J Food Sci Technol (September–October 2012) 49(5):530–536
DOI 10.1007/s13197-011-0462-5

REVIEW

Cactus: a medicinal food

Anoop A. Shetty · M. K. Rana · S. P. Preetham

Revised: 21 June 2011 / Accepted: 5 July 2011 / Published online: 16 July 2011
© Association of Food Scientists & Technologists (India) 2011

Abstract With excellent quality and flavour of fresh fruits, young leaves of cactus serve as nutritious vegetable and salad dish and the immature fruits for making mock-gherkins. Cactus, with high water use efficiency produce forage for animals, vegetables, and fruits with 14% glucose. Traditionally cactus used as a valuable health supporting nutrient and it also has applications in pharmaceutical industries. Cactus with number of uses has immense potential to be the food of future.

Keywords Cactus · Opuntia · Uses · Food · Medicine

Introduction

Cactus (plural: cacti, cactuses, or cactus) is a member of the succulent plant family Cactaceae. They are often used as ornamental plants, but many are also cultivated as crop plants. Cacti are almost exclusively 'new world' plants. This means that they are native only to North America, South America, and the West Indies. Many cacti grown as wild plants in arid and semiarid regions of India. In Mexico, USA, Spain, Italy and northern Africa, cactus form an important part of the people's dietary requirement. With excellent quality and flavour of fresh fruits, its young leaves serve as nutritious vegetable and salad dish and the immature fruits for making mock-gherkins.

The high water use efficiency of cactus is attributed to Crassulacean Acid Metabolism (CAM) which is present in rapidly growing cactus species such as *Opuntia ficus-indica*, *O. megacantha*, and *O. amychlea* (Cactaceae) that produce forage for animals, vegetables, and fruits with 14% glucose (FAO 1996). Cacti are distinctive and unusual plants, which are adapted to extremely arid and hot environments, showing a wide range of anatomical and physiological features which conserve water. Their stems have expanded into green succulent structures containing the chlorophyll necessary for life and growth, while the leaves have become the spines for which cacti are so well known.

Importance

In India an important part of the population is settled in rainfed dry areas which need perennial vegetation to protect them from erosion using drought hardy and economically viable plants. cacti seem to be an option to sustain livelihood, reduce poverty and generate employment opportunities. Cactus is drought tolerant due to its CO2 fixation capacity (CAM), it is well suited to dry areas, where it can be used as an alternative food and fodder, as well as live fence to protect agricultural fields. In the seventh century the British introduced the cactus to India for cochineal dye production but these plantations gradually

A. A. Shetty (✉)
Department of Vegetable Science,
G.B. Pant University of Agriculture and Technology,
Pantnagar 263145, India
e-mail: anoopshettyforyou@gmail.com

M. K. Rana
Department of Vegetable Science,
CCS Haryana Agricultural University,
Hisar 125004, India

S. P. Preetham
Department of Horticulture,
G.B. Pant University of Agriculture and Technology,
Pantnagar 263145, India

disappeared due to pests and flooding of the areas. Recent attempts to introduce cultivated cactus pear started late in the 1980's (Singh 2006). Pitaya (*Stenocereus griseus*) is a cactus fruit used as a complementary part of diet since ancient times in Southern Mexico. In this region approximately 30 types of Pitayas like Amarilla, Jarra, Melon, Crema, and Olla have been identified. Olla and Jarra showed the best quality attributes for the fresh and processed market (Yanez et al. 2005). Some countries, such as Australia, have water restrictions in many cities, so drought-resistant plants are increasing in popularity.

