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Original article

Health benefits of Cactus

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Abstract

Xerophytes are the great fighters due to their amazing abilities to deal with extremely challenging environment. These plants are distinct from other mesophytes in having morphological, anatomical and physiological adaptations. Due to these adaptive modifications the biochemistry of these plants is also unique and they are the vital source of valuable phytochemical contents of a range of uses, especially medicinal utilization. Cactus is one of the most widely distributed plants in the xeric environment and has special characteristics. In this review an attempt is made to provide an all-encompassing account of this plant with special focus to its medicinal properties.

Key words: Cactus, medicinal importance, phytochemical, xerophytes

1. Introduction

The term Cactus is derived from an ancient Greek word '*kaktos'*, which was used by Theophrastus to demarcate the spiny plants. Cactus has a great economical value as it is the no maintenance wild/ornamental plant of the family Cactaceae. It is also referred to as 'new world' plants (Shetty *et al*., 2012). It is extensively cultivated for its various uses such as fodder and food (tastier fruit is used as a vegetable). It is also considered as an energy source as it contains 14% glucose (Salim *et al*., 2009). It grows in hot, arid and semi-arid regions. Its morphology, physiology and anatomy are such that it conserves water. It is used as an energy source and also for ecosystem remediation (Small and Catling, 2004).

Cactus is fleshy and pulpy due to its amazing capacity to retain huge amounts of water into it, therefore this plant is capable to flourish in deserts. Physiologically it exhibits CAM metabolism, which has a mechanism to tolerate the environmental stress, mostly the unavailability of water (Gibson and Nobel, 1986; Anderson, 2001; Bensadón *et al*., 2010). Morphologically, the stem of cacti is modified and become fleshy, flat and cylindrical or globular and forms cladode. The pollination and the seed dispersal take place with the help bats, birds and insects (Gibson and Nobel, 1986; Godýnez-Alvarez *et al.,* 2002; Godý´nez-Alvarez, 2004).

1.2 Taxonomy

In *Species Plantarum*, all the species of cactus were placed under a sole genus *Cactus* L. But later, the cacti were divided into many genera. According to current classification these species belong to the Division: Magnoliophyta; Class: Magnoliopsida; Order: Caryophyllales; Family: Cactaceae; subfamily: Cactoideae.

1.3 Characteristics

The characteristic feature of *Cactus* is the presence of areoles which give rise to spines and flowers. The stem is fluted which helps in the better absorption of water during the occasional rainfall, the stored water later helps to survive the plant during extended drought. The plant has scotoactive stomata which open during night, hence helpful to check the water loss avoiding the transpiration during the day. Cactus lacks true leaves, because leaves modified into spines which give protection to the plants from herbivores and also assist to reduce transpiration, and the broad green stem carries out the photosynthesis. Its habit is variable; *Pachycereus pringlei* and *Blossfeldia liliputiana* are considered as tallest and smallest, respectively.

1.4 Distribution

The cactus grows as wild in the arid and semi-arid regions of the world. Mainly it is distributed in South, North and Central America. Few endemic species are found in the Madagascar region. The cactus grows extensively in the desert regions of the Sonora desert of Arizona and Northern Mexico. In India, *Opuntia ficus-indica* grows in abundance as wild in Rajasthan and considered as an agriculturally important plant of non-irrigated lands for this dry region. The indigenous population generally used this plant as food, fodder, and dye. It is also popular among the tribes as a source of energy, and contemporary ecologists consider it an important player in phytoremediation.

