Open Access Research Journal of
Chemistry and Pharmacy
Journals home page: https://oarjpublication/journals/oarjcp/
ISSN: 2783-0276 (Online)

OARJ OPEN ACCESS RESEARCH JOURNALS

(REVIEW ARTICLE)

Check for updates

Herbal remedies through cactus nutrients

Muhammad Arshad Ullah [1,*] and Ali Hassan [2]

[1] *Pakistan Agricultural Research Council, Islamabad, Pakistan.*
[2] *PMAS- University of Arid Agriculture, Rawalpindi, Pakistan.*

Open Access Research Journal of Chemistry and Pharmacy, 2021, 01(01), 033–046

Publication history: Received on 25 February 2021; revised on 25 March 2021; accepted on 28 March 2021

Article DOI: https://doi.org/10.53022/oarjcp.2021.1.1.0030

Abstract

The main constituent of *Opuntiaficus-indica* cladodes is water (80-95%), followed by small amounts of carbohydrates (3-7%), fiber (1-2%), and protein (0. 5-1%); other compounds are only partly known and have not been quantitatively determined. The sugar moiety includes mucilaginous components containing polymers, such as chains of (1-4)-linked β-D-galacturonic acid and R (1-2)-linked L-rhamnose residues. Beneficial effects of herbal remedies can be obtained from active constituents present in the whole plant, parts of the plant (e. g., flowers, fruits, roots or leaves), or plant materials or combinations thereof, whether in crude or processed state. Cactus (*Opuntiaficus-indica*) commonly known as prickly pear belongs to the family Cactaceae. *Opuntiaficus-indica* produces sweet, nutritionally rich edible fruits; its tender cladodes are used as fresh green vegetable and salad. In South Africa, Mediterranean areas and South American this species is also cultivated for its edible fruit (prickly pear), although in some countries different parts of the plant are utilized in the food and cosmetic industry. *Opuntiaficus-indica*, fruits and stems, have been traditionally used in folk medicine in several countries for several medicinal purposes. Cactus dietary fiber is composed of several chemical components that are resistant to digestive enzymes such as cellulose, hemicelluloses, pectin, lignin, gums, etc. The benefits associated with fiber content are well known, especially for the prevention of illnesses such as diabetes, treatment of gastrointestinal disorders, illnesses associated with low dietary fiber intake, reduction of glucose values in the blood, anti-hyperlipidemic and anti-hypercholesterolemic effects. Throughout history, the benefits of consuming dietary fiber have been recognized. Soluble fibers, including pectins, gums, and mucilages, increase the viscosity of food in the gut, slowing or reducing sugar absorption. The effect of soluble fiber in reducing serum glucose concentrations is a proposed mechanism of action for the herbal hypoglycemic cactus. It has been reported that *Opuntiaficus-indica* contain phenolic compounds like ferulic acid, feruloyl-sucrose and sinapoyl-diglucoside, fatty acids like palmitic acid, stearic acid, oleic acid, vaccenic acid and linoleic acid (seeds, peel and juicy pulp). It has been observed that *Opuntiaficus-indica* oil extract with these components' present antioxidant and anti-free radical activity, having a potential as anticancer, anti-inflammatory, hypoglycemic, hypolipidemic and hypocholesterolemic activities. Cactus fiber tablet contains 500 mg standardized cactus fiber; as well as common tableting excipients were used. Cactus fiber showed an increased fecal fat excretion compared with placebo. No adverse events were reported throughout the study period. The fruit peel contains large amounts of isorhamnetin. Isorhamnetin (3'-methoxy-3,4',5,7-tetrahydroxyflavone) exerts anticancer action by inhibition of epidermal growth factor (EGF)-induced neoplastic cell transformation through a direct lowering of MAP (mitogen-activated protein)/ERK (extracellular signal regulated kinase) kinase1 and phosphoinositol 3-kinase signaling pathways. Isorhamnetin exhibits cardio protective effects by improving viability of neonatal rat ventricular myocytes under invitro ischemia/reperfusion (I/R) via inhibition of lactate dehydrogenase (LDH) activity and prevention of apoptosis. Isorhamnetin improves skin barrier function through activation of Peroxisome Proliferator-Activated Receptor (PPAR)-αand suppression of inflammatory cytokines production. It also inhibits a dipocyte differentiation of murine 3T3 fibroblasts via a decrease of adiponectine expression and secretion, and down regulation of mRNAs of PPAR-γand C/EBP-α, the major adipogenic nuclear receptors. In contrast, isorhamnetin significantly increases the expression of PPAR-γin tumor tissues obtained from xenograft model of gastric cancer cells and, in combination with chemotherapeutic drugs, causes strong antiproliferative effects and cytotoxicity. The linoleic acid content in cactus cladode (34. 87%) is thus close to the percentage (29% to 40. 41%) found in argan

*Corresponding author: Muhammad Arshad Ullah
Pakistan Agricultural Research Council, Islamabad, Pakistan.

oil. It is however lower than in extracts from barely (51. 26%) and soybean (53. 0%), respectively. Cactus pear (*O. boldinghii*) cladodes having high fiber content and potential health benefits bakery products have been produced and evaluated from composite flours of wheat (WF) and cactus pear stems (SF). Orange-yellow cactus pear fruit pulp has been used to produce a dehydrated cactus pulp sheet and pasteurized cactus pear fruit juices.

Keywords: Vaccenic acid; Anti-hyperlipidemic; Antiproliferative; Argan oil; Dehydrated cactus pulp

1. Introduction

It is generally accepted that the beneficial effects of herbal remedies can be obtained from active constituents present in the whole plant, parts of the plant (e. g., flowers, fruits, roots or leaves), or plant materials or combinations thereof, whether in crude or processed state [1]. Cactus (*Opuntiaficus-indica*) commonly known as prickly pear belongs to the family Cactaceae. *Opuntiaficus-indica* produces sweet, nutritionally rich edible fruits; its tender cladodes are used as fresh green vegetable and salad [2; 3]. In South Africa, Mediterranean areas and South American this species is also cultivated for its edible fruit (prickly pear), although in some countries different parts of the plant are utilized in the food and cosmetic industry [4; 5 and 6]. *Opuntiaficus-indica*, fruits and stems, have been traditionally used in folk medicine in several countries for several medicinal purposes [7].

The main constituent of *Opuntiaficus-indica* cladodes is water (80-95%), followed by small amounts of carbohydrates (3-7%), fiber (1-2%), and protein (0. 5-1%); other compounds are only partly known and have not been quantitatively determined [8]. The sugar moiety includes mucilaginous components containing polymers, such as chains of (1-4)-linked β-D-galacturonic acid and R (1-2)-linked L-rhamnose residues (9). The physiological role of the plant mucilage is to regulate the cellular water content during prolonged drought and to regulate the calcium fluxes of the plant [10; 11]. *Opuntiaficus-indica* cladodes also represent a source of phytochemicals, such as phenolics acids and flavonoids [12].

Cactus dietary fiber is composed of several chemical components that are resistant to digestive enzymes such as cellulose, hemicelluloses, pectin, lignin, gums, etc. The benefits associated with fiber content are well known, especially for the prevention of illnesses such as diabetes, treatment of gastrointestinal disorders, illnesses associated with low dietary fiber intake, reduction of glucose values in the blood, anti-hyperlipidemic and anti-hypercholesterolemic effects [13]. Throughout history, the benefits of consuming dietary fiber have been recognized. Soluble fibers, including pectins, gums, and mucilages, increase the viscosity of food in the gut, slowing or reducing sugar absorption. The effect of soluble fiber in reducing serum glucose concentrations is a proposed mechanism of action for the herbal hypoglycemic cactus [14]. It has been reported that *Opuntiaficus-indica* contain phenolic compounds like ferulic acid, feruloyl-sucrose and sinapoyl-diglucoside, fatty acids like palmitic acid, stearic acid, oleic acid, vaccenic acid and linoleic acid (seeds, peel and juicy pulp) [15]. It has been observed that *Opuntiaficus-indica* oil extract with these components present antioxidant and anti-free radical activity, having a potential as anticancer, anti-inflammatory, hypoglycemic, hypolipidemic and hypocholesterolemic activities [16]. Cactus fiber tablet contains 500 mg standardized cactus fiber; as well as common tableting excipients were used. Cactus fiber showed an increased fecal fat excretion compared with placebo. No adverse events were reported throughout the study period [17].