Botanical classification

Kingdom: Plantae
Division : Magnoliophyta
Class : Magnoliopsida
Order : Caryophyllales
Family : Cactaceae

Cactus is commonly known as prickly pears having about 130 genera and 1,500 species of cactaceae. Cacti exist in a wide range of shapes and sizes. The tallest is *Pachycereus pringlei,* with a maximum recorded height of 19.2 m, and the smallest is *Blossfeldia liliputiana*, only about 1 cm diameter at maturity. Cactus flowers are large and like the spines and branches arise from areoles. Many cactus species are night blooming, as they are pollinated by nocturnal insects or small animals, principally moths and bats. Numerous species have entered widespread cultivation, including members of Echinopsis, Mammillaria and Cereus among others. *Opuntia ficus-indica* is the most important cactus species in agriculture today and the first fruit crop especially adapted to semi-arid and non-irrigated lands. It has usefulness as food, fodder, dye, source of energy and has role in ecosystem remediation (Small and Catling 2004). Some of the useful species of cactus are given in Table 1.

Medicinal uses

Although traditionally used as a valuable health supporting nutrient, the vegetative parts of *Opuntia* spp. are scarcely used in modern nutrition and medicine. It also has applications in pharmaceutical industries (Stintzing and Carle 2005). Peyote (*Lophophora williamsii*) extracts have been associated with stimulating the central nervous system and regulating blood pressure, sleep, hunger and thirst (Franco et al. 2003). One of the most known cacti, since remote times by its use as hallucinogen, is peyote (*Lophophora williamsii*). The Peyote, *Lophophora williamsii*, is a well-known psychoactive agent used by Native Americans in the Southwest of the United States of America. Some species of Echinopsis (previously Trichocereus) also have psychoactive properties. It is suggested that Opuntia streptacantha dialysate could be considered as a new approach in treating non-insulin dependent diabetes mellitus (NIDDM) (Castaneda et al. 1997). Prickly pear is widely used as folk medicine for burned wound, oedema and indigestion and it is found that the effect of fruit extract is better than those of stem extract (Choi et al. 2002). Cactus pear fruit contains vitamin C and the radical scavenging properties. Consumption of cactus pear fruit positively affects the body redox balance, decreases oxidative damage to lipids and improves antioxidant status in healthy humans. Supplementation of vitamin C at a comparable dosage enhances overall antioxidant defense but does not significantly affect body oxidative stress (Tesoriere et al. 2004; Nalin and Jeon 2004). A study of antioxidant compounds in cactus pear fruits revealed that kaempferol was found in green skinned, purple skinned and red skinned varieties and isorhamnetin in green skinned and purple skinned varieties the red skinned fruit contained the most ascorbic acid and the yellow skinned fruits the most carotenoids (Kuti 2004). Thermal treatments increased the extractability of these pigments and the antioxidant activity was related to the carotenoid concentration. Total phenolic content decreased after the thermal treatments; however this result had little effect on the antioxidant activity (Jaramillo et al. 2003). A study revealed that both antioxidative and DNA damage-reduction activities are increased with increasing cactus pear fruits extract (CPFE). This demonstrates that the antioxidative and DNA damage-reduction efficacy of CPFE constituents as potential sources of raw material for pharmaceutical and functional food industries (Siriwrdhana et al. 2006). Arizona cactus pear extracts effectively inhibited cell growth in several different immortalized and cancer cell cultures, suppressed tumour growth in nude mice and modulate expression of tumour-related genes. The mechanism of the anticancer effects of cactus pear extracts needs to be further studied (Zou et al. 2005). The seeds of cordon cactus (*Pachycereus pringlei*) are edible and highly nutritious and plants have been used in traditional medicine (Holguin et al. 1993). A study revealed that supplementation with cactus pear oil or cactus pear seeds is useful in reducing the serum cholesterol level and thus reducing the atherogenic risk factors in rats (Ennouri et al. 2007).

