The antioxidant properties of cowpea (*Vigna unguiculata*) and African yam bean (*Sphenostylis sternocarpa*) were assessed with regard to their Vitamin C, total phenol and phytate content, as well as antioxidant activity, as typified by their reducing power and free radical scavenging ability. The results (Table 1) indicated that Cowpea and African yam bean could be considered as a functional food due to their relatively higher antioxidant activity (free radical scavenging ability and redox potential), attributable to total phenol content [60].

Table 1: Vitamin C and phenol content in leguminous vegetables [36].

Leguminous vegetables	Vitamin C (mg/100 g)	Phenol Content (mg/g)
Cowpea (*Vigna unguiculata*)	0.5-0.9	0.3-1.0
African yam bean (*Sphenostylis sternocarpa*)	0.8	0.7

In a study involving winged beans (*Psophocarpus tetragonolobus*), French bean (*Phaseolus vulgaris*), string bean (*Vigna sinensis*) and snow pea (*Pisum sativum*), string beans showed the highest antioxidant capacity compared to the other vegetables. However, the total phenolic, ascorbic acid and ß-carotene contents of snow peas were significantly higher than the other vegetables [61]. The HPLC analysis of pea crude extract shows the presence of such phenolic compounds as vanillic, caffeic, p-coumaric, ferulic and sinapic acids, quercetin and kaempherol, which are responsible for the antioxidant and antiradical properties of pea seeds [62].

Vegetables like daikon sprout, spinach and onion show high antioxidant activity against different reactive oxygen species and reactive nitrogen species, while broccoli, cabbage and Chinese cabbage show high antioxidant activity against hypochlorite ion [63]. Raw and fresh vegetables exhibit most consistent protection against cancer, with over 85% of studies finding an inverse association. Findings are consistent for lettuce, leafy green and cruciferous vegetables, allium, tomatoes and carrots, with about 70% of studies reporting a protective role against cancer. More than 60% of studies on other vegetables and fruits found a protective effect against total cancer risk. Only about 40% of studies found some protection by legumes and potatoes [64,65]. β-carotene, vitamin E and calcium shows a significant inverse relation with breast cancer risk [66].

Conclusion

Apparently, vegetables contain significant antioxidants to offer great potential as protective food. They are gaining importance in human diet as anticarcinogenic agents. Consumption of vegetables and their products should be promoted among common people to improve nutrition and derive health benefits.

References

1. Paganga G, Miller N, Rice-Evans CA (1999) The polyphenolic content of fruits and vegetables and their antioxidant activities. What does a serving constitute? Free Radic Res 30: 153-162.
2. Weisburger JH (1999) Mechanisms of action of antioxidants as exemplified in vegetables, tomatoes and tea. Food Chem Toxicol 37: 943-948.