Opuntiaficus-indica was found to have various classes of bioactive compounds [10; 18]. It has been established that the amount of phytochemicals varies between genuses Opuntia; for example, it has been demonstrated that red-skinned prickly pear fruits contain taurine (7. 7-11. 2 mg/100g fresh fruit) at the same level of Sicilian cultivars of *Opuntiaficus-indica* but at a lower concentration than that reported for American and African cultivars [19]. It has been observed the presence of total phenolic and polyphenolic compounds (free and conjugated) in concentrations of 80-90 mg/100g dried weight, which include aromadendrin, taxifolin or dihydroquercetin, isorhamnetin, vitexin, kaempferol, quercetin, betalains, betacyanins, rutin and isorhamnetin and derivatives like myricetin, orientin and some derivatives of pyrone [20]. A great deal of plant essential oils has beneficial properties such as antioxidant and antimicrobial activities, among other, [21; 22] and the presence of antioxidant and antimicrobial compounds found in this study Traditional preparations from those species have been evaluated in temporarily hyperglycemic rabbits, in alloxan-diabetic rabbits, type II diabetic patients and normal volunteers [23; 24; 25; 26; 27 and 28]. It is cultivated in America, Africa, Asia, Europe and Oceania [29]. When first discovered by the European explorers, opuntias were distributed from Mesoamerica to Cuba and other Caribbean islands [4]. It became invasive in areas with a wet season characterized by high temperatures, for example, in South Africa and Australia [30].

Argentina has a cactus pear production surface area of 1 650 ha; 80% is in the northeastern region, the remainder scattered in the centre and Cuyo [31]. The main cultivar is a local selection called 'Amarilla sin espinas' (yellow without spines). The main areas of fruit production are the Metropolitana area and the regions of Coquimbo and Valparaíso [32]. The second crop produces just one-third the volume of the first, but it reaches higher prices [33]. Opuntias in Mexico

have the highest degree of genetic diversity and the greatest level of consumption [2]. Today, cactus pear production is distributed among various states mainly in Federal District, State of Mexico, San Luis Potosí, Zacatecas, Tamaulipas, Aguas-calientes and Guanajuato [34]. Cactus pear is the sixth fruit crop in Mexico, after orange, avocado, banana, mango and apple; it is more important than peach, guava or table grapes [34]. The available figures illustrate its importance: the planted area covers 53 876 ha; it is the fifth fruit crop in the country; about 20 000 families obtain income from cactus pear cultivation; and gross annual production has reached 428 763 tonnes $year^{-1}$ [35]. Cactus plantations are common under mixed plantation systems growing alongside other fruit trees, as well as in family gardens for self-consumption. Extensive production systems for commercial fruit production exist in a very limited area in south and north Lebanon [36]. Cactus pear cultivars grown in Lebanon are 'Baldi' (spiny cactus) and imported cultivars from Europe, Brazil etc. The imported cultivars include both spiny and spineless ones [36].

Opuntiaficus indica (L.) Mill. commonly called prickly pear ornopal cactus, belongs to the dicotyledonous angiosperm Cactaceae family, a family that includes about 1500 species of cactus. *O. ficusindica* is a tropical and subtropical plant. It can grow in arid and semi-arid climates with a geographical distribution encompassing Mexico, Latin America, South Africa and Mediterranean countries [37]. Recent scientific reports have highlighted the presence of natural cactus molecules, which may have high potential interest in human health and medicine [38; 39 and 40]. *Opuntiaficus indica* is known for its high content in polyphenols exhibiting antioxidant and anti-inflammatory properties [37; 41]. Interestingly, alkaloids, indicaxanthin, neobetanin, and various flavonoids have been isolated from the cactus [42], along with polysaccharides which are abundant in cladode extracts and endowed with antidiabetic and antiglycation effects [43].

Cactus fruit contains substantial amounts of ascorbic acid, vitamin E, carotenoids, fibers, amino acids and antioxidant compounds (phenols, flavonoids, betaxanthin and betacyanin) which have been put forward to account for its health benefits such as hypoglycemic and hypolipidemic action, and antioxidant properties [44; 45 and 46]. Several reports have documented the abundance of vitamins and minerals in cactus [47]. In this respect, the fruit of *O. ficusindica* is a valuable source of nutrients [48] as well as antiulcerogenic [49], antioxidant [41; 49; 50 and 51], anticancer [*51]*, neuroprotective [52], hepatoprotective [49], and antiproliferative [53] compounds. *Opuntiaficus indica* flowers contains different flavonoids notably kaempferol and quercetin [54]. Cactus peel and seeds can be used to prepare cactus oil, peel lipids being enriched in essential fatty acids and liposoluble antioxidants [55]. The cactus cladodes contain vitamins, antioxidants and various flavonoids, particularly quercetin 3-methyl ether, a highly efficient radical scavenger [20; 56].

All parts of the cactus plant are rich in members of the polyphenol family such as various flavonoids and phenolic acids. In the flower, gallic acid and 6-isorhamnetin 3-O-robinobioside are the major compounds, amounting to 4900 and 4269 mg/100 g of dry matter, respectively [54; 57 and 58]. In the fruit pulp, total phenol content is 218. 8 mg/100 g [59], along with a high content of isorhamnet in glycosides (50. 6 mg/100 g) compared to other flavonoids [16; 19; 60 and 61]. Fruit seeds contain high amounts of phenolic compounds ranging from 48 to 89 mg/100 g and including feruloyl derivatives, tannins and sinapoyldiglucoside [15]. Interestingly, fruit peel has a very high phenol content of 45. 7 g/100 g. Several of these phenols are bioactive molecules, notably flavonoid derivatives such as kaempherol and quercetin, the contents of which are 0. 22 and 4. 32 mg/100 g, respectively [41; 60 and 62].

Interestingly, some polyphenols are produced only by cladodes of some varieties of cactus such as the snowshoeing cactus. This plant presents high amounts of unusual flavonoid-like compounds such as nicotiflorin (146. 5 mg/100 g) and narcissin (137. 1 mg/100 g) along with high content values found for isoquercetin and ferulic acid: 39. 67 and 34. 77 mg/100 g, respectively [16;40; 63; 64 and 65]. For instance, gallic acid, largely found in cactus flowers, exhibits high antioxidant activity responsible for its ability to reduce DNA damage [66] and to buffer free radicals [67]. At a concentration of 4. 17 mM, it may neutralize 44% of 2, 2-diphenyl-1-picrylhydrazyl radical and 60% of hydrogen peroxide in given experimental conditions. Gallic acid also exerts a cytotoxic activity against tumoral cells from leukemia, lung and prostate cancer origins [68].

Opuntiaficus-indica cladodes are rich in nicotiflorin which, through antiinflammatory and neuroprotectivemechanims, was shown to reduce brain infarct size, to attenuate neurological deficits induced by ischemia, and toup-regulate endothelial nitric oxide synthase in cultured rat brain vascular endothelial cells [69]. Nicotiflorin is neuroprotective against hypoxia-, glutamate- or oxidative stress-induced retinal ganglion cell death at nanomolar concentrations [70]. In a murine multi-infarct dementia model, nicotiflorin preserved spatial memory performances measured in Morris water maze tests. Besides this protective effect on memory dysfunction, nicotiflorin also protects against energy metabolism failure and oxidative stress. In ischemic brains, these beneficial effects were associated with attenuation of rises in lactic acid and malondialdehyde (MDA) and with prevention of drops in lactate dehydrogenase (LDH), Na^+ K^+ ATPase, $Ca^{2+}Mg^{2+}$ATPase and superoxide dismutase (SOD) activities [71].