A novel food product (NeOpuntia®- a trademark of Bio Serae Laboratories) which is a mixture of both soluble and insoluble fibers made from dehydrated leaves of the cactus *Opuntia ficus-indica* is found to have hypolipaemic properties and hence useful for patients

Table 1 Different species of cacti and their uses

Carnegiea gigantean (Saguaro):	Fruit pulp is processed into jelly and wine. It is part of Papago Indian's diet. Seeds are also ground and eaten.
Echinocactus sp. (Barrel Cacti):	The spines of this genus were fashioned into phonograph needles and fishhooks.
Echinocereus enneacanthus (Strawberry Hedgehog):	Edible fruit tastes similar to strawberries.
Echinocereus stramineus (Straw-colored Hedgehog):	Edible fruit tastes similar to strawberries.
Echinopsis chiloensis (Quiska):	Chilean cactus used in the manufacture of rainsticks.
Epithelantha bokei (Button Cactus):	Edible fruits are fed to cattle.
Escontria chiotilla (Jiotilla):	This species produces edible fruits known as jiotilla.
Ferocactus hamatacanthus (Texas Barrel Cactus):	Juicy, brown fruit is used as lemons and limes.
Ferocactus wislizenii (Candy Barrel):	Animals eat the fruit. Stems and fruits used to make cactus candy.
Hylocereus undatus (Pitaya, Dragon Fruit, Strawberry Pear):	Bright red or pink fruit with green scales is both attractive and edible. It is eaten raw or made into wine and other drinks
Lophocereus schottii (Senita):	Stem processed into drugs to fight cancer and diabetes.
Lophophora williamsii (Peyote, Mescal Buttons):	Plant contains mescaline, a hallucinogenic drug capable of inducing visions.
Myrtillocactus geometrizans (Blue Myrtle, Whortleberry Cactus):	Blue fruit resembling a blueberry is edible.
Nopalea cochenillifera (Nopal Cactus):	Plant used as a host for the female cochineal insect *(Dactylopius coccus)*. Cochineal, a crimson dye, is processed from the body of this insect.
Opuntia acanthocarpa (Buckhorn Cholla):	Pima Indians steamed and ate flower buds.
Opuntia ficus-indica (Indian Fig):	The edible fruit of this cactus, commonly known as a tuna has a sweet taste similar to watermelon. Fruits also are processed into jams and jellies.
Opuntia spinosior (Cane Cholla):	Skeleton of dead plants used for making furniture.
Pachycereus pecten-aboriginum (Hairbrush Cactus):	Indians used the bur-like fruit of this cactus as a hairbrush.
Peniocereus greggii (Queen of the Night):	Edible root and fruit eaten by Indians. Poultice reportedly used for respiratory ills.
Pereskia aculeata (Barbados Gooseberry):	The small, yellow fruit used in jellys and preserves. Fruit is juicy and slightly acidic.
Schlumbergera truncatus (Christmas Cactus):	Perhaps the most commercially grown cactus.
Selenicereus grandiflorus (Night-Blooming Cereus):	Stems and flowers processed into homeopathic medicine for urinary tract infections and angina. Reported to have a digitalis-like effect on the heart.
Stenocereus gummosus (Pitahaya agria):	Stems of this cactus were crushed and thrown into water by natives. Substances in the cactus act as a fish poison and stun fish. Natives using this method of fishing were all happy to gather the abundant harvest.
Stenocereus thurberi (Organ Pipe Cactus):	Fruits are edible.
Trichocereus pachanoi (San Pedro Cactus):	Plant contains mescaline, a hallucinogenic drug capable of inducing visions.

Stintzing and Carle 2006; Yanez et al. 2004; Yanez et al. 2005; Singh 2006; http://en.wikipedia.org

with lipid metabolism disorders. The stems of *Selenicereus grandiflorus* and other species contains a glucoside which, in extract form or tinctures, constitutes a diuretic and also have cardiac properties. The stems of the Buckhorn Cholla were burned, and the ashes were applied to cuts and burns to aid in the healing process.

