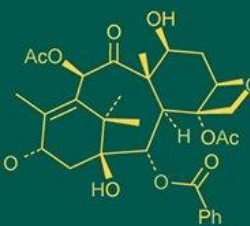
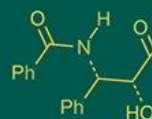


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(8): 113-118
www.biochemjournal.com
Received: 13-06-2024
Accepted: 16-07-2024

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A brief review of nutrient content of capsicum (Shimla Mirch)

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DOI: <https://doi.org/10.33545/26174693.2024.v8.i8b.1709>

Abstract

In contemporary times, stress has emerged as a predominant factor contributing to various human diseases. Consequently, scientists are endeavoring to ascertain natural reservoirs of antioxidant compounds. Given that plants abundantly yield antioxidants, they present a reservoir of novel compounds exhibiting promising antioxidant properties, with Capsicum among them. Fresh Capsicum is notably rich in ascorbic acid, numerous carotenoids pigments, and substantial quantities of phenolic compounds. Consumption of these bioactive compounds is associated with the prevention of cancer, cardiovascular diseases, cataracts, diabetes, Alzheimer's, and Parkinson's disease.

Keywords: Capsicum, antioxidant, phenol, flavonoids, β carotene, vitamin C and mineral

1. Introduction

Capsicum (*Capsicum annuum* L.), commonly known as bell pepper or Shimla Mirch, ranks among the most esteemed and popular vegetable crops cultivated in tropical and subtropical regions worldwide. It holds a distinguished status among vegetables due to its delicacy, pleasant flavor, and rich content of ascorbic acid, vitamins, and minerals. Capsicum thrives in warm climates with temperatures ranging from 18-27 °C and can be cultivated at altitudes up to 3,000 meters above sea level in the tropics, preferably with a rainfall of 600-1200 mm. However, it is sensitive to water logging and excessive rain (Lego *et al.*, 2016) ^[18].

Antioxidants serve as vital compounds in combating diseases. They are believed to mitigate and repair oxidative stress arising from normal cellular function, as oxidation is inherent to cellular metabolism. Of particular interest, antioxidants reduce free radicals and reactive oxygen species (ROS) within organisms, which are produced as part of cellular metabolism and in response to environmental factors such as ultraviolet irradiation. Carotenoids, responsible for the orange and red hues in vegetables, including peppers, comprise capsanthin and carotene. The consumption of carotenoid-rich foods has been associated with a decreased occurrence of numerous disorders, including cancers, cardiovascular diseases, age-related macular degeneration, cataracts, ailments related to compromised immune function, and other degenerative conditions. Capsicum, recognized primarily for its antioxidant attributes, harbors a variety of bioactive compounds. These compounds have demonstrated efficacy in inhibiting the oxidation of essential fats within brain cells, a process deemed essential for optimal brain function (Obboh and Rocha, 2008) ^[28].

Numerous epidemiological studies have consistently highlighted a negative association between elevated carotenoid intake and the risk of colon cancer. Fresh Capsicum exhibits notably high concentrations of ascorbic acid, diverse carotenoid pigments, and substantial quantities of phenolic compounds. Consumption of these bioactive constituents has been linked to the prevention of prevalent degenerative diseases, including cancer, cardiovascular disorders, cataracts, diabetes, Alzheimer's, and Parkinson's disease. Capsicum boasts levels of vitamin C comparable to those found in citrus fruits and other vegetables recognized for their vitamin C content. Additionally, it is abundant in phenolic compounds, antioxidants, and ascorbic acid. Consequently, emphasis on the diverse nutritional components of Capsicum is needed (Campos *et al.*, 2013) ^[4].

