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Physicochemical characteristics and antioxidant potential of *Opuntia* fruit: A review

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Abstract

In the era of healthy living there is demand of nutraceuticals having natural source. The nutraceutical value of *Opuntia* fruit can fulfill this demand for healthy lifestyle in more natural way. *Opuntia* fruits from the family of *Cactaceae* are one of the underutilized fruit despite of its good nutritional value. The *Opuntia* fruits are known for its high betalain content which is comparable to the red beet. This betalains have 2-3-fold higher antioxidant value than standard trolox. *Opuntia* fruit also contains various polyphenols and flavonoids. Among which quercetin, kaempferol and isorhamnetin are very crucial flavonoids. The high levels of betalains, flavonoids, polyphenols, taurine, calcium, magnesium are noteworthy. The review paper focuses on the physico-chemical properties of *Opuntia* fruit and its various polyphenolic compounds responsible for the antioxidant activity of the fruit.

Keywords: *Opuntia*, physicochemical characteristics, antioxidant activity

1. Introduction

Cactus pear can be known by many different names like Prickly Pear, Indian fig, Cactus fruit, *Opuntia*, etc. Cactus pear belongs to family *Cactaceae*, subfamily *Opuntioideae* and genus *Opuntia*^[3]. The genus *Opuntia* is specially known for its flat structured leaf and stem. The genus further includes 150 to 180 species^[37]. Hence, *Opuntia* is the largest and the most widely distributed genus under the subfamily *Opuntioideae*^[3, 15]. Despite of largest and widely distributed genus the cactus pear is still underutilized fruit with only 10 to 12 species being utilized for various purposes (fruits, tender leaves, color extraction, forage, etc). Some of the most utilized species of cactus fruits are *Opuntia ficus-indica*, *Opuntia leucotricha*, *Opuntia xocconostle*, *Opuntia megacantha* and *Opuntia streptacantha*. Wild species include *Opuntia hyptiacantha*, *Opuntia amyclae* and *Opuntia robusta*. Among the most utilized species *Opuntia ficus-indica* is widely cultivated species and used for various purposes^[72].

Opuntia fruits are known for their origin in Mexico, later on their cultivation was distributed to various continents^[26]. In some part of North Africa, the cactus fruit is called as “bridge of life” as it is the only source of food and feed for humans and animals respectively during drought period^[57]. Cactus can be found in various forms which include the tallest cactus with height 19.2m and the smallest cactus with 1cm in diameter. Mostly the cactus is night blooming, hence the pollination is done by various nocturnal insects or animals^[63]. *Opuntia* species shows greater and efficient use of water hence, they are also known as the Crassulacean Acid Metabolism (CAM) plants. In CAM plants the stomata remain closed in day time to preserve the water and opens at night when the temperature of environment is low. Due to which the CAM plants fix the CO₂ in night and stored as malic acid and later on in day time the malic acid is converted to CO₂ for the photosynthesis^[35, 51].

The chemical composition and the nutraceutical properties of cactus fruit have been studied from long time. The fruit having the moisture content of 85%, 0.3% ash, 15% sugar and 1% protein are sweet to taste with no specific aroma. The fruit contribute about 50 kcal/100 g of energy^[39, 41, 66]. United States Department of Agriculture has given the daily value (DV) which is provided by cactus fruit for 100g serving. The vitamin C content has 23% of DV, dietary fiber has 14% of DV, and magnesium has 21% DV^[18]. Cactus fruit contains various amino acids like arginine, alanine, aspartic, glutamic and asparagine; among which aspartic and glutamic acids were found higher about 200mg/kg of *Opuntia ficus-indica* juice^[31].