Use as fruit

Cacti such as the prickly pear and Hylocereus bear edible fruits, which produces Dragon fruit or Pitaya. The fruits of *Opuntia ficus-indica* are known widely. Nevertheless, even when producing the sweetest fruit of cactus, the chumbera is not the only cactus with edible fruit. Other species of Opuntia, like *Opuntia tuna*, *streptacantha* and *cardona*, are also usually cultivated with the same purpose. The fruits of different Cereus species and *Hylocereus undatus* are also consumed. The bluish berries of *Myrtillocactus geometrizans* are sold in Mexican markets with the name of garambullos. The fruits of *Carnegiea gigantea* are also considered of excellent quality. Koubo (*Cereus peruvianus*) is a commercially grown columnar cactus that produces an apple sized, berry like, edible fruit. The unique aroma of this fruit is largely due to S- linalool and linalool derivatives. Enzyme activity levels were negligible in green immature

fruits and increased with the fruit development and during storage, concomitant with the timing of linalool accumulation in fruits (Strit et al. 2004). Jotilla, a fruit of cactus tree *Escontria chiotilla* is a non-climacteric fruit with sour-sweet flavour. Its pH is 4.2 with 10–12 degrees Brix, which makes it tasty as natural dessert, minimally processed product, frozen with sugar and also a proximal analysis determines its suitability for marmalades and jams as well as dressing products (Yanez et al. 2004).Out of season fruits were regular in size and per cent flesh with only a slight reduction in total soluble solid content. Seedless fruits are obtained by emasculating flowers 2 days before bloom and by spraying indole butyric acid and gibberellic acid (Corrales and Hernandez 2005). Ethaphon is used for ripening of the cactus pear fruits. Ethaphon at the concentration of 500 and 250 ppm induced the beginning of fruit veraison 9 and 5 days before the natural ripening (Esparza et al. 2006). Cactus plantations in semiarid lands produce large quantities of cactus fruits with short shelf lives in sparsely populated areas where production rapidly surpasses demand. Improvements in shelf life are needed for following reasons (Rodriguez et al. 2005):

1. To permit international shipments by refrigerated ship of approximately 3 week duration.
2. To be compatible with 2 °C fruit fly quarantine treatments.
3. To function without the use of fungicide as none are currently registered and as registration for additional minor crops is not likely.

Fruits are rich in sugars, vitamins, minerals and amino acids. Fruit weight of cactus pear varied from 80 g to 140 g and average edible portion was 54.18% (Bekir 2006). Cactus pear is a food of neutraceutical and functional importance. The pulp yields of cactus pear fruits were approximately 62% and the total and reducing sugar contents were approximately 9 and 8% respectively. Ascorbic acid and beta carotene were present in moderate levels (14.7 mg/100 g and 334.0 micro g/100 g respectively) (Ghaleb et al. 2003). The total pectin content of cactus pear ranged from 5.32 to 14.19%, while the mucilage content varied between 3.78 and 8.5% (Pena and Sanchez 2006). Cactus fruits are considered to be rich source of betalain pigments and coloured cactus fruit concentrates are used in yoghurt and ice cream (Stintzing and Carle 2006). Purple fruits are a source of betalains, a potential antioxidant as well as a potential colorant similar to the pigment obtained from red beet which is widely used in the food industry (Saenz 2006). It was found that the cactus pear cultivar gialla contains 13 kinds of betaxanthins (Kugler et al. 2007a; Kugler et al. 2007b). In *Opuntia undulata* and *Opuntia ficus-indica* both betacyanins and betaxanthins were identified, while in *Opuntia stricta* fruits only betacyanins (betanin and isobetanin) were detected. *Opuntia stricta* fruits showed the highest betacyanin content i.e., 80 mg/100 g fresh fruit (Casteller et al. 2003) (Table 2).

Unfortunately, the low acidity and the high soluble solids content make the fruit very attractive for growth of microorganisms requiring a thermal treatment (>115.5 °C) to obtain good control of the microbial invasion. Cold storage maintained fruit firmness and reduced water loss and fungal decay (Ochoa et al. 2006). Hot water treatment was highly beneficial in reducing chlling injury, fungal development and visual quality and the temperature of 2 °C approved for control of fruit fly would not cause chilling injury (Rodriguez et al. 2005). The respiration rate and tissue permeance decreased as the RH is increased. RH in the range of 65 to 90% has a marked effect on the rate of gas exchange, especially for CO2, and consequently on the gas equilibrium inside modified atmosphere packages (Yahia et al. 2005). Fresh prickly pear cactus stems can be stored up to 32 days in modified atmosphere package (MAP) with CO2 concentration of 20 kPa without significant increase in microbial population. The shelf life of fresh cut cactus pear, packed in bidirectional polypropylene bags and stored at 4 °C can be extended up to