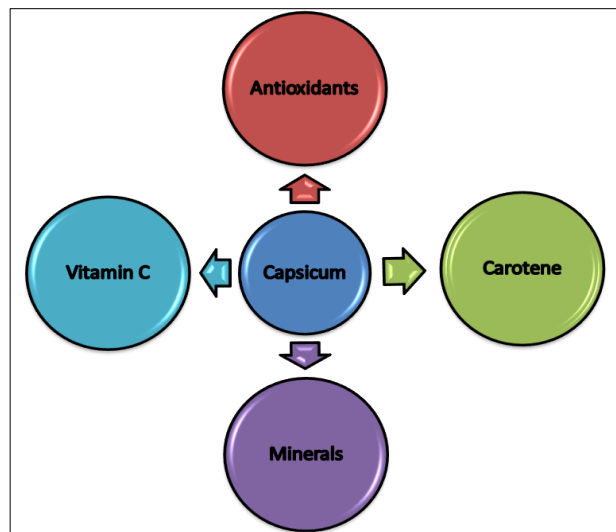


Fig 1: Illustrative depiction of Phytochemical associated with *Capsicum annum*.

2. Antioxidant activity

In the pursuit of natural antioxidants derived from botanical origins, the antioxidant and radical scavenging properties of various medicinal plants and fruits have been subject to extensive investigation in recent decades. Fruits and vegetables harbor a plethora of antioxidants, which mounting experimental evidence suggests play a pivotal role in shielding cellular components, including DNA, proteins, and lipids, from detrimental free radicals. Moreover, these antioxidants have been linked to reduced incidence and mortality rates of cancer and cardiovascular disease, along with a spectrum of additional health advantages (Park *et al.*, 2012) [31].

Flavonoids, ubiquitously present in plants, exert a myriad of biochemical and pharmacological effects, encompassing antioxidant, anti-inflammatory, and anti-allergic properties. Their consumption has been associated with a reduced risk of cancer and inhibition of enzymes such as prostaglandin synthase, lipoxygenase, and cyclooxygenase, which are closely linked to tumorigenesis. Studies examining Pepper mild mottle virus (PMMoV)-infected *Capsicum annum* revealed variations in Total Antioxidant Status (TAS), Total Oxidant Status (TOS), Total Phenol (TP), Free Phenol (FP), and Conjugated Phenol (CP) content. TAS levels were diminished in infected capsicum plants, whereas TOS, OSI, TP, FP, and CP levels exhibited significant elevation in infected specimens compared to healthy counterparts.

Total antioxidants are comprised of phenolic compounds, which are found in peppers in conjunction with sugars (Materska *et al.*, 2003 (a); Materska *et al.*, 2003 (b)) [22-23]. The values of phenolic compounds ranged from 0.058 to 0.085 mg/100 g (Perucka and Materska, 2007) [33]. Studies conducted on phytochemical compounds in nine fruit variants (morphotypes - Chile de Agua, Guero, Nanchita, Piquin, Solterito, Tusta, Costeno, Canario, and Tabaquero) of peppers revealed that the total phenol values ranged from 61 to 402 mg/100 g fresh weight (Guzman *et al.*, 2011) [10].

Bell peppers have risen in popularity among vegetables, largely due to their rich concentration of antioxidants. Among these antioxidants, polyphenols, a class of phytochemicals, stand out for their exceptional ability to scavenge free radicals. These compounds, which undergo significant fluctuations in levels throughout the growth and maturation stages of peppers, play a crucial role in

determining the pungency, bitterness, color, and flavor of the fruits (Estrada *et al.*, 2000) [6].

Various studies have been conducted to evaluate the antioxidant compounds and activities in bell peppers of different colors, namely green, yellow, orange, and red (*Capsicum annum* L.). One such study focused on the assessment of total phenolic content across these color variants. The findings indicated that the total phenolic content varied across the different colored peppers, with green peppers exhibiting 2.4 μmol catechin equivalent/g fresh weight, yellow peppers showing 3.3 μmol catechin equivalent/g fresh weight, orange peppers displaying 3.4 μmol catechin equivalent/g fresh weight, and red peppers boasting the highest content at 4.2 μmol catechin equivalent/g fresh weight (Nadeem *et al.*, 2011) [26].

