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Nutritional and medicinal use of Cactus pear (*Opuntia* spp.) cladodes and fruits

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TABLE OF CONTENTS

1. ABSTRACT

Natural products and health foods have recently received a lot of attention both by health professionals and the common population for improving overall well-being, as well as in the prevention of diseases including cancer. In this line, all types of fruits and vegetables have been re-evaluated and recognized as valuable sources of nutraceuticals. The great number of potentially active nutrients and their multifunctional properties make cactus pear (*Opuntia spp.*) fruits and cladodes perfect candidates for the production of health-promoting food and food supplements. Although traditionally appreciated for its pharmacological properties by the Native Americans, cactus pear is still hardly recognized because of insufficient scientific information. However, recent studies on *Opuntia spp*. have demonstrated cactus pear fruit and vegetative cladodes to be excellent candidates for the development of healthy food. Therefore, this review summarizes current knowledge on the chemical composition of *Opuntia* cacti with particular emphasis in its use as food and medicine.

2. INTRODUCTION

The growing demand for nutraceuticals is paralleled by an increased effort in developing natural products for the prevention or treatment of human diseases. According to several studies demonstrating both cactus fruit and cladode yielding high values of important nutrients, such as betalains, amino compounds including taurine, minerals, vitamins, as well as further antioxidants, the cactus pear (*Opuntia spp.*) appears to be an excellent candidate for the inclusion in food. Even though Native Americans and ancient medicine have realized its anti-diabetic and anti-inflammatory function, *Opuntia spp*. have hardly been considered in the development of health-promoting food, most probably due to the scattered information available.

In addition, cactus pear has been mainly ignored by the scientific community until the beginning of the 1980s when several studies and reports were published on their biological functions. More recent investigations on the

Table 1. Selected *Opuntia spp.*, their synonyms and locations [1]

Species	Common Synonyms	Locations
Subgenus *Opuntia*[2]		
Opuntia basilaris	Beavertail Cactus	Southwest U.S. and northwest Mexico
Opuntia chlorotica	Pancake prickly pear, clockface prickly pear, flap jack prickly pear	Native to southwest U.S. and the Sonoran an Mojave deserts
Opuntia engelmannii	Engelmann's pear, cow's tongue cactus, Engelmann prickly pear	Mexico
Opuntia ficus-indica	Indian fig, mission cactus, smooth prickly pear	Originally in south-central Mexico; cultivated in warm parts of the world for its edible fruit
Opuntia fragilis	Little prickly pear, Brittle cactus, fragile prickly pear, loose prickly pear	Northern Great Plains and as far west as British Columbia, also found in the southern Great Plains
Opuntia humifusa, Opuntia compressa var. humifusa	Eastern prickly pear, low prickly pear, smooth prickly pear	Throughout the U.S. east of the Great Plains and into southern Ontario
Opuntia leucotricha	Arborescent prickly pear, Aaron's Beard cactus, semaphore cactus, duraznillo blanco, nopal blanco	Mountains of Central Mexico
Opuntia macrocentra	Black spined prickly pear, purple prickly pear	Southwest U.S. and Northern Mexico
Opuntia macrorhiza	Plains prickly pear, starvation prickly pear, delicate prickly pear	Throughout the Great Plains except for the northernmost areas (not found in North Dakota), and extending sporadically eastward as far as Kentucky.
Opuntia microdasys	Bunny ears prickly pear, Angels' wings prickly pear	Mexico (Hidalgo)
Opuntia santa-rita	Santa Rita Prickly Pear	Texas, Arizona and Northern Mexico
Opuntia stricta	Coastal Prickly Pear, Yaaxpakan	Coastal regions
Opuntia polyacantha	Hedgehog prickly pear, grizzly bear prickly pear	
Opuntia phaeacantha	New Mexico prickly pear	
Opuntia lindheimeri, Opuntia engelmanii var. *lindheimeri*	Texas prickly pear	
Opuntia littoralis	Sprawling prickly pear, coastal prickly pear	
Opuntia erinacea	Grizzly bear Opuntia	
Opuntia pusilla	Creeping cactus	
Subgenus *Cylindropuntia*[3]		
Cylindropuntia acanthocarpa	Buckhorn cholla, major cholla	
Cylindropuntia arbuscula	Pencil cholla, bush cholla	
Cylindropuntia bigelovii	Teddy-bear cholla	
Cylindropuntiaa echinocarpa	Silver cholla, golden cholla	
Cylindropuntia fulgida	Jumping cholla	
Cylindropuntia imbricate	Cane cholla, Tree cholla	
Cylindropuntia leptocaulis	Desert Christmas cholla	
Cylindropuntia ramosissima	Diamond cholla	
Cylindropuntia spinosior	Tasajo cholla, morada cholla	
Cylindropuntia stanlyi	Devil cholla, plateau cholla	
Cylindropuntia versicolor	Staghorn Cholla	

[1] According to (3-9); [2] True prickly pears, often difficult to identify, due to hybridization; [3] Chollas

chemical components and the nutritional value of *Opuntia spp.* have attracted attention both in food, nutritional, and even pharmacological science. However, the scarcity of studies into the respective mechanism of positive actions on human metabolism still render cactus products unpopular and thus undeveloped. Therefore, the present review provides an overview on *Opuntia* fruit and cladode constituents including their pharmacological actions described so far to offer a scientific basis for future studies and to achieve a more widespread recognition of this valuable crop.

3. BOTANICAL ASPECTS, GEOGRAPHICAL DISTRIBUTION AND PRODUCTION

3.1. Botanical Aspects

The term cactus (*Cactaceae*) refers to a group of approximately 1,600 species in 130 genera subdivided in the three subfamilies Pereskioideae, Opuntioideae and Cactoideae (1). The most common and widespread *Opuntia* genus covered in this review regroups a number of more than 300 species, among which over 100 have been found in wild habitats in Mexico, 60 of them being endemic (2). The prickly pear cactus (*Opuntia spp.*), more recently re-named cactus pear, and the cholla (*Cylindropuntia spp.*) species represent the major branches of *Opuntia* cactus, some of which are listed in table 1 (3-9). The prickly pear plants are known for (a) their flattened stems, (b) the edibility of their pleasant-tasting fruits, (c) the areoles having minute-barbed spines easily detachable, (d) rudimentary leaves on new pads, and (e) the seeds with a pale covering (1). Cactus pear plants show a widespread and shallow root system ready to absorb water even from mist or a light rain. This allows the plants to take in water and store it sponge-like in the parenchyma. It has been demonstrated that the ability of Cactaceae to retain water even under unfavorable climatic conditions (10) is due to the high mucilage production in both cladodes and fruits (11).

From a morphological point of view, the cactus pear plant can be divided into the root, the vegetative part, the fruit and the flower. The vegetative or vegetable part, frequently addressed as pads, joints, or cladodes are modified stems which replace the leaves in their photosynthetic function. They are succulent and bear organs with an ovoid or elongated form of 18–25 cm length. The outer cladode, the chlorenchyma, is crucial for its photosynthetic action; the inner part is composed of a white medullar parenchyma mainly for water storage.

The cactus pear fruit also known as prickly pear, tuna or fico d'india comes in a rainbow of colors from

Table 2. Chemical constituents of both despined cladodes and fruit pulp from *Opuntia* spp [1]

Constituents	Dry weight basis	Fresh weight basis	
	Cladodes	Cladodes (g/100g)	Fruit pulp (%)[2]
Water	-	88-95	84-90
Carbohydrates	64-71	3-7	12-17
Ash	19-23	1-2	0.3-1
Fibers	18	1-2	0.02-3.15
Protein	4-10	0.5-1	0.21-1.6
Lipids	1-4	0.2	0.09-0.7

[1] According to (30), (41) and (42). [2] All of which are similar to other fruits.

white, green, yellow, orange, red, purple, and even brown. Interestingly, the pulp colors do not necessarily correspond with those of the flowers, which may be canary yellow, orange or red-rose like. Fruit weights range from 100 to 150 g, depending on origin, cultivar and edaphic conditions. It is an oval and elongated berry with a thick pericarp and a juicy pulp with many seeds. The pulp is the edible part of the fruit and is mainly composed of water (84-90%) and reducing sugars (10-15%).

Cactus pear fruit seeds exhibit considerable variations in form, size, structure, embryo characteristics, and testa color. They represent about 10-15% of the edible pulp and are usually discarded as waste after pulp extraction. Several authors have reported a great variation in the number of seeds, from 1-5 to more than 2000 per fruit (12-15). This variation is observed within and/or between species depending on factors such as the age and size of the plant, and the number of flowers per plant. Seed vitality under natural or controlled storage conditions will depend on many factors, including seed type, maturity stage, viability and moisture content during storage, temperature and degree of fungal or bacterial infection (14).

Research on *Opuntia spp.* is inflicted with the challenge of their proper identification (16). Therefore, possible markers are being investigated to understand genetic relationships and allow reliable classification (17-19).

3.2. Geographical Distribution

The Cactaceae are one of the most intriguing plant families of the world's arid and semi-arid regions, the latter covering about 30% of the world's continental surface (20). This is due to their peculiar adaptations to water scarcity and sun irradiation, such as (1) CAM metabolism (Crassulacean Acid Metabolism), the reduction of (2) leaf tissues and (3) cuticular waxes covering the cladodes and fruit surfaces, which allow them to grow year-round and stay evergreen despite harsh environmental conditions. The genus *Opuntia* is most widespread, presumably due to its capacity to regenerate either from root calluses, pads, fruits, seeds, tissue culture and grafting (see table 1) (21, 22). It can be encountered from temperate (Italy, Israel), subtropical African and American zones, Asia (China, South Korea) as well as in cold regions with winter snowfalls as in Canada or Argentina (23, 24).