As mentioned above, the fruit peel contains large amounts of isorhamnetin. Isorhamnetin (3'-methoxy-3,4',5,7-tetrahydroxyflavone) exerts anticancer action by inhibition of epidermal growth factor (EGF)-induced neoplastic cell transformation through a direct lowering of MAP (mitogen-activated protein)/ERK (extracellular signal regulated kinase) kinase1 and phosphoinositol 3-kinase signaling pathways [72]. Isorhamnetin exhibits cardioprotective effects by improving viability of neonatal rat ventricular myocytesunder invitro ischemia/reperfusion (I/R) viainhibition of lactate dehydrogenase (LDH) activity and prevention of apoptosis [73]. Isorhamnetin improves skin barrier function through activation of Peroxisome Proliferator-Activated Receptor (PPAR)-αand suppression of inflammatory cytokines production [74]. It also inhibits adipocyte differentiation of murine 3T3 fibroblasts viaa decrease of adiponectine expression and secretion, and down regulation of mRNAs of PPAR-γ and C/EBP-α, the major adipogenic nuclear receptors [75]. In contrast, isorhamnetin significantly increases the expression of PPAR-γin tumor tissues obtained from xenograft model of gastric cancer cells and, in combination with chemotherapeutic drugs, causes strong antiproliferative effects and cytotoxicity [76]. The linoleic acid content in cactus cladode (34. 87%) is thus close to the percentage (29% to 40. 41%) found in argan oil [77]. It is however lower than in extracts from barely (51. 26%) and soybean (53. 0%), respectively [78].

Several studies have indicated that cactus particularly; fruits, pulp, seed and pickely pear peel were rich in linolenic, oleic and palmitic acids [55; 79]. In contrast, the oil extracted from the fruit's seeds has a low content in vitamin E: 0. 403 g/kg, mostly γ-tocopherol (0. 330 g/kg) [55]. Such a Cactus pear contains 180 to 300 mg/kg of vitamin C. This content is higher than that found in other common fruits like apple, banana, or grape [80]. Vitamin K1 is present in all parts of the fruit, ranging from 0. 5 to 1g/kg [55]. Vitamin B is present only in the cladodem in which it is found in trace amounts [13]. Amount is very low compared to argan oil content (7. 6 to 8. 6 g/kg) [81; 82]. Similar contents of campesterol are found in some other food oils such as argan oil (4 g/kg) [83], whereas higher contents have been measured in soybean oil (between 19 and 23 g/kg) [83]. Remarkable also is the presence of large quantities (given in mg/100 g) of magnesium (74. 8), sodium (67. 6) and calcium (16. 2) [84]. In cladode, the major minerals are potassium and calcium, with amounts ranging from 235 to 5520 mg/100 g [13; 85]. In pulp, potassium is present at 161 mg/100 g, exceeding the concentration of other minerals like calcium and magnesium [85]. By contrast, in cactus seed the major amino acid is glutamic acid at a percentage varying from 15. 73% to 20. 27%, followed by arginine, (4. 81% to 14. 62%) [86; 87]. Thus, fruit seeds and pulp can be considered as very good sources of amino acids and proteins [21; 86].

The antioxidant properties of these betalain pigments represent an additional argument in favor of the development of their use in nutrition and health [88; 89]. Therapeutic potential has been suggested for metabolic syndrome (including diabetes type 2 and obesity), non-alcoholic fatty liver disease (NAFLD), rheumatism, cerebral ischemia, cancers, and virological and bacterial infections [90; 91 and 92]. Interestingly, cactuspreparations might exert preventive and therapeutic effects against alcoholism and alcoho l addiction [93]. In human intestinal epithelial cancer cells (Caco-2) stimulated by IL-1β, co-treatment with indicaxanthin (a pigment from the edible fruit of *Opuntiaficus-indica*) prevents activations of NOX-1 and NF-kB and attenuates the rise in inducible NO synthase. In human chondrocyte cultures stimulated with IL-1β, lyophilized extracts of *Opuntiaficus-indica* cladodes reduce the production of key molecules usually released upon chronic inflammation such as nitric oxide (NO), glycosaminoglycans, prostaglandin-E2 (PGE-2) and reactive oxygen species [94]. On human umbilical vein endothelial cells (HUVECs), non-cytotoxic micromolar concentrations of betalain (a pigment of *Opuntiaficus-indica* purified from fresh pulp of cactus pear) decrease the expression of cell adhesion molecules such as ICAM-1 [95]. Because it has also radical scavenging/antioxidant properties [95].

On the murine microglial cell line (BV-2), a butanol fraction (obtained from 50% ethanol extracts of *Opuntiaficus indica* and hydrolysis products) inhibits the production of NO in LPS-activated BV-2 cells via suppression of iNOS protein and mRNA expressions, inhibits the degradation of IκB-α, and displays peroxynitrite scavenging activity [96]. Moreover, in cultured mouse cortical cells, the butanol fraction of *Opuntiaficus indica* significantly reduces N-methyl-D-aspartate-, kainate-, and oxygen-glucose deprivation-induced delayed neurotoxicity [97]. In a rat model of acute inflammation (pleurisy), the oral administration of indica xanthin (mentioned above) reduces exudate size and leukocytes recruitment in the pleural cavity, as well as the protein and/or mRNA expressions of PGE-2, NO, IL-1β, iNOS, and cyclooxygenase-2 (COX^2) in the recruited leukocytes [98]. A higher concentration of adiponectin and a greater abundance of genes involved in lipid peroxidation, lipids export and production of carnitine palmitoyltransferase-1 and microsomal triglyceride transfer proteins are observed in livers from cactus-treated animals. Furthermore, rats fed with cactus have a lower postprandial serum insulin concentration and a greater phosphorylated protein kinase B (pAkt): Akt ratio in the postprandialstate [99]. Noteworthy, the extracts of Opuntiaficusindicahave marked bactericidal effects on the growth of Campylobacter jejuniand Campylobacter coli. Moreover, adherence of Campylobacter to Vero cells is strongly reduced [100]. Antimicrobial activities of methanolic, ethanolic, or aqueous extracts of *Opuntiaficus indica* have also been studied on Vibrio cholerae, indicating that the methanolic extract was the most efficient [101].

Molecular interactions between mucilage monosaccharides and membrane phospholipids (mainly phosphatidylcholine and phosphatidylethanolamine) may represent the molecular basis for changes in the functions of membrane-attached proteins observed during the healing process consecutive to chronic gastric mucosal damages [102]. Moreover, in humans, an extract of the *Opuntiaficus indica* plant has been reported to reduce the symptoms of alcohol hangover like nausea, dry mouth, and anorexia [103]. Cacti do not need much water and accordingly they exhibit unusual physiological and morphological features. Cacti are known to contain several useful chemical compounds having nutritional and medicinal desirable 106]. Cacti have been exploited as a cheap, alternate source of food suitable for humans and feed for animals and are cultivated asornamental crops [107].

The prickly pear (*Opuntiaficus indica*) is native of the semi-arid regions of South and Central America [108]. This branched cactus is a long-domesticated crop critically important in agricultural economies throughout the arid and semiarid parts of the world [4; 108). This particular cactus is a valuable resource especially during periods of drought when there is a shortage of other herbaceous plants for forage [109]. Areoles may be the origin of flowers and depending on the species they give rise to spines and/or glochids (small, detachable barb-tipped bristles) [110]. The cellulose microfibrils, 0. 4 mm length and6–10 mm in diameter and are loosely imbedded in an arabinan matrix. The latter is partly present as a solid gel, partly woven tightly with the cellulose fibers [111]. Functions of the spines include mechanical protection from herbivores, reflection of light, and shading of the cladode to reduce water loss and for condensing fog [111]. Areoles on fruit are 45–60 in number and evenly distributed. The seeds within the pulp are disk-shaped, sub circular and have numerous colors but are generally pale tan. [18; 112; 113 and 114). [115] found that chemical scarification of *O. ficusindica* seeds with concentrated H_2SO_4 or with Schweizer reagent, followed by incubation of the treated seeds in solutions of H2O2, under photoperiodic conditions of 14 h light per day gave the highest germination percentage in the shortest time.