These detailed analyses shed light on the significant antioxidant potential inherent in bell peppers, particularly highlighting the role of polyphenols in contributing to their health benefits and sensory attributes. Such insights deepen our understanding of the nutritional value of bell peppers and underscore their importance in promoting overall well-being through dietary consumption (Alieozaman *et al.*, 2023) [5].

The chemical compounds present in bell peppers actively prevent the oxidation of essential fats within brain cells, which are considered necessary for optimal brain function (Obob and Rocha, 2008) [28]. The stability of phenol compounds depends on various factors, such as pH value and temperature (Zhang *et al.*, 2001) [44]. Shotorbani and colleagues conducted a study on the antioxidant activity in two different colored (red and green) sweet bell peppers at various temperatures. They reported that the total phenol and flavonoid contents of pepper extracts increased with rising temperatures up to 65 °C. They concluded that maintaining an appropriate temperature resulted in high antioxidant activity of phenolic compounds, possibly due to the combined effect of non-enzymatic reactions and phenolic compound stability (Shotorbani *et al.*, 2012) [41].

The bell pepper undergoes a transition in color as it matures, starting from green and progressing to various hues such as orange, red, or yellow. Phytochemicals found in fruits and vegetables can be influenced by several factors, including the stage of maturation, genotype, and storage and processing conditions (Lightbourn *et al.*, 2008) [19].

Methanol extracts of four different colored bell peppers (red, orange, yellow, and green) exhibit varying levels of total phenolic content (TPC) and antioxidant activities. Research indicates that red and orange bell peppers possess significantly higher TPC levels compared to yellow or green bell peppers. Among these, orange bell pepper demonstrates the highest radical scavenging activity and total antioxidant activity, while green bell pepper exhibits the highest superoxide dismutase-like activity. Researchers suggest that the disparity in antioxidant activities may be linked to the types of antioxidant compounds associated with the pepper's color (Park *et al.*, 2012) [31].

In aqueous extracts of *Capsicum annum* (Bell Pepper), antioxidant activities, total phenolic contents, and total flavonoid contents range from 0.795 to 1.893 μmol BHA/g, 0.739 to 1.291 μmol of gallic acid equivalent, and 0.306 to 0.551 μmol of quercetin equivalent, respectively (Rahim and Mat, 2012) [34].

Due to the economic and nutritional significance of bell peppers, grafting is increasingly utilized in this crop, primarily for controlling nematodes and soil-borne diseases.

Grafting has also been assessed for its impact on crop yield and fruit morphological characteristics. Additionally, grafting enhances the presence of specific phytochemical compounds and antioxidant activity (Kokalis *et al.*, 2009; Oka *et al.*, 2004; Leal *et al.*, 2013) [14, 29, 17]. Different cultivar/rootstock combinations of bell pepper exhibit varied responses, with Fascinato/Robusto showing the highest concentration of total phenols and the greatest antioxidant activity among the combinations evaluated. The optimal sampling time for peppers to achieve the highest concentrations of bioactive compounds and antioxidant activity was found to be September (Celia *et al.*, 2015) [45]. Evaluation of phytochemical compounds in nine fruit variants of pepper reveals that flavonoid content ranges from 9.5 to 97 mg/100 g (Guzman *et al.*, 2010) [10]. Habanero pepper fruit is recognized as an excellent source of phytochemicals, including vitamins A and C, phenolic compounds, flavonoids, and carotenoids (Antonious *et al.*, 2009) [2]. Studies on polyphenol and antioxidant properties in seven genotypes of Habanero Pepper (*Capsicum chinense*) indicate that phenolic content and Trolox equivalent antioxidant capacity (TEAC) vary from 20.54 to 20.75 mg/100 g and 1.55 to 3.23 mM/mg, respectively (Campos *et al.*, 2013) [4]. However, the values of DPPH radical scavenging activity (%) and total phenol content (mg/g) in *Capsicum annum* Linn. var. *grossum* were recorded at 25.0 percent and 4.20 mg/100 g, respectively (Gacche *et al.*, 2010) [8]. Research also suggests a decline in phenol concentration in *Capsicum chinense* Jacq. (Gayathri *et al.*, 2016) [9].