3.3. Production

The plant is used mainly for fruit production, although in some countries it is used as a vegetable for human consumption and also as fodder. The high season for harvesting *Opuntia* cactus fruits is from April to August in Africa and America (25), and November to December in the Mediterranean regions (26).

3.3.1. Cladodes

The weight and length of harvested vegetables vary depending on the specie. However, they generally range from 40-100 g and 11-20 cm in length (27-29), and the plants are generally aged from 1 to 3 years (26). Due to the diurnal acidity modification of cladodes, harvesting a couple of hours after sunshine provides best cladodes for vegetable use, which are turgid, rich in sugars, pro-vitamin A and vitamin C, but poor in nitrogen (26). Furthermore, postharvest technologies have been developed that have been reviewed recently (30).

3.3.2. Fruits

Unfortunately, cactus fruits have a short shelf life from 3–4 weeks, thus limiting long-term storage and worldwide distribution. Typically, a high pH value which varies from 5.3 to 7.1 is found, and the very low acidity (0.05-0.18% citric acid equivalents) compromises extended fruit storage (31, 32). Various efforts to reduce postharvest decay have therefore been carried out, taking into account reduction of microbial contamination while maintaining the nutritional as well as sensorial properties (33-38). Peeled fruits are good for eight days at 4°C when packed in special films (39), while the same temperature was recommended to control microbial spoilage (33). It must be noted that each variety and fruits from different harvest seasons might require changing preharvest treatments and storage conditions (37, 40). Sterilization of processed fruits at greater than 115^{o} C is required to avoid growth of pathogenic micro-organisms (31, 41). Alternatively, after acidification (pH 4.0-4.3), products only require less severe pasteurization temperatures below 100° C for preservation.

4. CACTUS CONSTITUENTS

The Opuntia cladodes and fruits are known as a source of a varied number of nutritional compounds (table 2). Their concentrations being dependent both on the cultivation site, climate and respective fruit variety (41-55). Cactus pear fruits exhibit an ascorbic acid content of 20 to 40 mg/100 g fresh weight, and a titratable acidity of 0.03 to 0.12% with pH values ranging from 5.0 to 6.6. Its soluble solids content of 12-17% is greater than that present in other fruits, such as prunes, apricots, and peaches (31, 56). Generally, cladodes are rich in pectin, mucilage and minerals, whereas the fruits are good sources of vitamins, amino acids and betalains. While the seed endosperm was reported to consist of arabinan-

Table 3. Free amino acids contents in both cladodes (L-amino acids) and fruit pulps from Opuntia *ficus-indica* [1]

Amino acids	Fresh weight basis	
	Cladodes (g/100 g)	Fruit juice (mg/L) [2]
Alanine	0.6	87.2
Arginine [3]	2.4	30.5
Asparagine	1.5	41.6
Asparaginic acid	2.1	Not valid
Glutamin acid	2.6	66.1
Glutamine [3]	17.3	346.2
Glycine	0.5	11.33
Histidine [3]	2.0	45.2
Isoleucine	1.9	31.2
Leucine	1.3	20.6
Lysine	2.5	17.4
Methionine	1.4	55.2
Phenylalanine	1.7	23.3
Serine [3]	3.2	174.5
Threonine	2.0	13.3
Tyrosine	0.7	12.3
Tryptophane	0.5	12.6
Valine	3.7	39.4
Alpha-Aminobutyric acid [3]	Not available	1.1
Carnosine	Not available	5.9
Citrulline	Not available	16.3
Ornithine	Not available	Not detectable
Proline [3]	Not available	1265.2
Taurine [3, 4]	Not available	434.3

[1] According to (42) and (45); [2] Mean values for the pulp from three cultivars. Some amino acids present variations of 1.5 to 3 depending on the respective cultivar (42); the total content of free amino acids (257.24 mg/100g) is above average for most fruits except citrus and grape; [3] Amino acids with higher contents in comparison with other fruits (44); [4] 8-12 mg/100 g fruit reported (45).

rich polysaccharides (57), the principal seed coat component was D-xylan (58). In addition to lipids, seeds have been reported to accumulate proanthocyanidins (59). The fruit skin polysaccharide fraction has been subject to thorough investigations (60-63), whereas the pectin substances in fruit pulp remain to be characterized. The flowers predominantly accumulate betalains and colorless phenolics (64-69).

4.1. Amino acids, vitamins and carotenes

4.1.1. Cladodes

The fresh young stems are a source of proteins including amino acids, and vitamins (tables 3 and 4) (30, 70-73).

4.1.2. Fruits

Various numbers of amino are also found in cactus fruits (table 3). Vitamins are nutritionally important cactus pear fruit constituents (table 4). The fat soluble vitamin E or tocopherols, and beta-carotene are found in the lipid fraction of both the cactus fruit seed and pulp (52, 74, 75). The vitamin E homologues isoforms gamma- and delta-tocopherol are the main components in seed and pulp oils, respectively, amounting to about 80% of the total vitamin E content (table 5). Similar to beta-carotene, it is predominant in pulp lipids (75). Carotenes and vitamin E improve the stability of the fatty oil through their antioxidative properties (76).

Ascorbic acid, often erroneously addressed as vitamin C, is the third major vitamin in cactus pears. It is important to note that the total vitamin C content of cactus fruits might have been underestimated due to the presence of dehydroascorbic acid that has not been considered so far. Finally, only trace amounts of vitamin B1, vitamin B6, niacin, riboflavin, and pantothenic acid have been reported (42, 77).

Phytochemical investigation of *Opuntia* revealed a great number of amino acids, eight of which are essential (table 3). Cactus fruits contain high levels of amino acids, especially proline, taurine and serine (42, 44, 45), while the seeds are rich in protein (78).

4.2. Minerals, sugars and organic acids

4.2.1. Cladodes

The cladodes are characterized by high malic acid contents oscillating due to a CAM-based diurnal rhythm (30, 50, 51). The mineral and organic acid contents of cactus pads have been reviewed recently (30) (see table 6).

4.2.2. Fruits

Based on various studies on *Opuntia* composition, fruit pulp is considered a good source of minerals (table 6), especially calcium, potassium and magnesium (42, 47, 72, 79). The seeds are rich in minerals and sulphur amino acids (80).

The fairly high sugar content and low acidity (31, 81) render the fruits a delicious, sweet but sometimes a bland taste. The sugar pattern in the fruit pulp is very simple and consists of glucose and fructose in virtually equal amounts (23, 31, 82, 83), while the organic acid pattern is dominated by citric acid (42, 84). Due to the high water content of the fruit, a total caloric value of 50 kcal/100 g is attained, which is comparable to that of other fruits such as pears, apricots and oranges (56, 82). Directly absorbed, high glucose concentrations in cactus fruits represent an energy source instantly available for brain and nerve cells, while fructose being sweeter may enhance the fruit's flavor (85).

Table 4. Vitamin and antioxidant contents of both *Opuntia* spp. cladodes and fruit pulp [1]

Compounds	Fresh weight in cactus pear (per 100g)	
	Cladodes	Fruit pulps
Ascorbic acid	7-22 mg	12-81 mg [2]
Niacin	0.46 mg	Trace amounts
Riboflavin	0.60 mg	Trace amounts
Thiamine	0.14 mg	Trace amounts
Total carotenoid	11.3-53.5 µg	0.29-2.37 g
• Beta-carotene	Not available	1.2-3.0 µg
Total vitamin E	Not available	111-115 µg
Vitamin K_1	Not available	53 µg
Flavonols:		
• Kaempferol derivatives	Not available	0.11-0.38 g
• Quercetin derivatives	Not available	0.98-9 g
• Isorhamnetin derivatives	Not available	0.19-2.41 g

[1] According to (30), (42), (43), (46) and (47); [2] Indicates concentrations higher than that of apple, pear, grape and banana (48) and (49)

Table 5. Levels of sterols and fat-soluble vitamin E derivatives in cactus pear (Opuntia *ficus-indica L.*) seed and pulp oils [1]

Components	Seed oil[2] (g/100g)	Fruit pulps oil[2] (g/100 g)
Cholesterol	Not detectable	Not detectable
Campesterol	1.66	8.74
Beta-Sitosterol	67.5	11.2
Vitamin E:		
• Alpha-Tocopherol	0.56	8.49
• Beta- Tocopherol	0.12	1.26
• Gamma- Tocopherol	3.3	0.79
• Delta- Tocopherol	0.05	42.2

[1] From (52); [2] Data are expressed as g/100g of seed or pulp dry weight.

Table 6. Mineral contents of *Opuntia* spp. spineless cladode[1] and fruit pulp [2]

Components	Dry weight in cladode (g/100g DW)	Fresh weight in fruit pulp (mg/100g)
Calcium (Ca)	5.64 (5.6)	12.8-59
Magnesium (Mg)	0.19 (0.2)	16.1-98.4
Potassium (K)	2.35 (2.3)	90-220
Phosphorus (P as PO_4)	0.15 (0.1)	15-32.8
Natrium (Na)	0.4 (0.4)	0.6-1.1
Ferrous (Fe)	0.14 µg (trace)	0.4-1.5

[1] Adapted from (51). The numbers in parenthesis represent the percentage of dry weight (DW); [2] From (47) and (50)

4.3. Lipids

Several authors have suggested cactus pear as a new source of fruit oils (52, 75, 84, 86-89). Fruit pulp provides lower yields of oil (0.1-1.0%), representing about 8.70 g total lipid/kg pulp dry weight compared to 98.8 g total lipids/kg for seeds (52). Furthermore, it has been shown that the seed oil contains a significant amount of neutral lipid (87.0% of total lipids), while the polar lipids are at higher levels in pulp oil (52.9% of total lipid). Both oils are a rich source of essential fatty acids and sterols. Linoleic acid, as well as beta-sitosterol and campesterol (90% of the total sterols), are the major constituents of the fatty acid and sterol fractions, respectively. Finally, the peel fraction contains 36.8 g lipids per kg (75). It is important to remember that fat soluble vitamins such as alpha-, beta-, delta-, and gamma-tocopherols, vitamin K1 and beta-carotene are associated with the cactus fruit seed and pulp oils, and will prevent the lipid fractions from oxidative damage (table 5). This fact corroborates the understanding that whole fruit consumption is more reasonable than the ingestion of fruit isolates.