Table 2 Composition of Opuntia fruits

Parameter	Content in fresh fruit mass
Pulp (%)	43–57
Seeds (%)	2–10
Peel (%)	33–55
Moisture (%)	84–90
TSS(° Brix)	12–17
pH	5.3–7.1
Protein (%)	0.2–1.6
Fat (%)	0.09–0.7
Fibre (%)	0.02–3.1
Ash (%)	0.3–1
Total sugars (%)	10–17
Pectin (%)	0.19
Vitamin C (mg·100 g^{-1})	1–41
β-carotene	In traces
Calorific value (K cal.100 g^{-1})	47.30
Calcium (mg·100 g^{-1})	12.8–59
Magnesium (mg·100 g^{-1})	16.1–98.4
Sodium (mg·100 g^{-1})	0.6–1.1
Potassium (mg·100 g^{-1})	90–217
Phosphorus (mg·100 g^{-1})	15–32.8
Iron (mg·100 g^{-1})	0.4–1.5

Askar and El-Samahy 1981; Nieddu et al. 1997; Sawaya et al. 1983; Stintzing et al. 2001

20 days without affecting the quality (Corrales et al. 2006), whereas storage at 2 °C was optimum for preserving the minimally processed up to 12 days (Anorve et al. 2006a). Minimal processing of cactus fruits is important and has a great potential because it offers the opportunity to differentiate and add value to cactus pears and nepalitos as long as nutritive quality, sensorial quality, and safety are guaranteed. Minimally processed cactus (*Opuntia ficus-indica*) cladodes have a shelf life of 1–2 days at room temperature, which can be extended to 7 days at 5 °C. The main drawbacks that shorten the shelf life of cactus cladodes are browning and mucilage secretion (Quevedo et al. 2005). Controlled atmosphere storage of minimally processed cactus pear fruits at 2 °C in 10% CO2 showed high values of visual quality, soluble sugar content and sugar content, as well as a reduced tendency toward browning. Under these conditions the quality of minimally processed fruits was preserved up to 20 days (Anorve et al. 2006b).

The fresh juice is clarified by ultrafiltration and then it is clarified by osmotic distillation upto a TSS content of 61° Brix (Cassano et al. 2007). Comminution with pledged filtration effectively reduced the loss in polysaccharide content. Homogenization with higher pressure and shorter pulping time effectively retained the polysaccharide content. The peeling process had little effect on the polysaccharide content, suggesting that the peel should be kept to preserve the nutrients in cactus (Wu et al. 2006).

Use as vegetable

Different parts of cacti are used as vegetable and also for salad purposes. The young tender spring vegetative growth of wild cactus (nopalitos) has been extensively consumed by Hispanics during Lent (Russell and Felker 1987), only recently plantations of spineless cacti been established in Texas for nopalito production. An improved nopalito cultivar with greater year round production, lack of spines, lack of glochids (nearly microscopic spines), and low mucilage is available as Texas A and M 1308. In contrast, spineless Opuntia plantations for nopalito production have been common in central Mexico (Milpa Alta) for many years (Russell and Felker 1987). Vegetable clone 1308 can yield biomass production of 80–90 t/ha/year. In some of the American and African countries its produce is used as vegetable.