3. Ascorbic acid content (Vitamin C)

Peppers are renowned for their rich array of phytochemicals

and serve as a notable source of vitamin C, which is hypothesized to play a role in cancer prevention by inhibiting the formation of N-nitroso compounds in the stomach and stimulating the immune system (Byers and Perry, 1992; Palevitch and Craker, 1995; Howard *et al.*, 2000; Marin *et al.*, 2004) [3, 30, 11, 21]. Vitamin C also stands out as the most abundant water-soluble antioxidant in the human body (Frei *et al.*, 1989) [7]. Numerous reports have highlighted lower vitamin C content in infected capsicum (Murat *et al.*, 2011) [25]. Range of Vitamin C is given in Table 1.

The quantity of vitamin C present in peppers depends on factors such as the cultivar, stage of maturity, and season of the crop. In *Capsicum annum*, vitamin C values range from 101 to 114.85 mg/100 g (Perucka and Materska, 2007) [33] although these ranges may differ across variants. For instance, in nine fruit variants of pepper, vitamin C content ranged from 1.9 to 183.2 mg/100 g (Guzman *et al.*, 2011) [10]. *Capsicum annum* Linn. var. *grossum* is reported to have a vitamin C content of 20.48 mg/100 g (Gacche *et al.*, 2010) [8].

Bell pepper holds a significant place among vegetables in India due to its delicacy, pleasant flavor, and richness in ascorbic acid, vital for a strong and healthy immune system (Agarwal *et al.*, 2007) [1]. Kumar *et al.* conducted experiments on fifteen genotypes of capsicum, noting that maximum ascorbic acid content (111.97 mg/100 g) was recorded in the hybrid Orobelle, followed by Bomby (106.20 mg/100 g) and Paladin (104.83 mg/100 g) (Kumar *et al.*, 2015) [15]. In Habanero Pepper (*Capsicum chinense*), ascorbic acid content varied from 187.24 to 281.73 mg/100 g sample (Majidi and Hazim, 2016) [20].

Table 1: Range of Vitamin C in Capsicum Variants:

Pepper Type	Vitamin C Content (mg/100 g)
<i>Capsicum annum</i>	101 - 114.85
Various fruit variants of pepper	1.9 - 183.2
<i>Capsicum annum</i> Linn. var. <i>grossum</i>	20.48
Bell pepper (various genotypes)	104.83-111.97 mg/100 g
Habanero Pepper (<i>Capsicum chinense</i>)	187.24 - 281.73

Vitamin C, as a potent antioxidant, has the capacity to eliminate various reactive oxygen species. The requirement for vitamin C increases during pregnancy, lactation, adolescence, hyperthyroidism, infection, and post-surgery (Kumar *et al.*, 2013) [16]. Maintenance of daily dietary intake of vitamin C is crucial for preventing scurvy, a deficiency disease state of vitamin C. An analysis of vitamin C content in *Capsicum* under fresh and storage conditions by the titrimetric method revealed that fresh red pepper and green pepper contained 81.53 mg/100 g and 27.62 mg/100 g of vitamin C, respectively, while under storage conditions, red pepper and green pepper contained 28.26 mg/100 g and 10.65 mg/100 g of vitamin C (Patrick *et al.*, 2016) [32]. Overall, green bell peppers contain approximately 16.52 mg of vitamin C per 100 g, yellow bell peppers contain 159.61 mg per 100 g, orange bell peppers contain 121.38 mg per 100 g, and red bell peppers contain 81.19 mg per 100 g (Nerdy, 2018) [27]. The characterization of accessions with higher vitamin C content is of interest in plant breeding. In 22 genotypes of *Capsicum chinense*, vitamin C content ranged from 54.1 to 129.8 mg/100 g (Teodoro *et al.*, 2013; Sayin *et al.*, 2015) [38].