The fatty acid composition of prickly pear seed oil is similar to sunflower and grape seed oils as reported by (90). Notwithstanding, the levels of total lipids, sterols and fat soluble vitamins may depend on the fruit cultivar, degree of ripeness and fruit processing, and/or storage conditions.

4.4. Phenolic compounds

Phenolics comprise a wide variety of compounds, divided into several classes such as hydroxybenzoic acids, hydroxycinnamic acids, anthocyanins, proanthocyanidins, flavonols, flavones, flavanols, flavanones, isoflavones, stilbenes and lignans, that occur in a great number of fruits (grapefruits, oranges, berries, dark grapes, apples, etc.) and vegetables (onions, broccoli, cauliflower, Brussels sprouts, tomatoes, peppers, etc.), wine, tea, chocolate and other cocoa products in varying quantitative and qualitative amounts (91-94).

4.4.1. Cladodes

The phenolic composition and their specific effects on human metabolism have been recently reviewed (30).

4.4.2. Fruits

The presence of phenolics has been detected in cactus pulp fruit (45, 46, 95, 96). Kuti (96) has reported an antioxidative effect due to the major flavonoids encountered in cactus fruits (quercetin, kaempferol and isorhamnetin; table 4). There is clear evidence that these compounds are more efficient antioxidants than vitamins, since phenolic compounds are able to delay prooxidative effects on proteins, DNA and lipids by the generation of stable radicals (97). Furthermore, O. *ficus indica* polyphenolic compounds have been shown to induce a

Table 7. Potential products and by-products from cactus pear fruit and cladode [1]

Products from		By-products from
Fruits	Cladodes	Fruits and cladodes
Juice, nectar, pulp, puree	Lacto-fermented pickles	Oil from seeds
Jam, jelly	Candy	Oil from fruit pomace
Fruit leather	Jam	Pigments from peel
Syrup, sweetener	Flour	Pigments from pomace
Bioethanol, wine, "coloncheˮ	Cooked vegetable	
Canned fruit	Ethanol	Dietary fiber and mucilage from
Frozen fruit	Edible coating	Cladodes
Juice concentrate		
Spray-dried juice powder		

[1] According to (30), (52), (81), (82), (105) and (107-116)

hyperpolarization of the plasma membrane and to raise the intracellular pool of calcium in human Jurkat T-cell lines (98). Flavonol derivatives detected in *Opuntia ssp.* have been recently compiled (30, 99). When fruits are investigated, it must be taken into account that higher phenolic contents are expected in the peel, rather than the pulp. Consequently, from a nutritional point of view processing both peel and pulp appears to be advantageous.

4.5. Betalains

The most obvious feature of cactus pear fruits and flowers are the yellow (betaxanthins) and red (betacyanins) betalains, nitrogen-containing vacuolar pigments that replace anthocyanins in most plant families of the Caryophyllales including the Cactaceae (100). While their characterization in cactus flowers has been scarce (101), their identification in cactus pear fruit has been of renewed interest recently (43, 102, 103). In addition to color, the same pigments have shown antioxidant properties being higher than for ascorbic acid (43, 46).

In conclusion, the specific particularities of cactus pear make it useful in several arenas: nutrition, traditional medicine and further industrial applications (104, 105).

5. CACTUS UTILIZATION FOR FOOD, MEDICINAL AND INDUSTRIAL APPLICATIONS

The nutritional and pharmacological properties of cactus pears are quality attributes that may contribute to their increased consumption in the future (106). However, the fruits' short shelf-life requires adequate processing techniques to provide products of high nutritional quality even in the countries where *Opuntia* cultivation is not possible. Consequently, numerous strategies have been proposed which, however, have not entered industrial production (table 7) (30, 52, 75, 81, 82, 105, 107 -116).

5.1. Nutritional use

Cacti have long been considered an important nutritional source in Latin America (bread of the poor) among which *Opuntia* has gained highest economic importance worldwide. It is cultivated in several countries such as Mexico, Argentina, Brazil, Tunisia, Italy, Israel and China. Both fruit and stems have been regarded to be safe for food consumption (72). The stems also serve as animal fodder and for hosting the cochineal insect *Dactylopius coccus costa* to exploit anthrachinone-derived pigments (30).

During drought periods, the spineless shrub of Opuntia *ficus indica* cactus plays a significant role in providing valuable nutrients for farming bovine, ovine and caprine animals. By feeding despined cactus stems, only limited amounts of conventional feeds such as concentrates, hay and straw are required (117). The use of cactus as a supplement to native forage in animal meat production is common during the dry season in some countries such as Tunisia, Brazil and Mexico where a significant acreage of more than 50,000 ha is dedicated for cactus production for fodder use (118-120). The digestibility of cactus cladodes decreases with age and only those aged from 1 to 3 years appear suitable for animal feed.

Both the cladodes and fruits are frequently consumed both fresh and processed in Latin America (104), whereas only the fresh fruits are more widespread on European and North-American markets (95).

5.1.1. Cladodes

In Mexico, where the consumption of cactus pear is deeply embedded in culture, the cactus pads are commonly known as *nopales* or *pencas* when whole, or *nopalitos* when cut into small pieces or as fresh young cladodes from 3-4 weeks of age. They are regularly served with meals, similar to green beans (30). The reported heat-resistance of cactus pear extract antioxidants, suggests the capability of these antioxidants to maintain their activity well after harvest and during adequate storage (121).

5.1.2. Fruits

The *Opuntia* fruit can be considered a valuable source for food supplementation. Far from being frequent, canned or bottled cactus pear juice, as well as pulp are exclusively encountered in specialized markets in Mexico and in the southwestern United States of America.

The nutritional changes of cactus pear upon processing have, only recently, been addressed (45, 113). While a total loss of GSH and beta-carotene was noted, and vitamin C together with cysteine contents decreased, betalains, taurine and vitamin E were less susceptible to decay. During storage of minimally processed cactus fruits at 4°C, polyphenolics decreased after 6 days while vitamin C contents remained stable (122).

5.2. Medicinal use

As with numerous fruits and vegetables (123-130), cactus plants have also been reported to be beneficial to health (131). These effects are demonstrated in the treatment of several diseases. However, most accessible information on pharmacological studies deal with cactus stems rather than the fruit, the former being even less frequently encountered in non-producing countries.

5.2.1. Anti-cancer effect

Most recent studies suggests that the cactus pear fruit extract (i) inhibits the proliferation of cervical, ovarian and bladder cancer cell lines *in vitro*, and (ii) suppresses tumor growth in the nude mice ovarian cancer model *in vivo* (132). These experiments showed that inhibition was dose- (1, 5, 10 and 25% cactus pear extract) and time- (1, 3 or 5 days treatment) dependent on *in vitro*-cultured cancer cells. The intra-peritoneal administration of cactus extract solution into mice did not affect the animal body weight, which indicated that cactus did not have a significant toxic effect in animals. More importantly, tumor growth inhibition was comparable to the synthetic retinoid N-(4-hydroxyphernyl) retinamide (4-HPR), which is currently used as a chemopreventive agent in ovarian cancer chemoprevention (133-135).

Growth inhibition of cultured-cancer cells was associated with an increase in apoptotic cells and the cell cycle arrest at the G1-phase. Moreover, the induced-growth inhibition seems dependent on the P53 pathway, which is the major tumor suppressor. Annexin IV was increased and the VEGF decreased in the tumor tissue obtained from animals having received the cactus solution (132).

The mechanism of action as well as the component(s) by which cactus pear extract exerts these effects is not yet elucidated. However, first an extrinsic effect through an activation of membrane death receptors such as tumor necrosis factor, nuclear factor kappa B, Fas appears to be feasible. Secondly, intrinsic actions via the mitochondria, playing a pivotal role by releasing a number of molecules favorable to the induction of apoptosis such as Bax, AIF, cytochrome C, reactive oxygen species such anion superoxide may be considered. Further investigations are needed to identify the potential active component(s) and the respective underlying mechanisms.

5.2.2. Anti-oxidant properties

The antioxidative action is one of many mechanisms by which fruit and vegetable substances might exert their beneficial health effects (45, 136-139). The presence of several antioxidants (ascorbic acid, carotenoids, reduced glutathione, cysteine, taurine and flavonoids such as quercetin, kaempferol and isorhamnetin) has been detected in the fruits and vegetables of different varieties of cactus prickly pear (table 4) (45, 46, 96, 140). More recently, the antioxidant properties of the most frequent cactus pear betalains (betanin and indicaxanthin) have been revealed (43, 46, 95, 139, 141, 142).

Numerous *in vitro* studies have demonstrated the beneficial effect of colorless phenolics and betalains (46, 76, 121, 139-143). These are generally attributed to the ability of antioxidants to neutralize reactive oxygen species such as singlet oxygen, hydrogen peroxide or H_2O_2, or suppression of the xanthine/xanthineoxidase system, all of which may induce oxidative injury, i.e. lipid peroxidation.

Polyphenolics are antioxidants with well-known cardioprotective, anticancer, antiviral and antiallergenic properties (144, 145). Especially with green tea polyphenols (i.e. epigallocatechin-3-gallate or EGCG), their beneficial effects have been reported in several types of cancers or tumors (146). Polyphenols are also potential modulators of the transcription factors' activities (147, 148), which is more likely through a calcium-dependent pathway. Indeed, cactus polyphenolics induce a rise of the intracellular pool of calcium ions from the endoplasmic reticulum and thus perturb the expression of the interleukin 2, which is associated with the S-phase transition in human Jurkat T-cells (98). These effects remain to be verified in cancer cells.