3. Podsedek A (2007) Natural antioxidants and antioxidant capacity of Brassica vegetables: A review. LWT Food Sci Technol 40: 1-11.
4. Steimez KA, Potter JD (1996) Vegetables, fruits and cancer prevention: a review. J Am Diet Assoc 96: 1027-1039.
5. Rimm EB, Ascherio A, Grovannucci E, Spielgelman D, Stampfer MJ, et al. (1996) Vegetable, fruit and cereal fiber intake and risk of coronary heart disease among men. JAMA 275: 447-451.
6. Prior RL, Cao G (2000) Antioxidant phytochemicals in fruits and vegetables: Diet and health implications. HortScience 35: 588-592.
7. Vecchia CL, Braga C, Negri E, Franceschi S, Russo A, et al. (1997) Intake of selected micronutrients and the risk of colorectal cancer. Int J Cancer 73: 525-530.
8. Mascio DP, Murphy ME, Sies H (1991) Antioxidant defense systems: the role of carotenoids, tocopherols, and thiols. Am J Clin Nutr 53: 194S-200S.
9. Steinmetz KA, Potter JD (1991) Vegetables, fruit and cancer. II. Mechanisms. Cancer Causes Control 2: 427-442.
10. Muller H (1997) Determination of the carotenoid content in selected vegetables and fruit by HPLC and photodiode array detection. Z Lebensm Unters Forsch A 204: 88-94.
11. Korotkova EI, Voronova OA, Dorozhko EV (2012) Study of antioxidant properties of flavonoids by voltammetry. J Solid State Electrochem 16: 2435-2440.
12. Weisburger JH (1998) International Symposium on lycopene and tomato products in disease prevention: an introduction. Proc Soc Exp Biol Med 218: 93-94.
13. Willcox JK, Catignani GL, Lazarus S (2003) Tomatoes and cardiovascular health. Crit Rev Food Sci Nutr 43: 1-18.
14. Sahlin E, Savage GP, Lister CE (2004) Investigation of the antioxidant properties of tomatoes after processing. J Food Compost Anal 17: 635-647.
15. Friedman M (2002) Tomato glycoalkaloids: role in the plant and in the diet. J Agric Food Chem 50: 5751-5780.
16. George B, Kaur C, Khurdiya DS, Kapoor HC (2004) Antioxidants in tomato (*Lycopersium esculentum*) as a function of genotype. Food Chem 84: 45-51.
17. Kerkhofs NS, Lister CE, Savage GP (2005) Change in colour and antioxidant content of tomato cultivars following forced-air drying. Plant Foods Hum Nutr 60: 117-121.
18. Giovannucci E (1999) Tomatoes, tomato-based products, lycopene, and cancer: review of the epidemiologic literature. J Natl Cancer Inst 91: 317-331.
19. Arab L, Steck S (2000) Lycopene and cardiovascular disease. Am J Clin Nutr 71: 1691S-1695S.
20. Rissanen TH, Voutilainen S, Nyyssonen K, Lakka TA, Sivenius J, et al. (2001) Low serum lycopene concentration is associated with an excess incidence of acute coronary events and stroke: the Kuopio Ischaemic heart disease risk factor study. Br J Nutr 85: 749-754.
21. Giovannucci E, Rimm EB, Liu Y, Stampfer MJ, Willett WC (2002) A prospective study of tomato products, lycopene, and prostate cancer risk. J Natl Cancer Inst 94: 391-398.
22. Muñoz ER, Ruiz GH, Aboytes GP, Piña GL (2009) Antioxidant capacity and antimutagenic activity of natural oleoresin from greenhouse grown tomatoes (*Lycopersicon esculentum*). Plant Foods Hum Nutr 64: 46-51.
23. Zanoni B, Pagliarini E, Giovanelli G, Lavelli V (2003) Modeling the effect of thermal sterilization on the quality of tomato puree. J Food Eng 56: 203-206.
24. Fernandez GA, Butz P, Tauscher B (2001) Effects of high-pressure processing on carotenoid extractability, antioxidant activity, glucose diffusion, and water binding of tomato puree (*Lycopersicon esculentum* Mill.). J Food Sci 66: 1033-1038.
25. Daood HG, Vinkler M, Markus F, Hebshi EA, Biacs PA (1996) Antioxidant vitamin content of spice red pepper (paprika) as affected by technological and varietal factors. Food Chem 55: 365-372.
26. Krinsky NI (1994) The biological properties of carotenoids. Pure Appl Chem 66: 1003-1010.
27. Krinsky NI (2001) Carotenoids as antioxidants. Nutrition 17: 815-817.