1.5 Various uses of cactus

1.5.1 As fruits

The fruits of cactus vary in weight from 50 to 150 gm depending on the environmental conditions and its origin. It's a berry with oval and elongated shape. The pericarp is very thick and the pulp is the consumable part of it. It consists of mainly water, which is 84 to 90%, and reducing sugar 10 to 15%. The fruits of *Opuntia ficus*

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indica are widely used as eatable. The fruit is also known as 'dragon fruit' or pitaya. Some of the cactus is widely cultivated for the fruit *e.g. Opuntia tuna*, *O. streptacantha* and *O. cardona*. The *Carnegiea gigantean* produces good quality of fruits (Plate 1; Figure 1). The *Cereus peruvianus* produces fruit which is of large size like an apple, berry sized. The fruit exhibit an excellent aromatic smell due to S-linalool and linalool derivatives. The fruits of cactus have a short shelf life, this is due to low acidity and high pH value that varies from 5.3 to 7.1. Due to this reason the cactus fruit cannot be stored. Since storage of cactus fruit can be enhanced by reducing the microbial content and by packing the peeled fruits in the special films for 8 days at 41ºC (Shetty *et al*., 2012).

Escontria chiotilla fruit 'jotilla' has a sweet-sour taste which becomes extremely tasty when frozen with sugar; also a proximal analysis determines its suitability for marmalades and jams as well as dressing products (Yañez-Lopez *et al*., 2005). Indole butyric acid (IBA) and Gibrellic acid (GA) are sprayed onto the flowers to produce seedless by inducing emasculation. Ethephon is generally used in 500 to 250 ppm concentration for the ripening of cactus fruit before 9 days of natural ripening (Esparza *et al*., 2004). Fruits have vitamins, amino acid and minerals. The usual edible part of the fruit is 54.18% (Bekir, 2004). Cactus contains betalains pigment which gives colour and used in making ice creams and yoghurts (Stintzing and Carle, 2005).

1.5.2 As vegetable

Figure 1: Cactus growing in natural condition.

The young or tender vegetative parts of wild cactus which lack glochids and spines are used as vegetables and salads (Russell and Felker, 1987).

1.5.3 As fodder

The prickly pears are the best crops found widely and they are also grown at the borders of the field to protect many other crops (Mondragón-Jacobo and Pérez-González, 2001). Before it is fed to cattle the spines are burnt and then used in feeding cattle in drought prone areas. Though it is low in protein content, but it is used in semi-arid regions to feed dairy cattle fodder. It imparts good flavour to milk and imparts good colour to butter (Salim *et al*., 2009). If this is replaced with corn and Tifton hay with forage cactus (*Opuntia ficus-indica*).

1.6 Medicinal uses

1.6.1 Anti cancerous effects of cactus

The anti-cancer effect was shown by the cactus pear fruit extract, and found that it inhibits the proliferation of *in vitro* cervical, ovarian and bladder cancer cell lines. It was also reported inhibitory to the growth of cancerous cells in the mice ovarian culture model *in vivo*. The inhibition dose of cactus in these effects was 1, 5, 10 and 25% cactus pear extract, and the time required was 1, 2, or 5 days that was depended on *in vitro* cultured cancer cells. The cactus pear extract when administrated intra-peritoneal in mice failed to show toxic effect on mice but it had the chemo preventive effect comparable to the synthetic chemo preventive agent, *i.e.,* Retinoid N-(4-Hydroxyphrenyl) retinamide (4-HPR) which is used in ovarian cancer (Zou *et al*., 2005; Camacho-Chab *et al*., 2016).