Opuntia fruit are known for its antioxidant activity which can be contributed to various components like betalains, pectin, carotenoids, ascorbic acid, flavonoids, etc. Among these components the flavonoids contribute to the major antioxidant activity present in cactus fruit as the polyphenolic components have more stable radical than vitamins which reduces

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oxidative damage to DNA, proteins and lipids in the body [2]. The flavonoids present in cactus fruit includes kaempferol, quercetin, narcissin, dihydro-kaempferol (aromadendrin, 6), dihydroquercetin, and eriodictyol [30, 73, 62]. Besides flavonoids, betalains are one of the important nutraceutical found in cactus fruit. Betalains are water soluble pigments specifically red to violet (betacyanins) and yellow to orange (betaxanthins) which also contribute to the antioxidant activity of cactus fruit [3, 9, 70].

Opuntia fruits show great resistance to drought and can be easily grown in arid and semi-arid areas. Cactus fruits can grow in cold area comprising of -40°C and even in desert areas showing great adaptability to environment. Due to the surviving nature of cactus fruit in various environments it can be very important resource as food during crises.

The review focuses on physico-chemical characteristics and antioxidant compounds present in *Opuntia* fruit. This review will definitely help to get thorough information about the *Opuntia* fruit.

Physical Properties of *Opuntia* Fruit

Mostly the *Opuntia* fruit is oval in shape and somewhat elongated; technically we can call it as fleshy berry. Its weight ranges from 67-216g per fruit. Different species of *Opuntia* fruit exhibit different colors like yellow, orange, red, white and purple. The color of the *Opuntia* fruits is based on the betalain content of the fruit [66].

The *Opuntia* fruit consist of pericarp which is thick and possess small barbed spines. The pulp of the fruit contains small non-edible seeds. Hence, we can differentiate the fruit into three major parts like peel, pulp and seeds. The seeds are of different varieties of shape and sizes with respect to the differing species. Some species of cactus fruits contains no seeds and spines. These cactus fruits are known as spineless *Opuntia* varieties. Each and every part of cactus fruit can be utilized in different ways and for different purposes [18, 19, 24, 25].

Table 1: Physical properties of *Opuntia* fruit

Sr. No.	Parameters	Results	References
1	Pulp (%)	39-67	[34, 52, 59, 10, 42, 32, 7, 40, 43, 25, 24, 68, 19, 48, 49, 50, 18, 66, 22, 38]
2	Peel (%)	33-55	
3	Seeds (%)	2-10	

The edible part of the cactus fruit consists of pulp. The yield of the fruit pulp is very important factor during processing in industries. From the comparative analysis done by many researchers (shown in Table 1) shows the pulp content of the cactus fruit ranged from 39-67%, the peel content was in range of 30-55% and the seed content ranged from 2-10%. The pulp:peel:seed ratio varies according to the different species of the *Opuntia* fruit [41].

Chemical composition of *Opuntia* Fruit

Opuntia fruit is non-climacteric and is well known for its nutritional value which is due to the minerals, vitamin C, dietary fibers and phyto-chemicals [66]. The major fraction of cactus fruit is consisting of water, even-though the water is very crucial in arid and semi- arid areas. This water in the fruit is protected by the thick mucilaginous peel. The chemical composition of the *Opuntia* fruit varies from species to species and even depends on the place of origin [59].

Research on *Opuntia* fruit is being done from many decades. The comparative studies on the chemical compositions of

Opuntia fruit pulp by various research sources is depicted in Table 2. According to the data collected the moisture content of *Opuntia* fruit ranges from 84 to 94%. As moisture content of the fruit is quite high, the fresh fruits have less shelf life of 2 to 3 days at room temperature. Thus, marketing of fresh cactus fruit is very difficult [22].