Cacti (Opuntia) have been used for centuries as common vegetables and medicines by Native Americans to treat a variety of ailments and disorders [50; 116]. Flavanoids, as those in cactus pear fruit, are known for their affirmative health-benefits [50; 117]. Metabolites accumulating in LCHAD and MTP deficiencies induce lipid and protein oxidative damage and decrease the antioxidant defenses in rat brain in vitro [118]. [118] demonstrated antioxidative effects of cacti fruit extract on lipid peroxidation inhibition in oils and emulsion model systems. Characterization of the antiox-idative properties proved that cacti antioxidants are heat stable offering a natural source for the stabilization of food oils [119]. The effects of dried cladode powder of *O. ficusindica* var. Saboten was investigated on gastric lesion and ulcer models in rats by [56]. Significant inhibition in indomethacin induced gastric lesion was noted without any anti-ulcer activity. Reports indicate that in addition to being able to heal minor cuts and wounds, prickly pear cacti may protect the immune system and prevent oxidative stress by acting as scavengers of free radicals [18]. Prickly pear antioxidant actions could protect mammalian cells and organs and slow the aging process, illness and dis ease [41]. The leaves are heated and applied as a poultice to abscesses to promote suppuration and discharge of pus [49]. Prickly pear cacti have shown promise for diabetes treatment. Clinical trials indicate that cacti help to stabilize blood sugar levels, and are effective for the treatment of type-II (adult onset) diabetes [23].

Research has shown that cacti can help to reduce the effects of excessive alcohol consumption if used prior to drinking alcoholic beverages. (Wiese *et al.,* 2004). Aqueous extracts of prickly pear cacti were found to inhibit in vitro cell growth effectively in several different immortalized and cancer cell cultures including ovarian, cervix, and bladder cancer cells and suppressed tumor growth in a nude mouse of ovarian cancer models. The mechanism of anticancer effect of cactus pear extracts is not understood [51]. Prickly pear cacti are well recognized for their wound healing properties and anticancer effects [51]. [49] studied the effect of *O. ficusindica* (L.) Mill cladodes in the wound-healing process. Cladodes have been used in Sicilian folk medicine as a cicatrizant. In a study by [49], a base cream containing 15% lyophilized cladodes and a commercial ointment was used on wounds produced on the backs of rats to evaluate healing activity of prickly pear.

Evidently, the *O. ficusindica* treatment accelerated wound healing, probably by involving the proliferation and migration of the keratinocytes in the healing process [49]. [120] reported technological charac-teristics and main difficulties in producing high-quality cactus pear juice. [121] reported that the fermentation process did not affect the thermo stability of the betalain pigments obtained from the cactus pear. Fruit pulp of the red cactus pear (*O. ficusindica*) has been used for ice cream production [122]. Sensory evaluation of the produced ice cream samples showed the sample with 5% cactus was very desirable and close to the control sample [122]. Based on cactus pear (*O. boldinghii*) cladodes having high fiber content and potential health benefits bakery products have been produced and evaluated from composite flours of wheat (WF) and cactus pear stems (SF) [123]. Orange-yellow cactus pear fruit pulp has been used to produce a dehydrated cactus pulp sheet and pasteurized cactus pear fruit juices [124].

Nopalitos, the prepared pads of cladodes, are very perishable with a storage life of only 1 day at room temperature and 6 days when packaged in polyethylene bags and stored at 5°C [125]. [126] reported the effect of edible coatings on nopalitos of Opuntia sp. during cold storage. [125] demonstrated hat O_2 concentration decreased up to 8. 6 kPa and CO_2 concentration increased up to 6. 9 kPa could significantly decrease quality deterioration and thus increase storage life when nopalitos were stored at 5°C for up to 30 days.

The arid and semi-arid areas of North Africa are becoming deserts [127]. Findings suggested that extension services will play a crucial role in creating awareness among farmers of the impact of this technology on yields and income diversifi-cation [127]. In vitro cultures of cacti were used to test the effect of degradation and/or biotransformation of dye precursors by plants [128]. Cacti were shown to produce protective compounds, such as alkaloids, from a family of aromatic hydrocarbons (Oliveira and Da Machado, 2003). Thus, it was hypothesized that the metabolic pathways and enzymes related to biotransformation of xenobiotic aromatics would more likely to be found in these plants [128]. Phytochelatinssyn-thesis has been evaluated in cladodes of O. ficusin relation to plant and soil levels of Cd, Pb, Cu and Ag [129]. The feasibility of genetic engineering to assure higher rates of phytochelatin induction has been explored for phytoremediation purposes [130; 131 and 132]. Researchers tested different types of milk for clotting time caused by extracts from cacti fruits [133].

Several bioassays by [134] indicated inhibitory activity of monoamine oxidase from methanolic extracts of cacti fruits. Four compounds isolated were tested for in vitro monoamine oxidase inhibitory activities and the authors concluded that industrial applications for these molecules may be found through further investigations [134]. [121] used cactus pear fruit juice as a feedstock for yeast fermentation. Two cactaceous powders were shown by X-ray diffractometry, spectroscopic, thermic, nitrogen and water adsorption methods to contain calcium oxalate and consist of globular or cubosome particles. [135] demonstrated differences in the type of calcium oxalate crystals among Cactaceae subfamilies and suggested the possibility of using the characteristic type of calcium oxalate crystals to classify species of this family. In addition, differences in chemical composition of cladodes among species of cactus pear have been reported [136]. Physical and spectral property methods have been used to identify eight flavonoid compounds synthesized in cacti cladodes and fruits [106].

The effect of two different media on in vitro growth of *O. ficusindica* explants was studied by [137]. [138] established conditions for micro propagation of the ornamental prickly pear cactus O. [139] developed a micropropagation system for three Opuntia lines used as vegetables in Mexico. [140] worked to establish a protocol for in vitro culture and plant regeneration of Notocactusmagnificus, an ornamental species called the blue cactus that is native to Brazil. Callus tissue of Cereusperuvianus was established and used for alkaloid production. Later cactus DNA extraction techniques included the use of DNAzol for the extraction of total DNA and use of and TRIazol for RNA from cactus pear cultivars [141]. 142] attempted to evaluate the level of genetic diversity in cactus clones by molecular markers to gather information for future breeding programs. RAPD markers detected DNA polymorphism in callus tissue of cacti for classification of Opuntia cacti. DNA polymorphisms in callus tissues of Cereus peruvianusMillwere detected by using RAPD markers [143]. RAPD analysis was also used to estimate the genetic relationship among five Hylocereusand nine Selenicereus species [144]. Twenty-two cactus pear varieties were characterized with RAPD and ISSR markers using DNA from seeds of Opuntia spp. [145]. Expression of ripening-related genes in fruit of prickly pear (Opuntiasp.) was studied by [146]. A system for genetic transformation of an elite prickly pear cactus (*O. ficusindica* L. cultivar Villa Nueva) by Agrobacterium tumefaciens was developed by [147]. The method described by [147] may be useful for routine transformation and introduction of agronomically important genes in prickly pear cactus. However; the spineless varieties are extensively used for fodder [148]. The cactus yield output is between 5 to 6 tons per hectare annually with 40 tons of dry matter achievable and fruit yield may be up to 20 ton per hectare [149]. Opuntia do not tolerate salinity and water logging, but thrive well in dry conditions, uneven rainfall and poor soil [150]. The presence of oxalate crystals in cactus reduces the presence of calcium in the body of the animal [151].

2. Conclusion

The article creates the awareness of the cactus plant as herbal remedy among the poor people of the world. The main constituent of *Opuntiaficus-indica* cladodes is water (80-95%), followed by small amounts of carbohydrates (3-7%), fiber (1-2%), and protein (0. 5-1). Beneficial effects of herbal remedies can be obtained from active constituents present in the whole plant, parts of the plant (e. g. flowers, fruits, roots or leaves), or plant materials or combinations thereof, whether in crude or processed state. In contrast, isorhamnetin significantly increases the expression of PPAR-γin tumor tissues obtained from xenograft model of gastric cancer cells and, in combination with chemotherapeutic drugs, causes strong antiproliferative effects and cytotoxicity. Cactus pear (*O. boldinghii*) cladodes having high fiber content and potential health benefits bakery products have been produced and evaluated from composite flours of wheat (WF) and

cactus pear stems (SF). Orange-yellow cactus pear fruit pulp has been used to produce a dehydrated cactus pulp sheet and pasteurized cactus pear fruit juices.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest.