5.2.3. Anti-viral effect

An interesting study by Ahmad *et al.* (149) demonstrated that administration of a cactus stem extract (*Opuntia streptacantha*) to mice, horses, and humans inhibits intracellular replication of a number of DNA- and RNA-viruses such as Herpes simplex virus Type 2, Equine herpes virus, pseudorabies virus, influenza virus, respiratory syncitial disease virus and HIV-1. An inactivation of extra-cellular viruses was also reported by the same authors. However, the active inhibitory component(s) of the cactus extract used in this study was not investigated, and as of yet, no further study dealt with this specific topic.

5.2.4. Anti- inflammatory effect

Numerous studies have evocated the analgesic and anti-inflammatory actions of the genus *Opuntia* by using either the fruit extract from *Opuntia dillenii* (150), the lyophilized cladodes (151), or the phytosterols from fruit and stem extracts (140). Park *et al.* (152) identified beta-sitosterol as the active anti-inflammatory principle from the stem extract. Gastric lesions in rat animal studies were reduced both by stem and fruit powders (153, 154). Finally, betanin and indicaxanthin stimulated an inhibitory effect on the chlorination activity of myeloperoxidase at neutral rather than at pH 5 (155).

5.2.5. Anti-diabetic (type II) effect

The prickly pear cactus stems have been used traditionally to treat diabetes in Mexico (156). Nowadays, *Opuntia spp.* is amongst the majority of products recommended by Italian herbalists that may be efficacious in reducing glycemia (157). Some studies have demonstrated the hypoglycemic activity of the prickly pear cactus extract on non-diabetics and diabetic-induced rats or diabetic humans (158-162). In a study on rats, the combination of insulin and purified extract of cactus (*Opuntia fuliginosa* Griffiths) was found to reduce blood glucose and glycated hemoglobin levels to normal (162). In this study, the oral dose of extract (1 mg/kg body weight per day) necessary to control diabetes contrast with the high quantities of insulin required for an equivalent hypoglycemic effect. A recent study has shown that a supplementation of rats' diets with cactus seed oil (25 mg/kg) decreases the serum glucose concentration, which is associated with a glycogen formation in the liver and skeletal muscle (163). These observations were explained by a potential induction of insulin secretion, converting glucose to glycogen.

Except for one study (72), similar research on fruit components are lacking. In the future, it should be remembered that a clear differentiation between stem and fruit components are required to pin down the most pharmacologically active plant parts.

5.2.6. Anti- hyperlipidemic and hypercholesterolemic effects

Experimental evidence suggest that cactus pear reduces cholesterol levels in human blood and modify low density lipoprotein (LDL) composition (30, 42, 104, 164, 165). Galati *et al.* (166) have found that the cholesterol, LDL and triglyceride plasma levels of rats were strongly reduced after 30 days of a daily administration (1 g/kg) of lyophilized cladodes of *Opuntia ficus indica L. Mill.*. Sterols which comprise the bulk of the unsaponifiables in many oils are of interest due to their ability to lower blood LDL-cholesterol by approximately 10–15% as part of a healthy diet (167). Recently, Ennouri *et al.* (163) observed a decrease in plasma total cholesterol and LDL (VLDL) cholesterol with no effect on HDL-cholesterol concentrations after addition of seed oil (25 g/kg) to the diet in rats.

Overall, the effects of cactus are generally attributed to the high fiber content of the cladodes, although other active ingredients (such as beta-carotenes, vitamin E and beta-sitosterol) may be involved.

5.2.7. Further positive health effects

Cactus fruits, cladodes or flower infusions have been traditionally used as folk medicine to treat other ailments such as ulcers (151, 154, 166), allergies (168), fatigue and rheumatism, and as an antiuric and diuretic agent (169). Alleviating effects towards alcohol hangover symptoms have been addressed recently (170) and were associated with reduced inflammatory responses after excessive alcohol consumption. Amongst the flavonoids extracted from either the cactus stem or fruit, quercetin 3-methyl appears to be the most potent neuroprotector (143). The cactus flower extract was able to exert an effect on benign prostatic hyperplasia (BPH) through the inhibition of aromatase and 5a reductase activities, both of which are involved in androgen aromatization and testosterone reduction (171). A diuretic effect was reported to be promoted by ingestion of flower, cladode and especially fruit infusions in a rat feeding trial (169). Though *Opuntia spp.* glochids may induce dermal irritations, peeled *Opuntia* fruits or cladodes appear to be non-allergenic (172). More recently, Galati *et al.* (173) reported a protective effect of cactus juice against carbon hydrochloride (CCl_4)-induced hepato-toxicity in rats.

5.3. Further uses

5.3.1. Cladodes

Further uses of the cactus plant have been suggested and recently reviewed, such as cladode pulp use for the production of shampoos, conditioners, face and body lotions, soaps, hair gels and sun protectors or bioethanol production (30, 105, 174-176). In addition, veterinary phytotherapy including *Opuntia spp.* (177) appears to be a promising field of research and a worthwhile application.

5.3.2. Fruits

Natural colorants from plant sources are receiving growing interest from both food manufacturers and consumers in the continuing replacement of synthetic dyes. Betalains present in fruit peel and pulp, but also in the flowers represent a potential healthy alternative. Because of the wide range of colors available, cactus fruits are highly appreciated in the countries of origin, e.g., Mexico, Argentina, and southern Italy (178, 179) for different purposes. Unfortunately, fruits are still considered a specialty in Western industrial countries, and processed products based on cactus are extremely rare. Therefore, a number of studies have recently dealt with the practical relevance of cactus fruit processing to open up ways for increased *Opuntia* fruit commercialization, such as juice and concentrate production for food coloring purposes (113).

Juice obtained from the strained pulp is suggested to be a good source of natural sweeteners and colorants (42, 102, 180, 181). Cactus pear represents a viable alternative to red beet for food coloring purposes: it neither exhibits negative sensorial impact nor high nitrate levels, but offers a broad color range. Both the particular ratio of betaxanthins and betacyanins, as well as their total concentrations, has shown to determine their visual appearance covering a broad coloring range from bright yellow to red-violet (43, 182). Total color yield depends on the respective species and clone investigated and may range from 5 to 110 mg/100g (43, 102). Therefore, cactus pear juice preparations are expected to be a suitable coloring foodstuff for low acid products such as ice-cream or yogurt (183).

For complete exploitation of the fruit and resulting wastes, the residual seeds may be used for oil extraction (52, 77), whereas the peels are considered a rich source of pectin, polyunsaturated fatty acids, natural antioxidant vitamins and sterols (75).

6. CONCLUSIONS AND PERSPECTIVES

From the presented data, it appears that *Opuntia spp.* has been subject to intensive exploitation due to its great compositional diversity. Nowadays, this hidden knowledge needs to be discovered and re-evaluated. Sophisticated analytical approaches and innovative processing technologies will open new avenues to further promote the use of cactus pear stems, fruits and flowers in food, medicine, cosmetic, and pharmaceutical industries. An increasing demand would help encourage farmers to increase their acreage and thus also help to counterbalance erosion (26) and increasing atmospheric CO_2 levels (184-186). Although much research still needs to be done, concerted actions of taxonomists, plant breeders, agriculturists, food technologists, nutritionists and pharmacologists will help discover and understand the big potential of the *Opuntia* cactus. The exact botanical classification of the respective *Opuntia* spp. under investigation and the growing location and time of harvest are prerequisites for analytical and pharmacological studies. The exact plant parts used in the extraction and processing conditions need to be accurately documented to allow proper data evaluation.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

1. RS Wallace & AC Gibson: Evolution and systematics. In: Cacti: Biology and Uses. Eds: Nobel PS, University of California Press Berkeley-Los Angeles-London, 1-21 (2002)

2. MA Anaya-Pérez: History of the use of Opuntia as forage in Mexico. In: Cactus (Opuntia spp.) as Storage. Eds: Mondragón-Jacobo C, Pérez-González S, FAO, Rome, Italy, 5–12 (2001)

3. D Griffiths: Yields of native prickly pear in southern Texas. In: Bull 208, USDA, Washington DC, 11 (1915)

4. J MacMahon & F Wagner: The Mojave, Sonoran and Chihuahuan Deserts of North America. In: Hot Deserts and Arid Shrublands, Ecosystems of the World. Eds: Evenari M, Noy-Meier I, Goodall D, Elsevier, Amsterdam, 12A, 105–202 (1985)

5. Stiling P., A. Rossi & D. Gordon: The difficulties of single factor thinking in restoration: replanting a rare cactus in the Florida Keys. *Biol Conserv* 94, 327-333 (2000)

6. Bobich E.G. & P.S. Nobel: Vegetative Reproduction as Related to Biomechanics, Morphology and Anatomy of Four Cholla Cactus Species in the Sonoran Desert. *Ann Bot* 87, 485-493 (2001)

7. Anderson E.F.: The Cactus Family. *Timber Press*, Portland/OR (2001)

8. Van Sittert L.: Our irrepressible fellow-colonist': the biological invasion of prickly pear (Opuntia ficus-indica) in the Eastern Cape c.1890–c.1910. *J Historical Geography* 28, 397-419 (2002)

9. Goettsch B. & H.M. Hernández: Beta diversity and similarity among cactus assemblages in the Chihuahuan Desert. *J Arid Environ*, In Press (2005)

10. Saag K.M.L., G. Sanderson, P. Moyna & G. Ramos: Cactaceae mucilage composition. *J Sci Food Agric* 26, 993–1000 (1975)

11. Sáenz C., E. Sepúlveda & B. Matsuhiro: Opuntia spp mucilage's: a functional component with industrial perspectives. *J Arid Environ* 57, 275-290 (2004)