28. Howard LR, Talcott ST, Brenes CH, Villalon B (2000) Changes in phytochemical and antioxidant activity of selected pepper cultivars (*Capsicum* sp.) as infuenced by maturity. J Agric Food Chem 48: 1713-1720.
29. Materska M, Perucka I (2005) Antioxidant activity of the main phenolic compounds isolated from hot pepper fruit (*Capsicum annuum* L.). J Agric Food Chem 53: 1750-1756.
30. Simonne AH, Simonne EH, Eitenmiller RR, Mills A, Green NR (1997) Ascorbic acid and provitamin A contents in unusually colored bell pepper (*Capsicum annuum* L.) J Food Compost Anal 10: 299-311.
31. Guerrero JLG, Guirado MC, Fuentes MMR, Pérez AC (2006) Nutrient composition and antioxidant activity of 10 pepper (*Capsicum annuun*) varieties. Eur Food Res Technol 224: 1-9.
32. Martí MC, Camejo D, Vallejo F, Romojaro F, Bacarizo S, et al. (2011) Influence of fruit ripening stage and harvest period on the antioxidant content of sweet pepper cultivars. Plant Foods Hum Nutr 66: 416-423.
33. Kumar AO, Tata SS (2009) Ascorbic acid contents in chilli peppers (*Capsicum annum* L.). Not Sci Biol 1: 50-52.
34. Martinez S, Mercedes L, Gonzalen RM, Alvarez BA (2005) The effects of ripening stage and processing systems on vitamin C content in sweet peppers (*Capsicum annuum* L.). Int J Food Sci Nutr 56: 45-51.
35. Hamouz K, Lachman J, Dvořák P, Dušková O, Čížek M (2007) Effect of conditions of locality, variety and fertilization on the content of ascorbic acid in potato tubers. Plant Soil Environ 53: 252-257.
36. Love SL, Salaiz T, Shafii B, Price WJ, Mosley AR, et al. (2003) Ascorbic acid concentration and stability in North American potato germplasm. Acta Hort 619: 87-93.
37. Weber L, Putz B (1999) Vitamin C content in potatoes. In: Abstr, 14th Trien. Conf. EAPR, Sorrento 230-231.
38. Beevi SS, Narasu ML, Gowda BB (2010) Polyphenolics profile, antioxidant and radical scavenging activity of leaves and stem of *Raphanus sativus* L. Plant Foods Hum Nutr 65: 8-17.
39. Alasalvar C, Grigor JM, Zhang D, Quantick PC, Shahidi F (2001) Comparison of volatiles, phenolics, sugars, antioxidant vitamins, and sensory quality of different colored carrot varieties. J Agric Food Chem 49: 1410-1416.
40. Potter AS, Foroudi S, Stamatikos A, Patil BS, Deyhim F (2011) Drinking carrot juice increases total antioxidant status and decreases lipid peroxidation in adults. Nutr J 10: 96.
41. Indrawati A, Loey V, Hendrickx M (2004) Pressure and temperature stability of water-soluble antioxidants in orange and carrot juice: a kinetic study. Eur Food Res Technol 219: 161-166.
42. Gorinstein S, Park YS, Heo BG, Namiesnik J, Leontowicz H, et al. (2009) A comparative study of phenolic compounds and antioxidant and antiproliferative activities in frequently consumed raw vegetables. Eur Food Res Technol 228: 903-911.
43. Jaiswal AK, Rajauria G, Abu-Ghannam N, Gupta S (2011) Phenolic composition, antioxidant capacity and antibacterial activity of selected Irish Brassica vegetables. Nat Prod Commun 6: 1299-1304.
44. Plumb GW, Price KR, Rhodes MJ, Wiliamson G (1997) Antioxidant properties of the major polyphenolic compounds in broccoli. Free Rad Res 27: 429-435.
45. Heinonen MI, Ollilainen V, Linkola EK, Varo PT, Koivistoinen PE (1989) Carotenoids in Finnish foods: Vegetables, fruits, and berries. J Agric Food Chem 37: 655-659.
46. Piironen V, Syvaoja EL, Varo P, Salminen K, Koivistoinen P (1986) Tocopherols and tocotrienols in Finnish foods: Vegetables, fruits, and berries. J Agric Food Chem 34: 742-746.
47. Kim DO, Padilla-Zakour OI, Griffiths PD (2004) Flavonoids and antioxidant capacity of various cabbage genotypes at juvenile stage. J Food Sci 69: C685-C689.
48. Borowski J, Szajdek A, Borowska EJ, Ciska E, Zielinski H (2008) Content of selected bioactive components and antioxidant properties of broccoli (*Brassica oleracea* L.). Eur Food Res Technol 226: 459-465.
49. Chu YH, Sun J, Wu X, Liu RH (2002) Antioxidant and antiproliferative activity of common vegetables. J Agric Food Chem 50: 6910-6916.