1.6.2 Antioxidant effects

The antioxidative present in the cactus exerts many beneficial health effects (Steinmetz and Potter, 1996; Leenen *et al.,* 2000; Martinez and Moreno*,* 2000; Tesoriere *et al.,* 2004; Tesoriere *et al.* 2005; Fernández-López *et al*., 2010). The fruits and vegetative parts of different varieties of cactus, largely *Opuntia* contains many antioxidants *e.g.* Ascorbic acid, carotenoid, reduced glutathione, cysteine, taurine, and flavonoids such as quercetin, kaempferol and isorhamnetin (Tesoriere *et al.,* 2005). The colorless phenolics and betalains have the beneficial activity of neutralizing reactive oxidative species such as singlet oxygen, hydrogen peroxide or may cause suppression of xanthine oxidase system (Park *et al*., 2001; Psomiadou and Tsimidou, 2001; Tesoriere *et al*., 2003; Dok-Go *et al*., 2003; Gentile *et al.*, 2004; Siriwardhana and Jeon, 2004; Tesoriere *et al*., 2004; Tesoriere *et al*., 2005; Stintzing *et al*., 2005; Moussa-Ayoub *et al*., 2011; Jorge *et al*., 2013; Khatabi *et al*., 2016). The antioxidants such as polyphenolics are cardio protective, anticancer, antiviral or anti-allergenic properties (Carbó *et al*., 1999; Tapiero *et al*., 2002; Chougui *et al*., 2013). These polyphenolics of cactus increases the intracellular calcium ions in endoplasmic reticulum this perturb the expression of interleukin 2 which is associated with human T cells (Aires *et al.,* 2004; Gallegos-Infante *et al*., 2009; Rebah and Siddeeg, 2017).

Plate 1: Differet types of Cactus: a. *Nopalea coccinellifera*, b. *Cephalocereus senilis*, c. *Cereus giganteus*, d. *Cereus giganteus*, e. *Mammillaria longimamma*, f. *Rhipsalis paradoxa*.

Table 1: Different types of cacti and their diverse uses (Anaya-Pérez, 2001; Ortega-Baes *et al.,* 2010)

Species	Uses
Carnegiea gigantean (Saguaro)	Its fruit is used to make wine and jelly. Its fruit is called Papago. It forms the people's diet.
Echinocactus sp. (Barrel cacti)	It is ornamental cacti. Its spines are used to form fishhooks.
Echinocereus enneacanthus (Strawberry hedgehog)	Fruit can be eaten raw. They are known for its tastier fruits.
Echinocereus stramineus (Straw-coloured hedgehog)	They are also known for its tastier fruit whose taste resembles strawberries.
Echinopsis chiloensis (Quiska)	It is used to make rainsticks.
Epithelantha bokei (Button cactus)	The fruits are used as a diet for cattle.
Escontria chiotilla (Jiotilla)	They have tasty fruit 'jiotilla' which can be eaten raw.
Ferocactus hamatacanthus (Texas barrel cactus)	Its fruit taste like lemon.
Ferocactus wislizenii (Candy barrel)	From the fruit candies are made and. Animals consume the fruit.
Hylocereus undatus (Pitaya, dragon fruit, strawberry pear)	The red and green fruits are attractive and can be consumed and can be used in the manufacture of wine.
Lophocereus schottii (Senita)	The stem of it has certain constituents which are used to treat cancer and diabetes.
Lophophora williamsii (Peyote, mescal buttons)	Plant contains mescaline, a hallucinogenic drug capable of inducing visions.
Myrtillocactus geometrizans (Blue myrtle, whortleberry cactus)	Its fruit is blue in color and can be eaten with a great taste.
Nopalea cochenillifera (Nopal cactus)	This plant is the host for the female cochineal insect
Opuntia acanthocarpa (Buckhorn cholla)	Flowers are eaten of this cactus.
Opuntia ficus-indica (Indian fig)	The fruit is called tuna is edible and sweet in taste. It is used to make jams and jellies.
Opuntia spinosior (Cane cholla)	The plant when dead the skeleton is used to make furniture.
Pachycereus pecten-aboriginum (Hairbrush cactus)	The fruit has bur so this is used as hairbrush.
Peniocereus greggii (Queen of the night)	The roots and fruits are consumed and are respiratory diseases.
Pereskia aculeata (Barbados gooseberry)	Fruit is yellow and used in making jams and jellies.
Schlumbergera truncatus (Christmas cactus)	It is the most widely cultivated cactus.
Selenicereus grandiflorus (Night-Blooming cereus)	The stems and flowers are used to treat infections of urinary tract and homeopathic medicines are made from them to treat asthma.
Stenocereus gummosus (Pitahaya agria)	The stem of this cactus has certain constituents such that when it is crushed and added to the nearby lake or ponds, it kills or stuns the fish and this helps in fishing.
Stenocereus thurberi (Organ pipe cactus)	Fruits are edible.
Trichocereus pachanoi (San pedro cactus)	The cactus has certain constituents which act as a hallucinogen and help in inducing vision