References

[1] De Smet PA. Herbal remedies. N Engl J Med. 2002; 347: 2046-2056.

[2] Reyes-Agüero JA, Aguirre-Rivera JR, Hernandez MH. Systematic notes and detailed description of *Opuntia ficus-indica* (L.) MILL. (Cactacea). Agrociencia. 2005; 39: 395-408.

[3] Pareek OP, Singh RS, Vashishtha BB. Performance of Cactus Pear [Opuntia ficusindica (L.) Mill.] Clones in Hot Arid Region of India. Journal of the Professional Association for Cactus Development. 2003; 5: 121-130.

[4] Griffith PM. The origins of an important cactus crop, *Opuntia ficus-indica* (Cactaceae): new molecular evidence. Am J Bot. 2004; 91(11):1915–1921.

[5] Saenz C. Processing technologies: an alternative for cactus pear (Opuntia spp.) fruits and cladodes. Journal of Arid Environments. 2000; 46: 209-225.

[6] Inglese P, Basile F, Schirra M. Cactus pear fruit production, in Cacti: Biology and uses. Park S. Nobel, Berkeley, California. 2002; 163-179.

[7] Hunt D, Taylor NP, Charles G. The new cactus lexicon. DH Books, Milborne Port, UK. 2006.

[8] Zhao M, Yang N, Yang B, Jiang Y, Zhang G. Structural characterization of water-soluble polysaccharides from Opuntia monacantha cladodes in relation to their anti-glycated activities. Food Chemistry. 2007; 105: 1480-1486.

[9] Kim EH, HJ, Song YS, Jin C, Lee KT, et al. Constituents of the stems and fruits of *Opuntia ficus-indica* var. saboten. Arch Pharm Res. 2003; 26: 1018-1023.

[10] Hernández-Urbiola MI, Pérez-Torrero E, Rodríguez-García ME. Chemical analysis of nutritional content of prickly pads (Opuntia ficus indica) at varied ages in an organic harvest. Int J Environ Res Public Health. 2011; 8: 1287-1295.

[11] Rodríguez-García ME, De Lira C, Hernández-Becerra E, Cornejo-Villegas MA, Palacios-Fonseca AJ, et al. Physicochemical characterization of prickly pads (Opuntia ficus indica) and dry vacuum prickly pads powders as a function of the maturation. Plant Foods Hum Nutr. 2007; 62: 107–112.

[12] Ginestra G, Parker ML, Bennett RN, Robertson J, Mandalari G, et al. Anatomical, chemical, and biochemical characterization of cladodes from prickly pear [*Opuntia ficus-indica*(L.) Mill.]. J Agric Food Chem. 2008; 57: 10323-10330.

[13] Feugang JM, Konarski P, Zou D, Stintzing FC, Zou C. Nutritional and medicinal use of Cactus pear (Opuntia spp.) cladodes and fruits. Front Biosci. 2006; 11: 2574-2589

[14] Nuñez-López MA, Paredes-López O, Reynoso-Camacho R. Functional and hypoglycemic properties of nopal cladodes (*O. ficusindica*) at different maturity stages using *in vitro* and *in vivo* tests. J Agric Food Chem. 2013; 61: 10981-10986.

[15] Chougui N, Tamendjari A, Hamidj W, Hallal S, Barras A, et al. Oil composition and characterisation of phenolic compounds of *Opuntia ficus-indica* seeds. Food Chem. 2013; 139: 796-803.

[16] Bensadón S, Hervert-Hernández D, Sáyago-Ayerdi SG, Goñi I. By-products of *Opuntia ficus-indica* as a source of antioxidant dietary fiber. Plant Foods Hum Nutr. 2010; 65: 210-216.

[17] Uebelhack R, Busch R, Alt F, Beah ZM, Chong PW. Effects of cactus fiber on the excretion of dietary fat in healthy subjects: a doble blind, randomized, placebo-controlled, crossover clinical investigation. Current Therapeutic Research, Clinical and Experimental. 2014; 76: 39-44.

[18] Saleem M, Kim HJ, Han CK, Jin C, Lee YS. Secondary metabolites from *Opuntia ficus-indica* var. saboten. Phytochemistry. 2006; 67: 1390-1394.

[19] Tesoriere L, Fazzari M, Allegra M, Livrea MA. 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. 2005; 53: 7851-7855.

[20] Stintzing FC, Carle R. Cactus stems (Opuntiaspp.): A review on their chemistry, technology, and uses. Mol. Nutr. Food Res. 2005; 49: 175–194.

[21] Zito P, Sajeva M, Bruno M, Rosselli S, Maggio A, et al. Essential oils composition of two Sicilian cultivars of *Opuntia ficus-indica* (L.) Mill. (Cactaceae) fruits (prickly pear). Nat Prod Res. 2013; 27: 1305-1314.

[22] Formisano C, Senatore F, Bancheva S, Bruno M, Rosselli S. Volatile components from aerial parts of Centaurea spinosociliata Seenus ssp. cristata (Bartl.) Dostál and Centaurea spinosociliata Seenus ssp. spinosociliata growing wild in Croatia. Croatica Chemica Acta. 2010; 83: 403-408.

[23] Alarcon-Aguilar FJ, Valdes-Arzate A, Xolalpa-Molina S, Banderas-Dorante T, Jimenez-Estrada M, et al. Hypoglycemic Activity of Two Polysaccharides Isolated from *Opuntia ficus-indica* and O. Streptacantha. Proc West Pharm Soc. 2003; 46: 139-142.

[24] Laurenz JC, Collier CC, Kuti JO. Hypoglycaemic effect of Opuntia lindheimeri Englem in a diabetic pig model. Phytother Res. 2003; 17: 26-29.

[25] Luo C, Zhang W, Sheng C, Zheng C, Yao J, et al. Chemical composition and antidiabetic activity of Opuntia Milpa Alta extracts. Chem Biodivers. 2010; 7: 2869-2879.

[26] Zhao LY, Lan QJ, Huang ZC, Ouyang LJ, Zeng FH. Antidiabetic effect of a newly identified component of Opuntia dillenii polysaccharides. Phytomedicine. 2011; 18: 661-668.

[27] Hahm SW, Park J, Son YS. Opuntia humifusa stems lowers blood glucose and cholesterol levels in streptozotocin-induced diabetic rats. Nutr Res. 2011; 31: 479-487.

[28] Becerra-Jiménez J, Andrade-Cetto A. Effect of Opuntia streptacantha Lem. on alpha-glucosidase activity. J Ethnopharmacol. 2012; 139: 493-496.

[29] Casas A,Barbera G. Mesoamerican domestication and diffusion. In P. S. Nobel, ed. Cacti: Biology and uses, pp. 143–162. Berke-ley, CA, USA, University of California Press. 2002.

[30] Zimmermann HG, Moran VC, Hoff-mann JH. Invasive cactus species (Cactaceae). In R. Muniappan, GVP. Reddy & A. Raman, eds. Biological control of tropical weeds using arthropods. 2009:108–129. Cambridge University Press.

[31] Targa MG, Leguizamon G, Coronel de Renolfi M, Ochoa MJ. Economic feasibility of scozzolatura in traditional and improved orchards of cactus pear in Santia-go del Estero, Argentina. Acta Hortic. 2013; 995: 189–200.

[32] ODEPA–Ciren. Catastro de superfi-cie frutícola regional: Región Metropol-itana. 2016.

[33] Saénz C, Berger H, Corrales García J, Galletti L, Garcia del Cortazar V, Higuera I, Mondragón C, Rodríguez Feliz A, Sepulveda E, Varnero MT, eds. Utilización agroindustrial del nopal. FAO Plant Production and Protection Paper No. 162. Rome, FAO. 2006; 165.