12. Zimmer K.: Über Samengewichte und Samenproduktion einiger Kakteenarten. *Kakteen und andere Sukkulenten* 17, 153–154 (1966)

13. Weiss J., L. Scheinvar & Y. Mizrahi: Selenicereus megalanthus (the yellow pitaya), a climbing cactus from Colombia and Peru. *Cactus and Succulent J* 67, 280–283 (1995)

14. Rojas-Aréchiga M. & C. Vázquez-Yanes: Cactus seed germination: a review. *J Arid Environ* 44, 85-104 (2002)

15. Reyes-Agüero J.A., J.R. Aguirre R. & A. Valiente-Banuet: Reproductive biology of Opuntia: A review. *J Arid Environ*, In Press (2005)

16. Rebmann J.P. & D.J. Pinkava: Opuntia cacti of North America – an overview. *Fla Entomol* 84, 474-483 (2001)

17. Khales A. & M. Baaziz: Quantitative and qualitative aspects of peroxidases extracted from cladodes of Opuntia ficus indica. *Scientia Hort* 103, 209-218 (2005)

18. Labra M., F. Grassi, M. Bardini, S. Imazio, A. Guiggi, S. Citterio, E. Banfi, S. Sgorbati: Genetic relationships in *Opuntia* Mill. genus (Cactaceae) detected by molecular marker. *Plant Sci* 165, 1129-1136 (2003)

19. Wang X., P. Felker, M.D. Burow & A.H. Paterson: Comparison of RAPD marker patterns to morphological and physiological data in the classification of *Opuntia* accessions. *J Professs Assoc Cactus Dev* 3, 1-12 (1998)

20. J Kigel: Seed germination in arid and semi-arid regions. In: Seed Development and Germination. Eds: Kigel J, Galili G, New York, 645–699 (1995)

21. Lazcano C.A., F.T. Davies Jr., A.A. Estrada-Luna, S.A. Duray, & V. Olalde-Portugal: Effect of auxin and wounding on adventitious root formation of prickly-pear cactus cladodes. *HortTechnol* 9, 99–102 (1999)

22. Estrada-Luna A.A.: Producción de Brotes e injertación in vitro de seis especies de nopal (Opuntia spp.) originarias del Altiplano Potosino-Zacatecano. *Tesis de MC. Colegio de Postgraduados*, Montecillo, Edo. de México, México, 160 (1988)

23. Russel C. & P. Felker: The prickly pear (Opuntia spp., Cactaceae): a source of human and animal food in semi-arid regions. *Econ Bot* 41, 433–445 (1987)

24. Mohamed-Yasseen Y., S.A. Barringer, & W.E Splittstoesser: A not on uses of Opuntia spp. In Central/North America. *J Arid Environ* 32, 347–353 (1996)

25. CA Flores-Valdez: Nopalitos production, processing and marketing. In: Agro-ecology, Cultivation and Uses of Cactus Pear. Eds: Barbera G, Inglese P, Pimienta-Barrios E, FAO-Plant Proiduction and Protection Paper, Rome, 132, 92-99 (1995)

26. Le Houérou H.N.: The role of cacti (Opuntia spp.) in erosion control, land reclamation, rehabilitation and agricultural development in the Mediterranean Basin. *J Arid Environ* 33, 135–159 (1996)

27. Nerd A., M. Dumoutier & Y. Mizrahi: Properties and post-harvest behavior of the vegetable cactus Nopalea cochenillifera.
Postharv Biol Technol 10, 135-143 (1997)

28. Cantwell M., Rodriguez-Felix A. & Robles-Contreras F.: Postharvest physiology of prickly pear cactus stems. *Scientia Hort* 50, 1-9 (1992)

29. M Cantwell: Post-harvest management of fruits and vegetables stems. In: Agro-ecology, Cultivation and Uses of Cactus Pear. Eds: Barbera G, Inglese P, Pimienta-Barrios E, FAO-Plant Production and Protection Paper, Rome 132, 120-136 (1995)

30. Stintzing F.C. & R. Carle: Cactus stems (Opuntia spp.): A review on their chemistry, technology, and uses. *Mol Nutr Food Res* 49, 175-194 (2005)

31. Sepulveda E. & C. Sáenz: Chemical and physical characteristics of prickly pear (Opuntia ficus indica) pulp. *Revista de Agroquimica y Tecnologia de Alimentos* 30, 551–555 (1990)

32. Sáenz C.: Food products from cactus pear (Opuntia ficus indica). *Food Chain* 18, 10–11 (1996)

33. Corbo M.R., C. Altieri, D. D'Amato, D. Campaniello, M.A. Del Nobile, & M. Sinigaglia: Effect of temperature on shelf life and microbial population of lightly processed cactus pear fruit. *Postharv Biol Technol* 31, 93-104 (2004)

34. Carrillo- López A., A. Cruz- Hernández, F. Guevara-Lara, O. Paredes-López: Physico-chemical changes during ripening in storage of two varieties of prickly pear stored at 18°C. *J Food Sci Technol* 40, 461-464 (2003)

35. Piga A., D. D'Hallewin, S. D'Aquino, & M. Agabbio: Influence of film wrapping and UV irradiation on cactus pear quality after storage. *Packaging Technol Sci* 10, 59-68 (1997)

36. Schirra M., G. Barbera, S. d'Aquino, T. La Mantia & R.E. Mc Donald: Hot dips and high-temperature conditioning to improve shelf quality of late-crop cactus pear fruit. *Tropical Sci* 36, 159-165 (1996)

37. Schirra M., G. D'hallewin, P. Inglese & T. La Mantia: Epicuticular changes and storage potential of cactus pear [Opuntia ficus-indica Miller (L.)] fruit following gibberellic acid preharvest sprays and postharvest heat treatment. *Postharv Biol Technol* 17, 79-88 (1999)

38. Schirra M., V. Brandolini, P. Cabras, A. Angioni & P. Inglese: Thiabendazole uptake and storage performance of cactus pear [Opuntia ficus-indica (L.) Mill. Cv Gialla] fruit following postharvest treatments with reduced doses of fungicide at 52°C. *J Agric Food Chem* 50, 739-743 (2002)

39. Piga A., S. D'Aquino, M. Agabbio, G. Emonti & G.A. Farriss: Influence and storage temperature on shelf-life of minimally processed cactus pear fruits. *Lebensm-Wiss Technol* 33, 15-20 (2000)

40. Carillo-López A., A. Cruz-Hernández, A. Cárabez-Trejo, F. Guevara-Lara, & O. Paredes-López: Hydrolytic activity and ultrastructural changes in fruit skins from two prickly pear *(Opuntia* sp.) varieties during storage. *J Agric Food Chem* 50, 1681-1685 (2002)

41. C Sáenz: Food Manufacture and by-products. In: Agro-ecology, cultivation and uses of cactus pear. Eds: Barbera G, Inglese P, Pimienta-Barrios E, FAO Plant Product and Protection Paper, Rome 132, 137–143 (1995)

42. Stintzing F.C., A. Schieber & R. Carle: Phytochemical and nutritional significance of cactus pear. *Eur Food Res Technol* 212, 396-407 (2001)

43. Stintzing F.C., K.M. Herbach, M.R. Mosshammer, R. Carle, W.G. Yi, S. Sellappan, C.C. Akoh, R. Bunch & P. Felker: Color, betalain pattern, and antioxidant properties of cactus pear (Opuntia spp.) clones. *J Agric Food Chem* 53, 442-451 (2005)

44. Askar A. & S. K. El-Samahy: Chemical composition of prickly pear fruits. *Dt Lebensm Rdsch* 77, 279-281 (1981)

45. Tesoriere L., M. Fazzari, M. Allegra & M.A. Livrea: Biothiols, taurine, and lipid-soluble antioxidants in the edible pulp of Sicilian cactus pear (Opuntia ficus-indica) fruits and changes of bioactive juice components upon industrial processing. *J Agric Food Chem* 53, 7851-7855 (2005)

46. Tesoriere L., D. Butera, M. Allegra, M. Fazzari & M.A. Livrea: Distribution of betalain pigments in red blood cells after consumption of cactus pear fruits and increased resistance of the cells to ex vivo induced oxidative hemolysis in humans. *J Agric Food Chem* 53, 1266-1270 (2005)

47. Piga A.: Cactus pear: a fruit of nutraceutical and functional importance. *J Profess Assoc Cactus Dev*, 9-22 (2004)

48. JC Cheftel & H. Cheftel: Frutta e verdure. In Biocemica e tecnologia degli alimenti. Eds: Cheftel JC, Cheftel H, Edagricole, Bologna, Italy, 147-240 (1983)

49. Sáenz C.: The prickly pear (*Opuntia ficus indica*) a cultivar with prospects. *Alimentos* 10**,** 47–49 (1985)

50. Kader A.A.: Cactus (prickly) pear: recommendations for maintaining postharvest quality. Available from *http://rics.ucdavis.edu/postharvest2/produce/ ProduceFacts/ Fruit/cactus.shtml* (2002)

51. Ben Salem H., H. Abdouli, A. Nefzaoui, El-Mastouri & L. Ben Salem: Nutritive value, behaviour, and growth of Barbarine lambs fed on oldman saltbush (Atriplex nummularia L.) and supplemented or not with barley grains or spineless cactus (Opuntia ficus-indica f. inermis) pads. *Small Ruminant Res* 59, 229-237 (2005)

52. Ramadan M.F. & J.-T. Mörsel: Oil cactus pear (Opuntia ficus-indica L.). *Food Chem* 82, 339–345 (2003)

53. Kuti J.O. & C.M. Galloway: Sugar composition and invertase activity in prickly pear. *J Food Sci* 59, 387–393 (1994)

54. Felker P., C. Soulier, G. Leguizamon & J. Ochoa: A comparison of the fruit parameters of 12 *Opuntia* clones grown in Argentina and the United States. *J Arid Environ* 52, 361-370 (2002)