1.6.3 Antiviral effect

The intracellular replication of DNA and RNA viruses, *e.g*., herpes simplex virus type 2, equine herpes virus, pseudorabies virus, influenza virus, respiratory syncitial virus and HIV can be stopped by the cactus stem extract of *Opuntia streptacantha* in mice and humans (Ahmad *et al*., 1996). However, the inhibitory substances present in the cactus stem extract were not studied properly.

1.6.4 Anti-inflammatory effect

Genus *Opuntia* has been used for its analgesic and anti-inflammatory effect. The fruit extract of *Opuntia dillenii* (Loro *et al*., 1999) and the lyophilized cladode have been used for anti-inflammatory effect. The phytosterols of fruit and stem extract is used in this. Beta-sitosterol is the component of stem extract which exhibits anti-inflammatory effect. By the help of the fruit and stem extracts the gastric lesions in mice were reduced remarkably (Park *et al*., 2001).

1.6.5 Antidiabetic effect

In Mexico the prickly pear cactus stems are used to treat diabetes (López *et al*., 1995). Now a day Italian herbalists are using *Opuntia* species to reduce glycemia (Cicero *et al.,* 2004). The prickly pear extract exerts a hypoglycemic effect on non-diabetic, diabetic induced rats and diabetic humans (Ibanez-Camacho *et al*., 1979; Ibanez-Camacho *et al*., 1983; Frati-Munari *et al*., 1988; Frati *et al*., 1990). When the insulin and purified extract of cactus *Opuntia fuliginosa* was given to the rats this reduced the blood glucose and also the glycated hemoglobin level was reduced to normal (Daiaz *et al*., 1999).

1.6.6 Anti-hyperlipidemic and hypercholesterolemic effect

The reduction in cholesterol in humans and modification in low density lipoprotein (LDL) is caused by the intake of the cactus pear extract (Gurbachan and Felker, 1998; Fernandez *et al*., 1992; Frati,1990; Stintzing *et al*., 2001; Stintzing and Carle, 2006). When the lyophilized cladode extract of *Opuntia ficus indica* (1 g/kg) was given to rats for 30 days it was seen that rat had reduced cholesterol level, LDL, triglyceride plasma levels (Galeti *et al*., 2003).

1.7 The bioactive compounds and constituents of *Opuntia ficus indica*

According to El-Mostafa *et al*. (2014) *Opuntia ficus indica* is rich in Polyphenols, vitamins, polyunsaturated fatty acid and amino acid. The components of *Opuntia* have many health benefits and therapeutic effects. In sub-Saharan countries in the drug pharmacopeia the cactus flowers and fruits are used as an anti-ulcerogenic and anti-diarrheal agent. Flowers are used as an anti hemorrhoid agent. Cladode sap is used in the treatment of whooping cough.

The phytochemical rich products can be made by the extraction of bioactive compounds from the cactus by the help of solvents. The Polyphenols which has antioxidant and anti-inflammatory properties are found in abundant amount in *Opuntia ficus-indica* (Butera *et al*., 2002; Kuti, 2004). Alkaloids, indicaxanthin and neobetanin are also present in cactus (Valente *et al*., 2007). The cladode extract has polysaccharide which has antidiabetic and antiglycation effects (Yang *et al*., 2008).