4. Chlorophyll and carotenoids content

Chlorophyll, a natural pigment derived from green plants and algae, plays a crucial role in absorbing energy from the sun, which is then utilized in synthesizing carbohydrates from CO₂ through photosynthesis (Raven *et al.*, 2005) [35]. Within the chloroplasts of higher plants, two main types of chlorophyll are found: chlorophyll a (blue-green) and chlorophyll b (yellow-green), distinguished by differences in the substituent of a pyrrole ring II. Apart from its pivotal role in photosynthesis, chlorophyll also finds application as a natural pigment in food and cosmetics (Humphery, 2004) [12].

In a study conducted by Sercan and colleagues, the effects of Tobacco mosaic virus (TMV) infection on growth and physiological parameters were analyzed in three pepper varieties (*Capsicum annum* L.) - Ergenekon F1, Kumsal F1, and 497 F1. A comparison between infected and non-infected plants revealed that TMV infection resulted in a reduction of chlorophyll a, chlorophyll b, and carotenoid content. Specifically, in the case of the Ergenekon variety infected with TMV, chlorophyll a content was reduced to 1.77 compared to 3.85 mg/L in the control group. Similarly,

the Kumsal variety infected with TMV exhibited a chlorophyll a content of 2.82 compared to 3.13 mg/L in the control, while the 497 variety infected with TMV showed a chlorophyll a content of 1.49 compared to 3.73 mg/L in the control. Regarding chlorophyll b content, the Ergenekon variety infected with TMV displayed 0.59 mg/L compared to 0.72 mg/L in the control, the Kumsal variety showed 0.33 mg/L compared to 0.57 mg/L in the control, and the 497 variety exhibited 0.12 mg/L compared to 0.77 mg/L in the control (Sercan *et al.*, 2013) [39].

Numerous reports have highlighted variations in chlorophyll content between healthy and diseased leaves of capsicum. One study indicated that in fresh tissue weight, chlorophyll a, b, and total chlorophyll content were 0.2834 mg/g, 0.1650 mg/g, and 0.4932 mg/g, respectively. Conversely, in diseased leaves, chlorophyll a, b, and total chlorophyll content decreased significantly, reaching 0.0489 mg/g, 0.0779 mg/g, and 0.1425 mg/g, respectively (Kesh *et al.*, 2016) [13].

Additionally, chlorophyll content varies based on the hybrid of capsicum. The Indam Mamatha F1 hybrid exhibited the highest chlorophyll content at 13.30 mg/100 g, followed by the Natasha F1 hybrid at 12.00 mg/100 g, Bachata at 11.94 mg/100 g, and Indian F1 hybrid at 11.84 mg/100 g [29]. Carotenoid content in fresh capsicum fruit ranged from 4 to 1173 µg/g, while in dried fruit, it varied from 187 to 10,121 µg/g (Wall *et al.*, 2001). In Habanero Pepper (*Capsicum chinense*), the carotenoid content ranged from 1.00 to 1.26 mg/100 g (Campos *et al.*, 2013) [4].

5. β-carotene content

Vitamin A plays a critical role in maintaining normal vision, supporting the integrity of epithelial tissues, and facilitating various metabolic functions within the body. In many developing regions, up to 80% of dietary vitamin A intake is derived from provitamin A-rich food sources. Provitamin A carotenoids serve as the precursor to vitamin A and are synthesized as pigments by numerous plants, particularly in green, orange, and yellow plant tissues. These provitamins, including alpha-carotene, beta-carotene, gamma-carotene, and cryptoxanthin, are commonly found in plant-based foods. Among these, beta-carotene emerges as the most predominant and active form in practical terms (McLaren, 2012) [24].