Table 2: Chemical Composition of *Opuntia* Fruit Pulp

S. No.	Parameters	Values per 100g	References
1.	Moisture	83-95g	[59, 7, 39, 58, 43, 68, 11, 24, 22, 14, 28, 69]
2.	Protein	0.2-1.6g	
3.	Fat	0.09-1.7g	
4.	Ash	0.3-0.51g	
5.	Fiber	0.02-3.16g	
6.	Total Sugars	8-17g	
7.	Ca	12.8-59mg	
8.	Mg	16.1-98.4mg	
9.	Na	0.6-1.1mg	
10	K	90-217mg	
11.	P	15-32.8mg	
12.	Fe	0.4-1.5mg	
13.	Acid	1-41mg	
14.	⁰ Bx	11.5-17	
15.	pH	5.0-7.1	
16.	Titrate acidity (%)	0.01-0.25	

Opuntia fruit contains only 0.2 to 1.6% of protein. By the previous studies it has been found that the cactus fruit possess free amino acids which are known for all essential amino acids. Among the essential amino acids, proline dominates with 883.4 To 1929.1 mg/L. later on it is followed by taurine with 323.6 to 407.3 mg/L, glutamine 98.3 to 574.6 mg/L, and serine 130.6 mg/L to 392.6 mg/L [64, 65, 31].

Fat or lipids ranges from 0.3 to 1 % of the cactus fruit pulp. The seeds of *Opuntia* fruit contain considerably high fat content as compared to the pulp. One Kg of seed yields 98.8 g of total lipids [50]. The predominant polyunsaturated acid in pulp oil and seed oil is Linoleic acid [49, 50]. Fiber content differs from species to species; it ranges between 0.02 to 3.16 % of the cactus fruit pulp. This fiber content of fruit gives good mouth-feel to the cactus fruit juice. Fibers also have been stated to reduce down the blood sugar level and plasma cholesterol levels in the body [20, 71]. Total sugars content ranges from 8 to 14.06% of the total pulp. The cactus fruit is mostly composed of glucose (53%) and rest is fructose. It has been found that there is absence or very low amount of sucrose present in the fruit [11, 24]. The calorific value of cactus fruit is 47.30 Kcal to 50Kcal per 100g [55]. Cactus fruits consists good amount of minerals. Cactus fruits are mostly rich in Calcium and magnesium. As a good source of calcium (up to 98.4 mg/100 g) and magnesium up to 59 mg/100 g cactus fruit can be used to prevent osteoporosis and cramps. Higher levels of Ca, Mg and K can be used to regain energy and to maintain the mineral balance during exhausting work. Phosphorous and iron are found in moderate level in cactus fruits comparable to other fruits. The low levels of sodium and chlorides help to maintain the blood pressure [47]. The cactus fruit is characterized with high sugar content and low acidity giving the fruit a mild and sweet taste. Hence, they are consumed mostly in fresh form. The flavor, mouth-feel and availability of fruit throughout the year show great potential to exploit the fruit for different industrial and traditional uses [55]. The cactus fruits can be used in fresh salads and desserts, jams and jellies, alcoholic beverages etc. [6, 29].

As reported by many different researchers the fruit pulp has

very low titratable acidity in the range of 0.01% to 0.2 %. Hence the cactus fruit is characterized as low acid foods. But the fruit shows high pH in the range of 5.3 to 7.1. The sweetness of the fruit pulp is due to reducing sugars hence, the total soluble solids in fruit range from 10.7° to 17°Brix [1, 5, 6, 24, 32, 44, 46, 57, 60]. The ascorbic acid in the cactus fruit can range from 1-41mg/100g. Ascorbic acid has free radical scavenging activity which protects our body from oxidative stress. It is found that the ascorbic acid is responsible for 30% to 40% of the total antioxidant activity of the fruit [9].

Antioxidant compounds present in *Opuntia* Fruit

Opuntia fruit is also known for its antioxidant activity. This antioxidant activity of *Opuntia* fruit can be contributed to

vitamin C and various bio-compounds like betalains, phenolic compounds and flavonoids [13, 17]. Flavonoids present in *Opuntia* fruit consists Glycosylated flavonols, dihydro flavonols, flavonones and flavonols [33]. From the studies done on the phenolic compounds and flavonoids, it was found that the flavonoids have more antioxidant activity than vitamins as it have the ability to delay the pro-oxidative effects in DNA, protein and lipids by generating stable radicals [61]. The antioxidant activity in cactus fruit is known to have therapeutic effect on the body. It is reported that the antioxidant activity prevents from degenerative diseases like diabetes, cancer, hypercholesterolemia, arteriosclerosis or cardiovascular and gastric diseases in the human body [27, 71, 23].