1.7.1 Phenolic compounds

The polyphenols are found in abundance in the cactus. Structurally the polyphenols are having large number of phenolic groups attached to high molecular weight chemical groups, the polyphenol is an important constituent of cactus because of its antioxidant effect, anti-inflammation effect (Laughton *et al*., 1991), and prevention of cardiovascular dysfunction and neurodegenerative diseases. Flower contains gallic acid and 6-isorhamnetin 3-O-robinobioside in the concentration of to 4900 and 4269 mg/100 g of dry weight respectively (Clark *et al*., 1980; Ahmed *et al*., 2005; De Leo *et al*., 2010; Ammar *et al*., 2012). Gallic acid is known to DNA damage (Ginestra *et al.,* 2009) and also buffer free radical (Yen *et al*., 2002). The tumoral cells from lung and prostate cancer can kill by cytotoxic activity of Gallic acid (You and park, 2010). Many phenolic compounds are in the concentration of less than 10 mg/g. The seed of cactus also contains phenolic compounds like sinapoyl diglucoside, feruloyl derivatives, tannins *etc.* atconcentrations 48 to 89 mg/100 g (Chougui *et al*., 2013). The cactus also contains flavinoids *e.g.* Isoquercetin 39.67 mg/100 g, narcissin (137.1 mg/100 g), ferulic acid (34.77 mg/100 g), nicotiflorin (146.5 mg/100 g). The nicotiflorin is present in the cladode of *Opuntia ficus indica* is a very good neuroprotective. When taken in nanomolar concentration it provides protection against hypoxia glutamate or oxidative stress induced retinal cell death. Isorhamnetin is present in the cactus fruit peel. It has anticancer effect and it inhibit the epidermal growth factor-induced neoplastic cell transformation.

1.7.2 Fatty acid

The fatty acid presents in cactus are linoleic acid, linolenic acid, palmitic acid, oleic acid. These linoleic acid and linolenic acid are the polyunsaturated fatty acid and constitute the 67.7%, while these four are the major lipids of the cactus and they constitute the 90% of the lipids. The cactus fruits, seed and the fruit peel contains oleic acid, linolenic acid, palmetic acid (Ramadan, 2003; Ennouri, 2005). The omega 6 linoleic acid is the precursor of arachidonic acid and it exerts hypercholestrolemic effect. This also inhibits colon cancer (Soel *et al*., 2007). The omega 3 linolenic acid is also found in cactus and helpful in immunological disorders, diabetes, autoimmune disorders, heart diseases.

1.7.3 Sterols

The fruits of cactus yields β-sitosterol (6.75 to 21.1 g/kg amount) majorly from its pulp seed and peel (Ramadan, 2003). It also yields campesterol from the fruit in amount of 1.66 to 8.76 g/kg (Gharby *et al*., 2011). It also contains stigma sterol, avenasterol and lanosterol. The cladode oil and flower oil sterol composition is not known exactly till now.

1.7.4 Cactus as a coagulant

In the chemical method the alum is the mostly used coagulant but it has severe health problems like it causes Alzheimer's diseases (Martyn *et al*., 1989; Letterman and Pero, 1990), so this water cannot be used to irrigate the fields (Aizawa *et al*., 1990). Cactus can be used as a coagulant (Sellami *et al*., 2014). Cactus reduces the turbidity, COD, and heavy metal content in water. The cactus based biopolymer is made which is used as coagulant e.g. *Cactus latifera* cladode (Diaz *et al*., 1999) and in the *Opuntia cactus*, inner pads are taken out and then they are dried and grinded into fine powder of size 53-106 μm (Jadhav and Mahajan, 2014). For coagulation the 50 mg/l aluminium sulphate is used along with 2.5 mg/l of cactus polyelectrolytes (Ikeda *et al*., 2002). If 300 mg/l of cactus juice is added to the coagulation process the removal of turbidity of waste water from industries is enhanced to 15.1% (Adjeroud *et al*., 2015).