[34] SIAP (Agricultural and Fishery Information System). Secretaria de agricultura, ganadería, desarrollo rural, pesca y alimentac-ión, Mexico(available at www. siap. gob. mx). 2014.

[35] Gallegos Vazquez C, Mendez Gallegos S de J, Mondragón Jacobo C. Produccion sustentable de la tuna en San Luis Potosí. San Luis Potosí, Mexico, Colegio de Postgraduados–Fundacion San Luis Potosí Produce. 2013.

[36] Chalak L, Younes J, Rouphael S,Hama-deh B. Morphological characterization of prickly pears (Opuntia ficus indica(L.) Mill.) cultivated in Lebanon. Int. J. Sci. Res. 2012; 3(6): 2541–2553.

[37] Butera D, Tesoriere L, di Gaudio F, Bongiorno A, Allegra M, Pintaudi AM, Kohen R, Livrea MA. Antioxidant activitiesof sicilian prickly pear (Opuntia ficus indica) fruit extracts and reducing properties of its betalains: Betanin and indicaxanthin. J. Agric. Food Chem. 2002; 50: 6895–6901.

[38] Alimi H, Hfaiedh N, Bouoni Z, Hfaiedh M, Sakly M, Zourgui L, Rhouma KB. Antioxidant and antiulcerogenic activities of Opuntia ficus indica f. inermis root extract in rats. Phytomedicine. 2010; 17: 1120–1126.

[39] Morales P, Ramírez-Moreno E, de Cortes Sanchez-Mata M, Carvalho AM, Ferreira ICFR. Nutritional and antioxidant properties of pulp and seeds of two xoconostlecultivars (Opuntia joconostle F. A. C. Weber ex Diguet and Opuntia matudae Scheinvar) of high consumption in Mexico. Food Res. Int. 2012; 46: 279–285.

[40] Valente LMM, da Paixão D, do Nascimento AC, dos Santos PFP, Scheinvar LA, Moura MRL, Tinoco LW, Gomes LNF, daSilva JFM. Antiradical activity, nutritional potential and flavonoids of the cladodes of Opuntia monacantha (Cactaceae). Food Chem. 2010; 123: 1127–1131.

[41] Kuti JO. Antioxidant compounds from fourOpuntiacactus pear fruit varieties. Food Chem. 2004; 85(4):527–533.

[42] Valente L, Scheinvar L, da Silva G, Antunes A, dos Santos F, Oliveira T, Tappin M, Aquino Neto F, Pereira A, Carvalhaes S, et al. Evaluation of the antitumor and trypanocidal activities and alkaloid profile inspecies of Brazilian Cactaceae. Pharmacogn. Mag. 2007; 3: 167–172.

[43] Yang, N. ; Zhao, M. ; Zhu, B. ; Yang, B. ; Chen, C. ; Cui, C. ; Jiang, Y. Anti-diabetic effects of polysaccharides from Opuntia monacantha cladode in normal and streptozotocin-induced diabetic rats. Innov. Food Sci. Emerg. Technol. 2008, 9, 570–574.

[44] Osorio-Esquivel O, Alicia-Ortiz-Moreno, Álvarez VB, Dorantes-Álvarez L, Giusti MM. Phenolics, betacyanins and antioxidant activity in Opuntia joconostle fruits. Food Res. Int. 2011; 44: 2160–2168.

[45] Paiz RC, Juárez-Flores BI, Aguirre RJR, Cárdenas OC, Reyes AJA, García CE, Álvarez FG. Glucose-lowering effect of xoconostle (Opuntia joconostle A. Web. Cactaceae) in diabetic rats. J. Med. Plants Res. 2010; 4: 2326–2333.

[46] Schaffer S; Schmitt-Schillig S, Müller WE, Eckert GP. Antioxidant properties of Mediterranean food plant extracts: Geographical differences. J. Physiol. Pharmacol. 2005; 56(Suppl. S1): 115–124.

[47] Stintzing FC, Schieber A, Carle R. Evaluation of colour properties and chemical quality parameters of cactus juices. Eur. Food Res. Technol. 2003; 216: 303–311.

[48] Stintzing FC, Schieber A, Carle R. Phytochemical and nutritional significance of cactus pear. Eur. Food Res. Technol. 2001; 212: 396–407.

[49] Galati EM, Mondello MR, Monforte MT, Galluzzo M, Miceli N, Tripodo MM. Effect of*Opuntia ficus-indica*(L.) Mill. cladodes in the wound-healing process. J PACD. 2003; 5:1–16.

[50] Tesoriere L, Butera D, Am P, Allerga M, Liverea MA. Supplementation with cactus pear (*Opuntia ficus-indica*) fruit decreases oxidative stress in healthy humans: a comparative study with vitamin C. Am J Clin Nutr. 2004; 80(2):391–395.

[51] Zou D, Brewer M, García F, Feugang JM, Wang J, Zang R, Liu H, Zou C. Cactus pear: a natural product in cancer chemo-prevention. Nutr J. 2005; 4:25–36.

[52] Dok-Go H, Lee KH, Kim HJ, Lee EH, Lee J, Song YS, Lee YH, Jin C, Lee YS, Cho J. Neuroprotective effects of antioxidative flavonoids, quercetin, (+)-dihydroquercetin and quercetin 3-Methyl ether, isolated from *Opuntia ficus-indica*var. saboten. Brain Res. 2003; 965: 130–136.

[53] Sreekanth D, Arunasree MK, Roy KR, Chandramohan Reddy T, Reddy GV, Reddanna P. Betanin a betacyanin pigment purified from fruitsof *Opuntia ficus-indica* induces apoptosis in human chronic myeloid leukemia Cell line-K562. Phytomedicine. 2007; 14: 739–746.

[54] De Leo M, Abreu MBD, Pawlowska AM, Cioni PL, Braca A. Profiling the chemical content of *Opuntia ficus-indica* flowers by HPLC–PDA-ESI-MS and GC/EIMS analyses. Phytochem. Lett. 2010; 3: 48–52.

[55] Ramadan MF, Mörsel JT. 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. 2003; 83: 447–456.

[56] Lee EB, Hyun JE, Li DW, Moon YI. Effect of*Opuntia ficus-indica* var. Saboten stem on gastric damages in rats. Arch Pharm Res. 2002; 25:67–70.

[57] Ahmed MS, Tanbouly NDE, Islam WT, Sleem AA, Senousy ASE. Antiinflammatory flavonoids from Opuntia dillenii (Ker-Gawl) Haw. Flowers growing in Egypt. Phytother. Res. 2005; 19: 807–809.

[58] Ammar I, Ennouri M, Khemakhem B, Yangui T, Attia H. Variation in chemical composition and biological activities of two species of Opuntia flowers at four stages of flowering. Ind. Crop. Prod. 2012; 37: 34–40.

[59] Fernández-López JA, Almela L, Obón JM, Castellar R. Determination of Antioxidant Constituents in Cactus Pear Fruits. Plant Food Hum. Nutr. 2010; 65, 253–259.

[60] Moussa-Ayoub TE, El-Samahy SK, Kroh LW, Rohn S. Identification and quantification of flavonol aglycons in cactus pear (Opuntia ficus indica) fruit using a commercial pectinase and cellulase preparation. Food Chem. 2011; 124: 1177–1184.

[61] Salim N, Abdelwaheb C, Rabah C, Ahcene B. Chemical composition of*Opuntia ficus-indica*(L.) fruit. Afr J Biotechnol. 2009; 8(8):1623–1624.

[62] Jorge AJ, de La Garza TH, Alejandro ZC, Ruth BC, Noé AC. The optimization of phenolic compounds extraction from cactus pear (*Opuntia ficus-indica*) skin in a reflux system using response surface methodology. Asian Pac. J. Trop. Biomed. 2013; 3: 436–442.