55. Felker P., S. del C. Rodriguez, R.M. Casoliba, R. Filippini, D. Medina & R. Zapata: Comparison of Opuntia ficus-indica varieties of Mexican and Argentine origin for fruit yield and quality in Argentina. *J Arid Environ* 60, 405-422 (2005)

56. Schmidt-Hebbel H., I. Pennacchiotti, L. Masson & M. A. Mella: Tabla de composición química de alimentos chilenos, Universidad de Chile, Facultad de Ciencias Químicas y Farmacéuticas, Santiago (1990)

57. Habibi Y., M. Mahrouz & M.R. Vignon: Arabinan-rich polysaccharides isolated and characterized from the endosperm of the seed of Opuntia ficus-indica prickly pear fruits. *Carbohydr Polymers* 60, 319-329 (2005)

58. Habibi Y., M. Mahrouz & M.R. Vignon : Isolation and structure of D-xylans from pericarp seeds of Opuntia ficus-indica prickly pear fruits. *Carbohydr Res* 337, 1593-1598 (2002)

59. Bittrich V. & M.D.C.E. Amaral, M.D.C.E.: Proanthocyanidins in the testa of centrospermous seeds. *Biochem System Ecol* 19, 319-321 (1991)

60. Habibi Y., M. Mahrouz & M.R. Vignon: Isolation and structure characterization of a (4-O-methyl-D-glucurono)-D-xylan from the skin of Opuntia ficus-indica prickly pear fruits. *J Carbohydr Chem* 22, 331-337 (2003)

61. Habibi Y., M. Mahrouz, M.-F. Marais & M.R. Vignon: An arabinogalactan from the skin of Opuntia ficus-indica prickly pear fruits. *Carbohydr Res* 339, 1201-1205 (2004)

62. Habibi Y., A. Heyraud, M. Mahrouz & M.R. Vignon: Structural features of pectic polysaccharides from the skin of *Opuntia ficus-indica* prickly pear fruits. *Carbohydr Res* 339, 1119-1127 (2004)

63. Habibi Y., M. Mahrouz & M.R. Vignon: Isolation and structural characterization of protopectin from the skin of Opuntia ficus-indica prickly pear fruits. *Carbohydr Polymers* 60, 205-213 (2005)

64. Arcoleo A., M. Ruccia & S. Cusmano: Sui pigmenti flavonici delle Opuntiae. Nota 1: Isoramnetina dai fiori di Opuntia ficus-indica Mill. (Cactaceae). *Ann Chim (Rome)* 51, 751-758 (1961)

65. Clark W.D. & B.D. Parfitt: Flower flavonoids of Opuntia series Opuntiae. *Phytochem* 19, 1856-1857 (1980)

66. Clark W.D., G.K. Brown & R.L. Mays: Flower flavonoids of Opuntia subgenus Cylindropuntia. *Phytochem* 19, 2042-2043 (1980)

67. Nair A.G.R. & S.S. Subramanian: Isolation of isoquercitrin from the flowers of Opuntia dillenii. *Current Sci (India)* 33, 211-212 (1964)

68. Rösler H., U. Rösler, T.J. Mabry & J. Kagan: Three flavonoid pigments of Opuntia lindheimeri. *Phytochem* 5, 189-192 (1966)

69. Shabir M. & A. Zaman: Chemical investigation of the flowers of Opuntia elatior (Cactaceae). *J Indian Chem Soc* 45, 11 (1968)

70. Teles F., J. Stull, W. Brown & F. Whitting: Amino and organic acids of prickly pear cactus (Opuntia ficus-indica L.). *J Sci Food Agric* 35, 421–425 (1984)

71. Teles F.F.F., F.M. Whiting, R.L. Price & V.E.L. Borges: Protein and amino acids of nopal (Opuntia ficus indica). *Revista Ceres* 44, 205–214 (1997)

72. Lee Y.-C., Y.-H. Pyo, C.-K. Ahn & S.-H. Kim: Food functionality of Opuntia ficus-indica var. cultivated in Jeju Island. *J Food Sci Nutr* 10, 103-110 (2005)

73. Majdoub H., S. Roudesli, L. Picton, D. Le Cerf, G. Muller & M. Grisel: Prickly pear nopals pectin from Opuntia ficus-indica physico-chemical study in dilute and semi-dilute solutions. *Carbohydr Polymers* 46, 69-79 (2001)

74. Breithaupt D.E. & A. Bamedi: Carotenoid esters in vegetables and fruits: a screening with emphasis on *b*-cryptoxanthin esters. *J Agric Food Chem* 49, 2064-2070 (2001)

75. Ramadan M.F. & J.-T. Mörsel: Recovered lipids from prickly pear [Opuntia ficus-indica (L.) Mill] peel: A good source of polyunsaturated fatty acids, natural antioxidant vitamins and sterols. *Food Chem* 83, 447–456 (2003)

76. Psomiadou E. & M. Tsimidou: Pigments in Greek virgin olive oils: occurrence and levels. *J Sci Food Agric* 81, 640–647 (2001)

77. Stintzing F.C., A. Schieber & R. Carle: Cactus pear—a promising component to functional food. *Obst Gemüse Kartoffelver* (Fruit Vegetable Potato Process) 85, 40–47 (2000)

78. Uchoa A.F., P.A.S. Souza, R.M.L. Zarate, E. Gomes-Filho & F.A.P. Campos : Isolation and characterization of a reserve protein from the seeds of Opuntia ficus-indica (Cactaceae), Brazilian *J Med Biological Res* 31, 757–761 (1998)

79. Gurrieri S., L. Miceli, C.M. Lanza, F. Tomaselli, R.P. Bonomo & E. Rizzarelli: Chemical characterization of Sicilian prickly pear (Opuntia ficus indica) and perspectives for the storage of its juice. *J Agric Food Chem* 48, 5424-5431 (2000)

80. Sawaya W. N., J. K. Khalil & M. M. Al-Mohammad: Nutritive value of prickly pear seeds, Opuntia ficus indica. *Plant Foods Human Nutr* 33, 91–97 (1983)

81. Joubert E.: Processing of the fruit of five prickly pear cultivars grown in South Africa. *Intern J Food Sci Technol* 28, 377- 387 (1993)

82. Sawaya W. N., H. A. Khatchadourian, W. M. Safi & H. M. Al-Hammad: Chemical characterization of prickly pear pulp, Opuntia ficus indica, and the manufacturing of prickly pear jam. *J Food Technol* 18, 183–193 (1983)

83. Kuti J.O. & C.M. Galloway: Sugar composition and invertase activity in prickly pear. *J Food Sci* 59, 387–393 (1994)

84. Barbagallo R.N., P. Pappalardo & G. Tornatore: Valutazione chimica y sensoriale di una purea concentrata di fichi d'India. *Industrie Alimentari* 37, 745-749 (1998)

85. Cheftel J. C., H. Cheftel & P. Besançon : Introducción a la bioquímica y tecnología de los alimentos. *Acribia, Zaragoza* (1983)

86. Coskuner Y. & A. Tekin: Monitoring of seed composition of prickly pear (Opuntia ficus-indica L) fruits during maturation period. *J Sci Food Agric* 83, 846-849 (2003)

87. Ennouri M., E. Bourret, L. Mondolot & H. Attia: Fatty acid composition and rheological behaviour of prickly pear seed oils. *Food Chem* 93, 431-437 (2005)

88. Salvo F., E.M. Galati, S. Lo Curto & M.M. Tripodo: Study on the chemical characterization of lipid composition of Opuntia ficus-indica L. seed oil. *Riv Italiana Sostanze Grasse* 79, 395–398 (2002)

89. Sawaya W.N. & P. Khan: Chemical characterization of prickly pear seed oil. *J Food Sci* 47, 2060–2061 (1982)

90. Tan C.P. & Y.B. Che Man: Differential scanning calorimetric analysis of edible oils: comparison of thermal properties and chemical composition. *J Am Oil Chem Soc* 77, 143–155 (2000)

91. Pelegrinin N., P. Simonetti & C. Gordana: Polyphenol content and total antioxidant activity of Vini Novelli (Young red wines). *J Agric Food Chem* 48, 732–735 (2000)

92. Manach C., A. Scalbert, C. Morand, C. Rémésy & L. Jimenez: Polyphenols: food sources and bioavailability. *Am J Clin Nutr* 79, 727–747 (2004)

93. Ross J.A. & C.M. Kasum: Dietary flavonoids: bioavailability, metabolic effects, and safety. *Annual Rev Nutr* 22, 19-34 (2002)

94. Cieslik E., A. Greda & W. Adamus: Contents of polyphenols in fruit and vegetables. *Food Chem* 94, 135-142 (2006)

95. Butera D., L. Tesoriere, F. Di Gaudio, A. Bongiorno, M. Allegra, A.M. Pintaudi, R. Kohen & M.A. Livrea: Antioxidant activities of Sicilian prickly pear (Opuntia ficus indica) fruit extracts and reducing properties of its betalains: Betanin and indicaxanthin. *J Agric Food Chem* 50, 6895–6901 (2002)

96. Kuti J.O.: Antioxidant compounds from four Opuntia cactus pear fruit varieties. *Food Chem* 85, 527-533 (2004)

97. Shahidi F., P.K. Janitha & P.D. Wanasundara: Phenolic antioxidanta, Critical previous term Reviews next term. *Food Sci Nutr* 32, 67–103 (1992)

98. Aires V., S. Adote, A. Hichami, K. Moutairou, E. S. E. Boustani & N. A. Khan: Modulation of intracellular calcium concentrations and T cell activation by prickly pear polyphenols. *Mol Cell Biochem* 260, 103-110 (2004)

99. Iwashina T.: Flavonoids and their distribution in plant families containing the betalain pigments. *Ann Tsukuba Botanic Gardens* 20, 11-74 (2001)