1.8 Ecological importance

1.8.1 Cactus in wastewater management

The water as it is a limited resource and it needs to be renewed so, that it can be used several times and meanwhile it should be better fitted for the use of living beings. The best renewable way for wastewater treatment is the use of a biomaterial. The one such biomaterial used in wastewater treatment is cactus. As the cactus is found in large number, so it can be widely used for this process. The cactus can be variously used as biosorbent, coagulant and biofilter. The cactus also has some enzymes which may help in the conversion of dyes which come from the textile industries. The cactus reduces the BOD, COD, turbidity, salinity of water. It also decreases the amount of heavy metals in the water (Carvalho Dos Santos and Lenzi, 2000).

The waste water from various sources is dumped out in the water bodies and other places hence according the characteristics of wastewater the waste water treatment is done. The waste water treatment can be done by three ways: 1) Physical method– by chromatography (ion absorption and absorption), membrane filtration; 2) Chemical method– by chemical oxidation of matter, coagulation of matter, electrochemical method; 3) Biological method– by batch reactor, biofilter. But the chemical method has a serious problem associated with it is that the chemical traces are retained in the body of animals and humans which consume this water and it gets accumulated in the food chain which causes serious health problems (Mallevialle *et al*., 1984) or certain chemical reactions may occur between the chemicals and hence certain health problems (Gebresamuel and Gebre-Mariam, 2012). The physical method of absorption technique is a very expensive method and after the treatment the carbon is needed to be restored (Ginos *et al*., 2006).

The chemical components of cactus are very useful and they are not harmful (Gebresamuel and Gebre-Mariam, 2012). The polysaccharide is the major mucilage component (Garvie, 2006; Sellami *et al*., 2014) and Ca and Mg ions are the gelatin components of mucilage (Sepúlveda *et al*., 2007). The mucilage has a good water holding capacity (Trachtenberg and Mayer, 2003). The carbohydrate present are l-arainose, dgalactose, l-rhamnose, d-xylose and galacturonic acid (Vijayaraghavan *et al*., 2011; Swathi *et al*., 2014). In this the galactouronic acid is the main coagulant its structure has a bridge which absorb particles and the functional group present are helpful in flocculation process.

1.8.2 As biosorbent

The activated carbon is mostly used for the absorption process, but because it is very expensive and need to be restored after every process so instead of it biomaterial are used like algae bacteria, yeast, fungi, shells of peanut, soybean hulls, *etc.,* for the removal of heavy metal (Madrid *et al*., 1998; Marshall *et al*., 1999; Vaughan *et al*., 2001; Wafwoyo *et al*., 1999). The removal of heavy metals such as Fe, Cd, Cu by *Opuntia ficus indica*. The removal of Cu(II) by biochar of *Opuntia ficus indica* fibers at pH=3.

2. Conclusion

On the basis of several studies, including *in vitro* and *in vivo* approaches on cacti is evident that this invariably neglected, but pleasant plant of the desert has various benefits related to health benefits besideits utilization as food and fodder. The medicinal value exists in its antidiabetic nature, anti-hyperlipidemic properties, ability to slow down cell proliferation. Its phytochemical composition includes beneficial antioxidants, vitamins, and protective peptides. In ethnomedicinal practices, this plant has been widely utilized for various purposes of the local population as it is one of the most widespread plants. Though numerous cacti have been found in different regions of India yet in the contemporary era of phytomedicines, it is one of the least explored plants despite of having great economical value. Now the time has come to recognize the importance of *Cactus* identical to *Aloe vera* so that our traditional as well as modern plant based medicinal systems get one more miraculous plant to their treasure (Alam *et al*., 2019). In this review, an attempt has been made to compile the overall account on Cactus with special reference to its medicinal properties. This study would be helpful to the researches that are associated with the production of phytomedicines and neutraceuticals.

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Conflict of interest

The authors declare that there are no conflicts of interest in the course of conducting the research. All the authors had final decision regarding the manuscript and decision to submit the findings for publication.

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