doi:http://dx.doi.org/10.4172/2324-9323.1000104

50. Plumb GW, Lambert N, Chambers SJ, Wanigatunga S, Heaney RK, et al. (1996). Are whole extracts and purified glucosinolates from cruciferous vegetables antioxidants? Free Radic Res 25: 75-86.
51. Lee KS, Kader AA (2000) Preharvest and post-harvest factors influencing vitamin C content of horticultural crops. Postharvest Biol Technol 20: 207-220.
52. Leja M, Mareczek A, Starzyhska A (2002) Some antioxidant and senescence parameters of broccoli as related to its developmental stages. Acta Physiol Plant 24: 237-241.
53. Porter Y (2012) Antioxidant properties of green broccoli and purple-sprouting broccoli under different cooking conditions. Biosci Horizons 5: hzs004.
54. Gupta S, Lakshmi JA, Manjunath MN, Prakash J (2005) Analysis of nutrient and antinutrient content of underutilized green leafy vegetables. LWT Food Sci Technol 38: 339-345.
55. Gupta S, Prakash J (2009) Studies on Indian green leafy vegetables for their antioxidant activity. Plant Foods Hum Nutr 64: 39-45.
56. Liu XS, Ardo M, Bunning J, Parry K, Zhou C, et al. (2007) Total phenolic content and DPPH gradical scavenging activity of lettuce (*Lactuca sativa* L.) grown in Colorado. LWT Food Sci Technol 40: 552-557.
57. Oh MM, Carey EE, Rajashekar CB (2011) Antioxidant phytochemicals in lettuce grown in high tunnels and open field. Hortic Environ Biotechnol 52: 133-139.
58. Ligor M, Trziszka T, Buszewski B (2012) Study of antioxidant activity of biologically active compounds isolated from green vegetables by coupled analytical techniques. Food Anal Methods 6: 630-636.
59. Sreelatha S, Padma PR (2009) Antioxidant activity and total phenolic content of *Moringa oleifera* leaves in two stages of maturity. Plant Foods Hum Nutr 64: 303-311.
60. Oboh G (2006) Antioxidant properties of some commonly consumed and underutilized tropical legumes. Eur Food Res Technol 224: 61-65.
61. Ismail A, Tiong NW, Tan ST, Azlan A (2009) Antioxidant properties of selected non-leafy vegetables. Nutr Food Sci 39: 176-180.
62. Amarowicz R, Troszyñska A (2003) Antioxidant activity of extract of pea and its fractions of low molecular phenolics and tannins. Polish Journal of Food and Nutrition Sciences 12: 10-15.
63. Terashima M, Fukukita A, Kodama R, Miki H, Suzuki M, et al. (2013) Evaluation of antioxidant activity of leafy vegetables and beans with myoglobin method. Plant Cell Rep 32: 349-357.
64. Tavani A, Vecchia LC (1995) Fruit and vegetable consumption and cancer risk in a Mediterranean population. Am J Clin Nutr 61: 1374S-1377S.
65. Block G, Patterson B, Subar A (1992) Fruit, vegetables, and cancer prevention: a review of the epidemiological evidence. Nutr Cancer 18: 1-29.
66. Negri E, Vecchia C, Franceschi S, D'Avanzo B, Talamini R, et al. (1996) Intake of selected micronutrients and the risk of breast cancer. Int J Cancer 65: 140-144.

Author Affiliations

Top

[1]Department of Vegetable Science, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand-263145, India
[2]Department of Genetics and Plant Breeding, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand-263145, India
[3]Department of Entomology, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand-263145, India