100. JP Zryd & L. Christinet: Betalains. In: Plant pigments and their manipulation. Eds: Davies K, *Ann Plant Rev* 14, CRC Press/ Blackwell Publishing: Oxford/UK-Victoria/Australia (2004)

101. Alard D.: Betalaine der Kakteen. Thesis, University of Cologne (1985)

102. Castellar R., J.M. Obón, M. Alacid & J.A. Fernández-López: Color properties and stability of betacyanins from Opuntia fruits. *J Agric Food Chem* 51, 2772–2776 (2003)

103. Stintzing F.C., A. Schieber, & R. Carle: Identification of betalains from yellow beet (Beta vulgaris L.) and cactus pear [Opuntia ficus-indica (L.) Mill.] by high-performance liquid chromatography –electrospray ionization mass spectrometry. *J Agric Food Chem* 50, 2302-2307 (2002)

104. Gurbachan S. & P. Felker: Cactus: new world foods. *Indian Horticulture* 43, 29–31 (1998)

105. Sáenz C.H.: Processing technologies: an alternative for cactus pear (*Opuntia* spp.) fruits and cladodes. *J Arid Environ* 46, 209-225 (2000)

106. Hegwood D.A.: Human health discoveries with Opuntia sp. (prickly pear). *HortSci* 25, 1315–1316 (1990)

107. Bustos O.E.: Alcoholic beverage from Chilean Opuntia ficus indica. *Am J Enol Vitic* 32, 228-229 (1981)

108. Del-Valle, V., P., Andez-Munoz, A. Guarda & M.J. Galotto: Development of a cactus-mucilage edible coating (Opuntia ficus indica) and its application to extend strawberry (Fragaria ananassa) shelf-life. *Food Chem* 94, 751-756 (2005)

109. Essa H.A. & M.F. Salama: Effect of macerate enzyme on the yield, quality, volatile compounds and rheological property of prickly pear juice. *Nahrung/Food* 46, 245-250 (2002)

110. Ewaidah E.H. & B.H. Hassan: Prickly pear sheets: a new fruit product. *Int J Food Sci Technol* 27, 353-358 (1992)

111. Lee S.-P., S.-K. Lee & Y-D. Ha: Alcohol fermentation of Opuntia ficus fruit juice. *J Food Sci Nutr* 5, 32-36 (2000)

112. Moreno Alvarez M.J., C. Medina, L. Antón, D. García, D.R. Belén Camacho: Uso de pulpa de tuna (Opuntia boldinghii) en la elaboración de bebidas cítricas pigmetadas. *Interciencia* 28, 539-543 (2003)

113. Moßhammer M.R., F.C. Stintzing & R. Carle: Development of a process for the production of a betalain-based colouring foodstuff from cactus pear. *Innovative Food Science & Emerging Technologies* 6, 221-231 (2005)

114. Sáenz C. & E. Sepúlveda: Cactus-pear juices. *J Profess Assoc Cactus Dev* 4, 3-10 (2001)

115. Sépúlveda E., C. Sáenz & M. Alvarez: Physical, chemical and sensory characteristics of dried fruit sheets of cactus pear (Opuntia ficus-indica L. Mill) and quince (Cydonia oblonga Mill). *Italian J Food Sci* 12, 47-54 (2000)

116. Son M.-J. & S.-P. Lee: Optimization of lactic acid fermentation of prickly pear extract. *J Food Sci Nutr* 9, 7-13 (2004)

117. A Nefzaoui: Crop livestock integration through better use of feed resources in Tunisia. In: Improvement of crop-livestock integration systems in West Asia and North Africa. Proceedings of the regional symposium on integrated crop-livestock systems in the dry areas of West Asia and North Africa. Eds: Haddad N, Tutwiler R, Thomson E, ICARDA, Amman, Jordan (1997)

118. Gillet T.: Bresil: les chevres de la caatinga. *Chevre* 178, 40–46 (1990)

119. Le Houérou H.N.: Drought-tolerant and water-efficient fodder shrubs (DTFS), their role as a 'drought insurance' in the agricultural development of arid and semi-arid zones in Southern Africa. Report to the Water Research Commission of South Africa, Pretoria, South Africa, 139 (1994)

120. A Nefzaoui & H. Ben Salem: Forage, fodder, and animal nutrition. In: Cacti. Biology and Uses. Eds: Nobel PS, University of California Press, Berkeley, 199-210 (2002)

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

122. Piga A., A. Del Caro, I. Pinna, & M. Agabbio: Changes in ascorbic acid, polyphenol content and antioxidant activity in minimally processed cactus pear fruits. *Lebensm-Wiss Technol* 36, 257-262 (2003)

123. Rice-Evans C. A. & N. J. Miller: Antioxidants: the case of fruit and vegetables in the diet. *Br Food J* 97, 35-40 (1985)

124. Ames B.N., M. K. Shigenaga & T.M. Hagen: Oxidants, antioxidants and the degenerative disease of aging. *Proc Natl Acad Sci* 90, 7915-7922 (1993)

125. Lampe J.W.: Health effects of vegetables and fruits: assessing mechanism of action in human experimental studies. *Am J Clin Nutr* 70, 475-490 (1999)

126. Hertog M.G.L., E.J.M. Feskens, P.C.H. Hollman, M.B. Katan & D. Kromhout: Dietary antioxidants, flavonoids and the risk of coronary heart disease: the Zutphen eldery study. *Lancet* 342, 1007-1011 (1993)

127. Rice-Evans C.A., N.J. Miller & G. Paganga: Antioxidant properties of phenolic compounds. *Trends Plant Sci* 2, 152-159 (1997)

128. Peterson J. & J. Dwyer: Flavonoids: dietary occurrence and biochemical activity. *Nutr Res* 12, 1995-2018 (1998)

129. Block G., B. Patterson & A. Subar: Fruit, vegetables, and cancer prevention: a review of the epidemiological evidence. *Nutr Cancer* 18, 1-29 (1992)

130. Donaldson M.S.: Nutrition and cancer: A review of the evidence for an anti-cancer Diet. *Nutr J* 3 (2004)

131. El Kossori R.L., C. Villaume, E. El Boustani, Y. Sauvaire & L. Mejean: Composition of pulp, skin and seeds of prickly pears fruits (Opuntia ficus indica sp.). *Plant Foods Human Nutr* 52, 263-270 (1998)

132. Zou D.M., M. Brewer, F. Garcia, J.M. Feugang, J. Wang, R. Zang, H. Liu & C.P. Zou: Cactus Pear - a Natural Product in Cancer Chemoprevention. *Nutr J* 4, (2005)

133. Supino R., M. Crosti, M. Clerici, A. Warlters, L. Cleris, F. Zunino & F. Formelli: Induction of apoptosis by

Fenretinide (4-HPR) in human ovarian carcinoma cells and its association with retinoic acid receptor expression. *Int J Cancer* 65, 491–497 (1996)

134. Veronesi U., G. De Palo, E. Marubini, A. Costa, F. Formelli, L. Mariani, A. Decensi, T. Camerini, M.R. Del Turco, M.G. Di Mauro, M.G. Muraca, M. Del Vecchio, C. Pinto, G. D'Aiuto, C. Boni, T. Campa, A. Magni, R. Miceli, M. Perloff, W.F. Malone & M.B. Sporn: Randomized trial of fenretinide to prevent second breast malignancy in women with early breast cancer. *J Natl Cancer Inst* 91, 1847–1856 (1999)

135. De Palo G., L. Mariani, T. Camerini, E. Marubini, F. Formelli, B. Pasini, A. Decensi & U. Veronesi: Effect of fenretinide on ovarian carcinoma occurrence. *Gynecol Oncol* 86, 24–27 (2002)

136. Steinmetz K.A. & J.D. Potter: Vegetables, fruit, and cancer prevention: a review. *J Am Diet Assoc* 96, 1027-1039 (1996)

137. Leenen R., A.J. Roodenburg, L.B. Tijburg & S.A. Wiseman: A single dose of tea with or without milk increases plasma antioxidant activity in humans. *Eur J Clin Nutr* 54, 87–92 (2000)

138. Martinez J. & J. J. Moreno: Effect of resveratrol, a natural polyphenolic compound, on reactive oxygen species and prostaglandin production. *Biochem Pharmacol* 59, 865–870 (2000)

139. Tesoriere L., D. Butera, A.M. Pintaudi, M. Allegra & M.A. Livrea: Supplementation with cactus pear (Opuntia ficus-indica) fruit decreases oxidative stress in healthy humans: a comparative study with vitamin C. *Am J Clin Nutri* 80, 391-395 (2004)

140. Park E.-H., J.H. Kahng & E.-A. Paek: Studies on the pharmacological actions of cactus: identification of its anti-inflammatory effect. *Arch Pharm Res* 21, 30–34 (1998)

141. Tesoriere L., D. Butera, D. D'Arpa, F. Di Gaudio, M. Allegra, C. Gentile & M.A. Livrea: Increased resistance to oxidation of betalain-enriched human low density lipoproteins. *Free Radic Res* 37, 689–696 (2003)

142. Gentile C., L. Tesoriere, M. Allegra, M.A. Livrea & P. D'Alessio: Antioxidant betalains from catus pear (Opuntia ficus-indica) inhibit endothelial ICAM-1 expression. *Ann NY Acad Sci* 1028, 481–486 (2004)

143. Dok-Go H., K.H. Lee, H.J. Kim, E.H. Lee, J. Lee, Y.S. Song, Y.-H. Lee, C. Jin, Y.S. Lee & J. Cho: Neuroprotective effects of antioxidative flavonoids, quercetin, (+)-dihydroquercetin and quercetin 3-methyl ether, isolated from Opuntia ficus-indica var. saboten. *Brain Res* 965, 130-136 (2003)