Sweet bell pepper (*Capsicum annuum* L.) stands out as an excellent source of carotenoids, including beta-carotene, capsantin, and capsorubin. Research indicates that red peppers exhibit higher levels of beta-carotene, with a content of 5.4 µg/g, while yellow peppers have the lowest beta-carotene content at 0.2 µg/g (Nadeem *et al.*, 2011) [26]. Studies utilizing high-performance liquid chromatography (HPLC) have demonstrated significant variability in beta-carotene levels among ripe and dried peppers. In ripe fruit, beta-carotene levels range from 0 to 166 µg/g, while in dried fruit, the content varies from 2 to 739 µg/g and 24 to 1198 µg/g (Wall *et al.*, 2001).

Furthermore, phytochemical screening and antimicrobial activity assessments of *Capsicum chinense* Jacq. revealed an increase in carotenoid concentration as peppers reached maturity (Gayathri *et al.*, 2016) [9]. These findings underscore the importance of sweet bell peppers as a valuable dietary source of carotenoids, particularly beta-carotene, and highlight the potential health benefits associated with their consumption.

6. Mineral content

Sweet pepper is a valuable vegetable with unique health-promoting and taste properties (Marin *et al.*, 2004) [21]. High concentrations of mineral components important for human health have been identified in pepper (Rubio *et al.*, 2002) [37]. *Capsicum annuum* serves as a good source of both micro and macro nutrients, including 0.08% calcium, 0.01% zinc, 0.02% sodium, 69.25% potassium, and 0.07% iron, respectively (Sharma *et al.*, 2017). It's noteworthy that the composition of red and green peppers differs significantly. Studies have shown that in red peppers, macroelements (mg/100 g) such as sodium range from 4.13 to 8.60, potassium from 120 to 250, calcium from 13 to 33.2, magnesium from 12.3 to 23.1, and phosphorus from 24.4 to 40.0, while microelements (mg/100 g) such as iron range from 0.22 to 0.46, copper from 0.03 to 0.13, zinc from 0.10 to 0.23, manganese from 0.03 to 0.08, and boron from 0.01 to 0.21.

On the other hand, in green peppers, macroelements (mg/100 g) such as sodium range from 2.28 to 9.85, potassium from 101 to 199, calcium from 10.8 to 23.4, magnesium from 10.1 to 17.7, and phosphorus from 16.2 to 50.3, while microelements (mg/100 g) such as iron range from 0.14 to 0.41, copper from 0.02 to 0.08, zinc from 0.08 to 0.23, manganese from 0.03 to 0.07, and boron from 0.01 to 0.12 (Rubio *et al.*, 2002) [37].

Moreover, pepper exhibits a vast genotypic diversity, influenced by factors such as genotype, fruit ripening stage, and the interaction between genotype and ripening stage. Consequently, variations occur in the mineral content of unripe and ripe fruit, with phosphorus (P) ranging from 190 to 351 mg/100 g in unripe fruit and 158 to 305 mg/100 g in fully ripe fruit, calcium (Ca) ranging from 25 to 61 mg/100 g in unripe fruit and 10 to 21 mg/100 g in fully ripe fruit, magnesium (Mg) ranging from 123 to 250 mg/100 g in unripe fruit and 102 to 274 mg/100 g in fully ripe fruit, and potassium (K) in fully ripe fruits ranging from 1509 to 2755 mg/100 g (Ribes *et al.*, 2014) [36].

7. Conclusion

The present review on *Capsicum annuum* (bell pepper) provides a comprehensive account of phytochemical constituents such as ascorbic acid, several carotenoid pigments, and a large amount of phenolic compounds. This article demonstrates that *Capsicum* is a natural source of nutrients, emphasizing the importance of consuming natural antioxidants over synthetic ones. In the current era, there is a growing trend towards selecting foods high in phytochemical and antioxidants to prevent diseases, and this article encourages people to consider consuming *Capsicum* as a source of antioxidants.

8. Acknowledgement

The authors are highly thankful to the Head of Department of Chemistry and Biochemistry for help and worthy suggestion.

9. Conflict of Interest Statement

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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