Use as fodder

Prickly pears can be a good alternative forage crop on land that is presently deemed marginal for other crops (Mondragon and Perez 2001). The spines can be burnt before feeding the cattle. In mexico and south west Texas, propane torches known as pear burners have been used to burn off cactus spines. Though cactus leaves are low in proteins but they can serve as a very good source of roughages, especially in rainfed and severe drought-prone areas. *Nopalea cochenillifera* (*Opuntia cochenillifera*) is the species widely used in semiarid regions as a forage crop (Brasil et al. 2005). The material not sold in the vegetable market is being used as dairy cattle fodder. It imparts better flavour and quality to the milk and also enhances the colour of the butter. A study revealed that although milk production and composition were not affected by replacing corn and tifton hay with forage cactus (*Opuntia ficus-indica*) significant changes were found in the milk profile of medium and long chain fatty acids by increasing the proportion of forage cactus in the diet (Oliveira et al. 2007). In Texas the primary use of cactus has been in times of drought when the spines have been burned off the cactus to feed cattle. A daily ration of 40 kg of cactus, 0.5 kg of mineral salts, and 0.5 kg of protein supplement is sufficient to permit excellent live weight gain, reproduction, and lactation from nursing cattle (Maltsberger 1991). The fruits of two columnar cacti, cardon dato (*Stenocereus griseus*) and cardon lefaria (*Cereus repandus*) have good potential as food and feed in arid zones (Emaldi et al. 2004).

Other uses

Its other uses include preparations of mock-gherkins, jams and syrups, soap from its leaves, alcoholic drinks, seeds for honey and cheese production. Cactus pears from *Opuntia stricta* are considered as a potential source natural red colourants (Casteller et al. 2003). A study about the use of prickly pear cactus mucilage as an edible coating to extend the shelf life of strawberries revealed that use of mucilage coatings leads to increased strawberry shelf life (Del-Valle et al. 2005). Opuntia genus is widely known for its mucilage production. Mucilage, a complex carbohydrate with a great capacity to absorb water, should be considered a potential source of industrial hydrocolloid. Mucilage contains varying proportions of L-arabinose, D-galactose, L-rhamnose, and D-xylose, as well as galacturonic acid. The mucilage content found in the cactus cladodes is influenced not only by the management of the crop but also on the temperature, irrigation and the rain. In some countries, small farmers use cactus mucilage to purify drinking water. Another traditional use is for improving house paint. Recently, a cactus cladode extract was tested to improve water infiltration in soil (Saenz et al. 2004). The cladodes dehydrated and ground into powder are source of dietary fiber which may be used as natural ingredient in

different foods to enhance their beneficial properties. Cactus mucilage can be used as natural thickener. All these components could be used as natural ingredients in foods to enhance their healthy properties. The new functions of some compounds open new possibilities for adding value to the cactus pear, a new crop for semiarid regions of the world (Saenz 2006). Cacti are commonly used for fencing material where there is a lack of either natural resources or financial means to construct a permanent fence.

In spite of considerable research on its nutritional importance, medicinal uses and food value, cacti remains to be underutilized and unexploited crop. Cactus with number of uses has immense potential to be the food of future.

References

Anorve MJ, Aquino BEN, Mercado SE (2006a) Effect of storage temperature on quality of minimally processed cactus pear. Acta Hortic 728:217–222

Anorve MJ, Aquino BEN, Mercado SE (2006b) Effect of controlled atmosphere on the preservation of cactus pears. Acta Hortic 728:211–216

Askar A, El-Samahy SK (1981) Chemical composition of prickly pear fruits. Dtsch Lebensm Rundsch 77:279–281

Bekir EA (2006) Cactus pear (*Opuntia ficus-indica*) in turkey: growing regions and pomological traits of cactus pear fruits. Acta Hortic 728:51–54

Brasil JN, Jereissati ES, Santos MRA, Campos FAP (2005) In vitro micropropagation of *Nopalea cochenillifera*(Cactaceae). J Appl Bot Food Qual 79(3):160–162

Cassano A, Conidi C, Timpone R, D-Avella M, Drioli E (2007) A membrane based process for the clarification and the concentration of the cactus pear juice. J Food Eng 80(3):914–921

Castaneda AI, Gonzalez SJ, Frati MAC (1997) Hypoglycemic effect of an Opuntia streptacantha Lemaire dialysate. J Prof Assoc Cactus Dev 2:73–75