[63] Gallegos-Infante JA, Rocha-Guzman NE, González-Laredo RF, Reynoso-Camacho R, Medina-Torres L, Cervantes-Cardozo V. Effect of air flow rate on the polyphenols content and antioxidant capacity of convective dried cactus pear cladodes (Opuntia ficus indica). Int. J. Food Sci. Nutr. 2009; 60: 80–87.

[64] Ginestra G, Parker ML, Bennett RN, Robertson J, Mandalari G, et al. Anatomical, chemical, and biochemical characterization of cladodes from prickly pear [Opuntia ficus-indica(L.) Mill.]. J Agric Food Chem. 2009:57: 10323-10330.

[65] Guevara-Figueroa T, Jiménez-Islas H, Reyes-Escogido ML, Mortensen AG, Laursen BB, Lin LW, de León-Rodríguez A, Fomsgaard IS, Barba de la Rosa AP. Proximate composition, phenolic acids, and flavonoids characterization of commercial and wild nopal (Opuntiaspp.). J. Food Compos. Anal. 2010; 23: 525–532.

[66] Khan NS, Ahmad A, Hadi SM. Anti-oxidant, pro-oxidant properties of tannic acid and its binding to DNA. Chem. Biol. Interact. 2000; 125: 177–189.

[67] Yen GC, Duh PD, Tsai HL. Antioxidant and pro-oxidant properties of ascorbic acid and Gallic acid. Food Chem. 2002; 79: 307–313.

[68] You BR, Park WH. Gallic acid-induced lung cancer cell death is related to glutathione depletion as well as reactive oxygen species increase. Toxicol. *In Vitro.* 2010; 24: 1356–1362.

[69] Li R, Guo M, Zhang G, Xu X, Li Q. Nicotiflorin reduces cerebral ischemic damage and upregulates endothelial nitric oxide synthase in primarily cultured rat cerebral blood vessel endothelial cells. J. Ethnopharmacol. 2006;107: 143–150.

[70] Nakayama M, Aihara M; Chen YN, Araie M, Tomita-Yokotani K, Iwashina T. Neuroprotective effects of flavonoids on hypoxia-, glutamate-, and oxidative stress–induced retinal ganglion cell death. Mol. Vis. 2011; 17: 1784.

[71] Huang JL, Fu ST, Jiang YY, Cao YB, Guo ML, Wang Y, Xu Z. Protective effects of Nicotiflorin on reducing memory dysfunction, energy metabolism failure and oxidative stress in multi-infarct dementia model rats. Pharmacol. Biochem. Behav. 2007; 86: 741–748.

[72] Kim JE, Lee DE, Lee KW, Son JE, Seo SK, Li J, Jung SK, Heo YS, Mottamal M, Bode AM, et al. Isorhamnetin Suppresses Skin Cancer through Direct Inhibition of MEK1 and PI3-K. Cancer Prev. Res. 2011; 4: 582–591.

[73] Zhang N, Pei F, Wei H, Zhang T, Yang C, Ma G, Yang C. Isorhamnetin protects rat ventricular myocytes from ischemia and reperfusion injury. Exp. Toxicol. Pathol. 2011; 63: 33–38.

[74] Kim B, Choi YE, Kim HS. Eruca sativa and its Flavonoid Components, Quercetin and Isorhamnetin, Improve Skin Barrier Function by Activation of Peroxisome Proliferator-Activated Receptor (PPAR)-αand Suppression of Inflammatory Cytokines. Phytother. Res. 2014.

[75] Lee J, Jung E, Lee J, Kim S, Huh S, Kim Y, Kim Y, Byun SY, Kim YS, Park D. Isorhamnetin represses adipogenesis in 3T3-L1 cells. Obesity. 2009; 17: 226–232.

[76] Ramachandran L, Manu KA, Shanmugam MK, Li F, Siveen KS, Vali S, Kapoor S, Abbasi T, Surana R, Smoot DT, et al. Isorhamnetin inhibits proliferation and invasion and induces apoptosis through the modulation of peroxisome proliferator-activated receptor γactivation pathway in gastric cancer. J. Biol. Chem. 2012; 287: 38028–38040.

[77] Charouf Z, Guillaume D. Phenols and Polyphenols from Argania spinosa. Am. J. Food Technol. 2007; 2: 679–683.

[78] Abidi S, Ben Salem H, Vasta V, Priolo A. Supplementation with barley or spineless cactus (Opuntia ficus indicaf. inermis) cladodes on digestion, growth and intramuscular fatty acid composition in sheep and goats receiving oaten hay. Small Rumin. Res. 2009; 87: 9–16.

[79] Ennouri M, Evelyne B, Laurence M, Hamadi A. Fatty acid composition and rheological behaviour of prickly pear seed oils. Food Chem. 2005; 93: 431–437.

[80] Piga A. Cactus pear: A fruit of nutraceutical and functional importance. J. Prof. Assoc. Cactus Dev. 2004; 6: 9–22.

[81] Cayuela JA, Rada M, del Carmen Pérez-Camino M, Benaissa M, Abdelaziz E, Guinda Á. Characterization of artisanallyand semiautomatically extracted argan oils from Morocco. Eur. J. Lipid Sci. Technol. 2008;110: 1159–1166.

[82] Khallouki F, Younos C, Soulimani R, Oster T, Charrouf Z, Spiegelhalder B, Bartsch H, Owen RW. Consumption of argan oil (Morocco) with its unique profile of fatty acids, tocopherols, squalene, sterols and phenolic compounds should confer valuable cancer chemopreventive effects. Eur. J. Cancer Prev. 2003; 12: 67–75.

[83] Gharby S, Harhar H, Guillaume D, Haddad A, Matthäus B, Charrouf Z. Oxidative stability of edible argan oil: A two-year study. LWT-Food Sci. Technol. 2011; 44: 1–8.

[84] Medina EMD, Rodríguez EMR, Romero CD. Chemical characterization of Opuntia dillenii and Opuntia ficus indica fruits. Food Chem. 2007; 103: 38–45.

[85] Ayadi MA, Abdelmaksoud W, Ennouri M, Attia H. Cladodes from Opuntia ficus indica as a source of dietary fiber: Effect on dough characteristics and cake making. Ind. Crop. Prod. 2009; 30: 40–47.

[86] Nassar AG. Chemical composition and functional properties of prickly pear (Opuntia ficus indica) seeds flour and protein concentrate. World J. Dairy Food Sci. 2008; 3: 11–16.

[87] Contreras-Padilla M, Pérez-Torrero E, Hernández-Urbiola MI, Hernández-Quevedo G, del Real A, Rivera-Muñoz EM, Rodríguez-García ME. Evaluation of oxalates and calcium in nopal pads (*Opuntia ficus-indica*var. redonda) at different maturity stages. J. Food Compos. Anal. 2011; 24: 38–43.

[88] Castellanos-Santiago E, Yahia EM. Identification and Quantification of Betalains from the Fruits of 10 Mexican Prickly Pear Cultivars by High-Performance Liquid Chromatography and Electrospray Ionization Mass Spectrometry. J. Agric. Food Chem. 2008; 56: 5758–5764.

[89] Fernández-López JA, Giménez PJ, Angosto JM, Moreno JI. A process of recovery of a natural yellow colourant from opuntia fruits. Food Technol. Biotechnol. 2012; 50: 246–251.

[90] Kaur M, Kaur A, Sharma R. Pharmacological actions of Opuntia ficus indica: A Review. J. Appl. Pharm. Sci. 2012; 2: 1.

[91] Lee JA, Jung BG, Lee BJ. Inhibitory effects of Opuntia humifusa on 7, 12-dimethyl- benz[a]anthracene and 12-O-tetradecanoylphorbol-13- acetate induced two-stage skin carcinogenesis. Asian Pac. J. Cancer Prev. 2012; 13: 4655–4660.

[92] Lee JA, Jung BG, Kim TH, Lee SG, Park YS, Lee BJ. Dietary feeding of Opuntia humifusa inhibits UVB radiation-induced carcinogenesis by reducing inflammation and proliferation in hairless mouse model. Photochem. Photobiol. 2013; 89: 1208–1215.