144. Carbo N., P. Costelli, F.M. Baccino, F.J. Lopez-Soriano & J.M. Argiles: Resveratrol, a natural product present in wine, decreases tumour growth in a rat tumour model. *Biochem Biophys Res Commun* 254, 739–743 (1999)

145. Tapiero H., K.D. Tew, G.N. Ba & G. Mathe: Polyphenols: Do they play a role in the prevention of human pathologies? *Biomed Pharmacother* 56, 200–207 (2002)

146. Yang C.S. & Z.Y. Wang: Tea and cancer. *J Natl Cancer Inst* 85, 1038-1049 (1993)

147. Ahmad N., P. Cheng & H.H. Mukhtar: Cell cycle dysregulation by green tea polyphenol epigallocatechin-3-gallate. *Biochem Biophys Res Commun* 275, 328–334 (2000)

148. Ren F., S. Zhang, S.H. Mitchell, R. Butler & C.Y. Young: Tea polyphenols down-regulate the expression of the androgen receptor in LNCaP prostate cancer cells. *Oncogene* 19, 1924-1932 (2000)

149. Ahmad A., J. Davies, S. Randall & G.R.B. Skinner: Antiviral properties of extract of Opuntia streptacantha. *Antiviral Research* 30, 75-85 (1996)

150. Loro J.F., I. del Rio & L. Pérez-Santana: Preliminary studies of analgesic and anti-inflammatory properties of Opuntia dillenii aqueous extract. *J Ethnopharmacol* 67, 213-218 (1999)

151. Galati E.M., M.T. Monforte, M.M. Tripodo, A. d'Aquino & M.R. Mondello: Antiulcer activity of Opuntia ficus-indica (L.) Mill. (Cactaeceae): ultrastructural study. *J Ethnopharmacol* 76, 1–9 (2001)

152. Park E.H., J.H. Kahng S.H. Lee & K.H. Shin: An anti-inflammatory principle from cactus. *Fitoterapia* 72, 288-90 (2001)

153. Lee E.B., J.E. Hyun, D.W. Li & Y.I. Moon: The effect of Opuntia ficus-indica var. saboten fruit on gastric lesion and ulcer in rats. *Nat Prod Sci* 7, 90-93 (2001)

154. Lee B., J.E. Hyun, D.W. Li & Y.I. Moon: Effects of Opuntia ficus-indica var. Saboten stem on gastric damages in rats. *Arch Pharm Res* 25, 67–70 (2002)

155. Allegra M., P.G. Furtmüller, W. Jantschko, M. Zederbauer, L. Tesoriere, M.A. Livrea & C. Obinger: Mechanism of interaction of betanin and indicaxanthin with human myeloperoxidase and hypochlorous acid. *Biochem Biophys Res Commun* 332, 837-844 (2005)

156. Domínguez López A.: Use of the fruits and stems of the prickly pear cactus (Opuntia spp.) into human food. *Food Sci Technol Int* 1, 65–69 (1995)

157. Cicero A.F.G., G. Derosa & A. Gaddi: What do herbalists suggest to diabetic patients in order to improve glycemic control? Evaluation of scientific evidence and potential risks. *Acta Diabetologica* 41, 91-98 (2004)

158. Ibanez-Camacho R. & R. Roman-Ramos : Hypoglycemic effect of Opuntia cactus. *Arch Invest Med (Mex)* 10, 223–230 (1979)

159. Ibanez-Camacho R., M. Meckes-Lozoya & V. Mellado-Campos: The hypoglycemic effect of Opuntia streptaeantha studied in different animal experimental models. *J Ethnopharmacol* 7, 175-181 (1983)

160. Frati A.C., E. Jimenez & C.R. Ariza: Hypoglycemic effect of Opuntia ficus-indica in non insulin-dependent diabetes mellitus patients. *Phytother Res* 4, 195–197 (1990)

161. Frati-Munari A.C., B.E. Gordillo, P. Altamirano, & C.R. Ariza: Hypo-glycemic effect of Opuntia streptaeantha Lemaire in NIDDM. *Diabetes Care* 11, 63-66 (1988)

162. Trejo-González A., G. Gabriel-Ortiz, A.M. Puebla-Pérez, M.D. Huízar-Contreras, M. del Rosario Munguía-Mazariegos, S. Mejía-Arreguín & E. Calva: A purified extract from prickly pear cactus (Opuntia fuliginosa) controls experimentally induced diabetes in rats. *J Ethnopharmacol* 55, 27-33 (1996)

163. Ennouri M., H. Fetoui, E. Bourret, N. Zeghal & H. Attia H.: Evaluation of some biological parameters of Opuntia ficus indica. 1. Influence of a seed oil supplemented diet on rats. *Bioresour Technol, In press* (2005)

164. Fernandez M.L., E.C. Lin, A. Trejo & D.J. McNamara: Prickly pear (Opuntia sp.) pectin reverses low density lipoprotein receptor suppression induced by a hypercholesterolemic diet in guinea pigs. *J Nutr* 122, 2330–2340, (1992)

165. Frati A.: Medical implication of prickly pear cactus. In: Proc. 3rd Annual Texas prickly pear council. Eds: Felkar P, Moss LR, 24–25 July, Kingsville, Texas, 29-34 (1992)

166. Galati E.M., M.M. Tripodo, A. Trovato, A. d'Aquino & M.T. Monforte: Biological activity of Opuntia ficus indica cladodes II: Effect on experimental hypercholesterolemia in rats. *Pharm Biology* 41 (3): 175-179 (2003)

167. Jones P., M. Raeini-Sarjaz, F. Ntanios, C. Vanstone, J. Feng, & W. Parsons: Modulation of plasma lipid levels and cholesterol kinetics by phytosterol versus phytostanol esters. *J Lipid Res* 41, 697–705 (2000)

168. Lee H., J.-S. Yoon, B.H. Lee, B.W. Choi & K.H. Park: Screening of the radical scavenging effects, tyrosinase inhibition, and anti-allergic activities using Opuntia ficus-indica. *Kor J Pharmacogn* 31, 412–415 (2000)

169. Galati E.M., M.M. Tripodo, A. Trovato, N. Miceli, & M.T. Monforte: Biological effects of Opuntia ficus indica (L.) Mill. (Cactaceae) waste matter. Note I: diuretic activity. *J Ethnopharmacol* 79, 17-21 (2002)

170. Wiese J., S. McPherson, M.C. Odden & M.G. Shlipak: Effect of Opuntia ficus indica on symptoms of the alcohol hangover. *Arch Internal Med* 164, 1334-1340 (2004)

171. Jonas A., G. Rosenblat, D. Krapf, W. Bitterman & I. Neeman: Cactus flower extracts may prove beneficial in benign prostatic hyperplasia due to inhibition of 5 alpha reductase activity, aromatase activity and lipid peroxidation. *Urol Res* 26, 265-270 (1998)

172. Yoon H.J., C.H. Won & S.E. Moon: Allergic contact dermatitis due to Opuntia ficus-indica var. saboten. *Contact Dermatitis* 51, 311-312 (2004)

173. Galati E. M., M. R. Mondello, E. R. Lauriano, M. F. Taviano, M. Galluzzo & N. Miceli: Opuntia ficus indica (L.) Mill. Fruit Juice Protects Liver from Carbon Tetrachlorideinduced Injury. *Phytother Res* 19, 796–800 (2005)

174. Warschkow S. & K. Warschskow: Hair loss treatment and hair growth promoter – comprises drink and hair gel containing cold pressed juice of meristematic tissue of cacti plants and pampa grass. *DE Patent 43331252* (1994)

175. Sáenz-Hernandez C., J. Corrales-Garcia & G. Aquino-Perez: Nopalitos, mucilage, fiber, & cochineal. In: Cacti. Biology and Uses. Eds: Nobel PS, University of California Press, Berkeley, Los Angeles, 211-234 (2002)

176. Sáenz C.: Cactus pear fruit and cladodes: a source of functional components for foods. *Acta Hort* 581, 253-263 (2002)

177. Viegi L., A. Pieroni, P.M. Guarrera & R. Vangelisti: A review of plants used in folk veterinary medicine in Italy as basis for a databank. *J Ethnopharmacol* 89, 221-244 (2003)

178. Moreno P.R. & C.F. Flores: The world cactus pear market. *J Profess Assoc Cactus Dev* 1, 75–86 (1996)

179. Basile F.: Economic aspects of Italian cactus pear production and market. *J Profess Assoc Cactus Dev* 4, 31–49 (2001)

180. Sáenz A.M., E. Estévez, E. Sepúlveda & P. Mecklenburg: Cactus pear fruit: A new source for a natural sweetener. *Plant Foods Human Nutr* 52, 141-149 (1998)

181. Turker N., y. Coskuner, S. Ekiz-Hi Aksay & E. Karababa: The effect of fermentation on the thermostability of the yellow-orange pigments extracted from cactus pear (Opuntia ficus-indica). *Eur Food Res Technol* 212, 213–216 (2001)

182. Moßhammer M.R., F.C. Stintzing & R. Carle: Colour studies on fruit juice blends from Opuntia and Hylocereus cacti and betalain-containing model solutions derived therefrom. *Food Res Int* 38, 975-981 (2005)

183. Stintzing F.C. & R. Carle: Functional properties of anthocyanins and betalains in plants, food, and in human nutrition. *Trends Food Sci Technol* 15, 19–38 (2004)

184. Drennan P.M. & P.S. Nobel: Responses of CAM species to increasing atmospheric CO_2 concentrations. *Plant Cell Environ* 23, 767-781 (2000)

185. Nobel P.S., E. García-Moya & E. Quero: High annual productivity of certain agaves and cacti under cultivation. *Plant Cell Environ* 15, 329-335 (1992)

186. Nobel P.S. & A.A. Israel: Cladode development, environmental responses of CO_2 uptake, and productivity for *Opuntia ficus-indica* under elevated CO_2. *J Exp Bot* 45, 295-303 (1992)

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