Casteller R, Obon JM, Alacid M, Fernandez LJA (2003) Color properties and stability of betacyanins from Opuntia fruits. J Agric Food Chem 51:2772–2776

Choi et al (2002) Biological activities of the extracts from fruit and stem of prickly pear (*Opuntia ficus-indica* var. saboten) 2. Effects on dietary induced hyperlipidemia. Korean J Pharmacol 33:230–237

Corrales GJ, Hernandez SJL (2005) Post harvest quality changes of seedless and seeded cactus pear varieties. Rev Fitotecnia Mex 28 (1):9–16

Corrales GJ, Ayala VG, Franco EAM, Garcia OP (2006) Minimal processing of cactus pear and tender cactus cladodes. Acta Hortic 728:223–229

Del-Valle V, Hernandez MP, Guarda A, Galotto MJ (2005) Development of a cactus mucilage edible coating and its application to extend strawberry shelf life. Food Chem 91:751–756

Emaldi U, Nassar JM, Semprun C (2004) Physicochemical character and food value of two Venezuelan cactus fruits. Trop Sci 44 (3):105–107

Ennouri M, Fetoui H, Hammami M, Bourret E, Attia H, Zeghal N (2007) Effects of diet supplementation with cactus pear seeds and oil on serum and liver lipid parameters in rats. Food Chem 101:248–253

Esparza F, Esparza G, Macias FJ, Mendez GSJ (2006) Effect of ethaphon on ripening of cactus pear fruits. Acta Hortic 728:165–171

FAO (1996) In: Inglese et al (eds) Cactus pear cultivation and uses. FAO Publ., Rome

Franco MM, Gomez FR, Tamez GP, Castillo LL, Rodriguez PC (2003) In vitro immunopotentiating properties and tumour cell toxicity induced by *Lophophora williamsii* (peyote) cactus methanolic extract. Phytotherapy Res 17:1076–1081

Ghaleb ADS, Al-Mamary MA, Al-Habori MA (2003) Yield and major chemical components in fruits of wild cactus pear (*Opuntia ficus-indica*) grown in Yemen. Ann Agric Sci 41(1):193–198

Holguin G, Bowers R, Bashan Y (1993) The degeneration of cardon populations in Baja California Sur, Mexico. Cactus Succulent J 65:64–67

Jaramillo FME, Gonzalez CL, Cornejo MM, Dorantes AL, Gutierrez LGF, Hernandez SH (2003) Effect of thermal treatment on the antioxidant activity and content of carotenoids and phenolic compounds of cactus pear cladodes (*Opuntia ficus indica*). Food Sci Technol Int 9:271–278

Kugler F, Stintzing FC, Carle R (2007a) Evaluation of antioxidant capacity of betalainic fruits and vegetables. J Appl Bot Food Qual 81(1):69–76

Kugler F, Graneis S, Stintzing FC, Carle R (2007b) Studies on betaxanthin profiles of vegetables and fruits from the chenopodiaceae and cactaceae. Biosci 62(5/6):311–318

Kuti JO (2004) Antioxidant compounds from four Opuntia cactus pear fruits varieties. Food Chem 85(4):527–533

Maltsberger WA (1991) Feeding and supplementing prickly pear cactus to beef cattle. Proc. 2nd Annual Texas Prickly Pear Council, Kingsville, pp. 104–118

Mondragon JC, Perez GS (2001) Cactus(*Opuntia* spp) as forage. FAO Plant Prod Protect Paper 169:146

Nalin S, Jeon Y (2004) Antioxidative effect of cactus pear (*Opuntia ficus-indica*) fruit extract on lipid peroxidation inhibition in oils and emulsion model systems. Eur Food Res Technol 219:369–376

Nieddu G, Pau LD, Schirra M, D'hallewin G (1997) Chemical composition of fruit and seeds of cactus pears during early and late-induced crop ripening. Acta Hortic 438:105–111