Table 3: Antioxidant compounds present in *Opuntia* Fruit

Species	Total phenolic acids	Total flavonoid	Betalains	Source
<i>O. stricta</i>	204.4 GAE/100g FW	9.8 mg QE/100g FW	80.1 (mg/100g FW)	[4, 21, 12, 16]
<i>O. streptacantha</i>	120 GAE/100g FW	18.0 mMol of quercetin /g of sample	3.5 (mg/100g FW)	
<i>O. hyptiacantha</i>	33.4 mMol of gallic acid/g of sample	17.1 mMol of quercetin/g of sample	-	
<i>O. megacantha</i>	130 GAE/100 g FW	50.24 mg QE/100g FW	27 µg/gFW	
<i>O. albicarpa</i>	40.8 mMol of gallic acid/g of sample	17.2 mMol of quercetin /g of sample	1 (mg/100g FW)	
<i>O. ficus-indica</i>	218mgGAE/ 100g FW	19.4 mMol of quercetin/g of sample	39.3 (mg/100g FW)	

Cactus fruit is mostly known for its violet-red color which is due to the presence of betalains. Betalains are water soluble coloring pigment which is characterized by red or violet colour. There are very few sources of betalains viz., beet root, amaranth, etc. Hence, cactus fruit is one of them. Cactus fruit possess both betacyanins (red-violet color) and betaxanthins (yellow color). Beet root contains approximately 50mg/100g of betanin whereas purple cactus pear juice contains 100mg of betanin per 100g of fresh weight [56]. In some species of cactus fruit like *O. stricta* the betacyanin content was 80 mg /100 g of fresh weight [13]. Betalains are known to have higher antioxidant activity as compared to ascorbic acid, catechin and rutin. It has 2 to 3 folds higher antioxidant value than ascorbic acid. Cactus fruit is superior in antioxidant activity than that measured for, apple, pear, tomato, banana, and white grape, and from the same order as pink grapefruit, orange, and red grape.

Cactus fruit contains some very crucial flavonoids viz., quercetin, kaempferol and isorhamnetin. The major antioxidant effect found in cactus fruit is due to the above-mentioned flavonoids [32].

From the Table 3 it is clear that the total phenolic content of cactus pear is variable and is dependent on environmental conditions, maturity stage, post-harvest treatment and species. The highest total phenolic content was found in wild species of *O. stricta* which is later followed by *O. undulata*, *O. megacantha*, *O. streptacantha*, and *O. dinellii* (164.6, 130, 120, and 117 mg/100 g FW pear, respectively) [21, 12, 16].

Conclusion

On realization of the importance of *Opuntia* fruit, cultivation initiated in some parts of Mexico and Africa. Still cultivation is very rare. Various hybrid varieties of fruits are also introduced which have more fruit pulp and small seed size. Cactus fruits are available in broad range of colors and are rich source of betalains. As the fruit do not show any problems like nitrate accumulation, earthy flavor or risk of microbiological contamination it can be considered as a superior source for betalains extraction than beet root; which is the only source from where betalains are extracted

commercially. The most color can be extracted near neutral pH which may allow us to use cactus fruit concentrates for coloring ice-creams, yoghurts, and various fruit preparations. Cactus fruit juice can be considered as valuable ingredient for energy and sports drink due to the high level of amino-acids such as proline and taurine and the minerals like magnesium and calcium. Various in-vitro and in-vivo studies have revealed effects of nutraceuticals found in cactus fruit on human health. The betalains, phenolic compounds, vitamin C and flavonoids present in the cactus fruit are found to possess good antioxidant activity. But there limited clinically proven evidences. Hence, further investigation is highly essential. The prime reason for the limited commercialization of cactus fruit product is due to the lack of knowledge of cactus fruit processing and the market price.

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