Ochoa MJ, Leguizamon G, Uhart S (2006) Nitrogen availability and fruit yield generation in cactus pear (*Opuntia ficus-indica*): 4. Effects on fruit quality. Acta Hortic 728:137–144

Oliveira VSD, Ferreira MDA, Guim A, Modesto EC, Arnaud BL, Silva FMD (2007) Effects of replacing corn and tifton hay with forage cactus on milk production and composition of lactating dairy cows. Rev Bras Zootec 36(4):928–935

Pena VBC, Sanchez UBA (2006) Nopalito and cactus pear polysaccharides: mucilage and pectin. Acta Hortic 728:241–247

Quevedo PKL, Villegas OMA, Gonzalez RH, Rodriguez FA (2005) Quality of minimally processed cactus stems. Effect of temperature and browning inhibitiors. Rev Fitotecnia Mex 28 (3):261–270

Rodriguez S, Casoliba RM, Questa AG, Felker P (2005) Hot water treatment to reduce chilling injury and fungal development and improve visual quality of opuntia ficus indica fruit clones. J Arid Environ 63(2):366–378

Russell CE, Felker P (1987) The prickly-pears (*Opuntia* spp., Cactaceae): A source of human and animal food in semiarid regions. Econ Bot 41:433–445

Saenz C (2006) Opuntia spp. Bioactive compounds in foods: a plus for health. Acta Hortic 728:231–239

Saenz C, Sepulveda E, Matsuhiro B (2004) Opuntia spp. mucilages: a functional component with industrial perspectives. J Arid Environ 57(3):275–290

Sawaya WN, Khatchadourian HA, Safi WM, Al-Hammad HM (1983) Chemical characterization of prickly pear pulp, *Opuntia ficus-indica*, and the manufacturing of prickly pear jam. J Food Technol 18:183–193

Singh G (2006) An overview of cactus pear research and development in India. Acta Hortic 728:43–50

Siriwrdhana N, Shahidi F, Joen Y (2006) Potential antioxidative effects of cactus pear fruit extract on radical scavenging and DNA damage reduction in human peripheral lymphocytes. J food lipids 13(4):445–458

Small E, Catling PM (2004) Blossoming treasures of biodiversity 11. Cactus pear (*Opuntia ficus-indica*)- miracle of water conservation. Biodivers 5(1):27–31

Stintzing FC, Carle R (2005) Cactus stems: a review on their chemistry, technology, and uses. Mol Nutr Food Res 49 (2):175–194

Stintzing FC, Carle R (2006) Cactus fruits- more than just colour. Fluss Obst 73(8):430–434

Stintzing FC, Schieber A, Carle R (2001) Phytochemical and nutritional significance of cactus pear. Food Res Technol Int 212:396–407

Strit Y, Ninio R, Bar E, Golan E, Larkov O, Ravid U, Lewinsohn E (2004) S- linalool synthase activity in developing fruit of the columnar cactus koubo (Cereus peruvianus). Plant Sci 167 (6):1257–1262

Tesoriere T, Butera D, Pintaudi AM, Allegra M, Livrea MA (2004) Supplementation with cactus pear fruit decreases antioxidative stress in healthy humans: a comparative study with vitamin C. Am J Clin Nutr 80(2):391–395

Wu J et al (2006) Influence of spray drying pretreatment conditions on cactus soluble polysaccharide. J Shangai-Jiaotong 24 (1):90–93

Yahia EM, Guevera JC, Tijskens LMM, Cedeno L (2005) The effect of relative humidity on modified atmosphere packaging gas exchange. Acta Hortic 674:97–104

Yanez L et al (2004) Jiotilla plant (*Escontria chiotilla*) as a new resource native to South Mexico. Acta Hortic 632:69–74

Yanez L et al (2005) Quality attributes of different types of cactus pitaya fruits (*Stenocereus griseus*). Acta Hortic 682:645–650

Zou DM, Brewer M, Garcia F, Feugang JM, Wang J, Zang RY, Liu HG, Zou CP (2005) Cactus pear: a natural product in cancer chemoprevention. Nutr J 4(25):75–95