[93] Tomczyk M, Zovko-Koncić M, Chrostek L. Phytotherapy of alcoholism. Nat. Prod. Commun. 2012; 7: 273–280.

[94] Panico AM, Cardile V, Garufi F, Puglia C, Bonina F, Ronsisvalle S. Effect of hyaluronic acid and polysaccharides from Opuntia ficus indica (L.) cladodes on the metabolism of human chondrocyte cultures. J. Ethnopharmacol. 2007; 111: 315–321.

[95] Gentile C, Tesoriere L, Allegra M, Livrea MA, D'Alessio P. Antioxidant betalains from cactus pear (*Opuntia ficus-indica*) inhibit endothelial ICAM-1 expression. Ann. N. Y. Acad. Sci. 2004; 1028: 481–486.

[96] Lee MH; Kim JY; Yoon JH. ; Lim HJ, Kim TH, Jin C, Kwak WJ, Han CK, Ryu JH. Inhibition of nitric oxide synthase expression in activated microglia and peroxynitrite scavenging activity by Opuntia ficus indica var. saboten. Phytother. Res. 2006; 20: 742–747.

[97] Kim JH, Park SM, Ha HJ, Moon CJ, Shin TK, Kim JM, Lee NH, Kim HC, Jang KJ, Wie MB. *Opuntia ficus-indica* attenuates neuronal injury inin vitroandin vivomodels of cerebral ischemia. J. Ethnopharmacol. 2006; 104: 257–262.

[98] Allegra M, Ianaro A, Tersigni M, Panza E, Tesoriere L, Livrea MA. Indicaxanthin from cactus pear fruit exerts anti-inflammatory effects in carrageenin-induced rat pleurisy. J. Nutr. 2014; 144: 185–192.

[99] Morán-Ramos S, Avila-Nava A, Tovar AR, Pedraza-Chaverri J, López-Romero P, Torres N. Opuntia ficus indica (nopal) attenuates hepatic steatosis and oxidative stress in obese Zucker (fa/fa) rats. J. Nutr. 2012; 142: 1956–1963.

[100] Castillo SL, Heredia N, Contreras JF, García, S. Extracts of edible and medicinal plants in inhibition of growth, adherence, and cytotoxin production of Campylobacter jejuni and Campylobacter coli. J. Food Sci. 2011; 76:M421–M426

[101] Sánchez E, García S, Heredia N. Extracts of Edible and Medicinal Plants Damage Membranes of Vibrio cholerae. Appl. Environ. Microbiol. 2010; 76: 6888–6894.

[102] Vázquez-Ramírez R, Olguín-Martínez M, Kubli-Garfias C, Hernández-Muñoz R. Reversing gastric mucosal alterations during ethanol-induced chronic gastritis in rats by oral administration of *Opuntia ficus-indica* mucilage. World J. Gastroenterol. 2006; 12: 4318–4324.

[103] Wiese J, McPherson S, Odden MC, Shlipak MG. Effect of *Opuntia ficus-indica*on symptoms of the alcohol hangover. Arch Intern Med. 2004; 164:1334–1340.

[104] Sahelian R. An anti-inflammatory principle from prickly pear cactus. Fitoterapia. 2001; 72(3):288–290.

[105] Fernández-López JA, Castellar R, Obón JM, Almela L. Screening and mass-spectral confirmation of betalains in cactus pears. Chromatographia. 2002; 56:591–595.

[106] Oliveira AJB, Da Machado MFPS. Alkaloid production by callous tissue cultures ofCereus peruvianus(Cactaceae). Appl Biochem Biotechnol. 2003; 104:149–155.

[107] Sirivardhana N, Jeon YL. Antioxidative effect of cactus pear fruit (*Opuntia ficus-indica*) extract on lipid peroxidation inhibi-tion in oils and emulsion model systems. Eur Food Res Technol. 2004; 219:369–376.

[108] Hau MKR. Nopalito (*Opuntia ficus-indica*) New Zealand Institute For Crop & Food Research Ltd. A Crown Research Institute Crop & Food Research [Broad Sheet] Number. 2002; 137.

[109] Juárez MC, Passera CB. *In vitro* propagation of Opuntia ellisiana Griff. and acclimatization to field conditions. Biocell. 2002; 26:319–324.

[110] Anderson EF. The cactus family. Timber Press, Portland, pp 15–72 Aranda-Osorio G, Flores-Valdez CA, Macário Cruz-Miranda F (2008) Inclusion of cactus pear cladodes in diets for finishing lambs in Mexico. J PACD. 2001; 10:49–55.

[111] Malainine ME, Dufresne A, Dupeyre D, Mahrouz M, Vuong R, Vignon MR. Structure and morphology of cladodes and spines of Opuntia ficus-indica. Cellulose extraction and charac-terisation. Carbohydr Polym. 2003: 51:77–83

[112] 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 Hist Geogr. 2002; 28(3):397–419.

[113] Defelice MS. Prickly pear cactus, Opuntia spp. a spine-tingling tale. Weed Technol. 2004; 18(3):869–877.

[114] SynmanHA. Agreenhouse studyon root dynamics of cactus pears, *Opuntia ficus-indica*andO. robusta. J Arid Environ. 2006; 65(4):529–542.

[115] Altare M, Trione S, Guevara JC, Cony M. Stimulation and promotion of germination in*Opuntia ficus-indica*seeds. J PACD. 2006; 8:91–100.

[116] Cornett J. How Indians used desert plants. Nature Trails Press,California Corro-Hernández G, Elizalde-González MP (2003) Characterization and adsorption properties of powders prepared from cactus pulp. J Mater Sci. 2000; 38:1339–1346.

[117] Goycoolea FM, Cárdenas A. Pectins fromOpuntia spp. : a short review. J PACD. 2003; 5:17–29.

[118] Tonin AM, Grings M, Busanello ENB, Moura AP, Ferreira GC, Viegas CM, Fernandes CG, Schuck PF, Wajner M. Long-chain 3-hydroxy fatty acids accumulating in LCHAD and MTP deficiencies induce oxidative stress in rat brain. Neurochem Int. 2010; 56:930–936.

[119] Tesoriere L, Attanzio A, Allegra M, Gentile C, Livrea MA. Indicaxanthin inhibits NADPH oxidase (NOX)-1 activation and NF-κB-dependent release of inflammatory mediators and prevents the increase of epithelial permeability in IL-1β-exposed Caco-2 cells. Br. J. Nutr. 2014; 111: 415–423.

[120] Saenz C, Sepúlveda E. Cactus-pear juices. J PACD. 2001; 4:3–10.

[121] Turker N, Coskuner Y, Ekiz HI, Aksay S, Karababa E. The effects of fermentation on the thermostability of the yellow-orange pigments extracted from cactus pear (*Opuntia ficus-indica*). Eur Food Res Technol. 2001; 212:213–216.

[122] El-Samahy SK, Youssef KM, Moussa-Ayoub TE. Producing ice cream with concentrated cactus pear pulp: a preliminary study. J PACD. 2009; 11:1–12.

[123] Moreno-Álvarez MJ, Hernández R, Belén-Camacho DR, Medina-Martínez CA, Ojeda-Escalona CE, García-Pantaleón DM. Making of bakery products using composite flours: wheat and cactus pear (Opuntia boldinghiiBrittonet Rose) stems (clad-odes). J PACD. 2009; 11:78–87.

[124] El-Samahy SK, Abd El-Hady EA, Habiba RA, Moussa-Ayoub TE. Cactus pear sheet and pasteurized and sterilized cactuspear juices. J PACD. 2007; 9:148–164.

[125] Guevara JC, Yahia EM, De la Fuente EB. Modified atmosphere packaging of prickly pear cactus stems (Opuntiaspp.). Lebensm Wiss Technol. 2001; 34:445–451.

[126] Rodríguez-Félix A, Villegas-Ochoa MA, Fortiz-Hernández J. Effect of edible coatings on the quality of cactus stems (Opuntia sp) during cold storage. J PACD. 2007; 9:22–42.

[127] Alary V, Nefzaoui A, Ben Jemaa M. Promoting the adoption of natural resource management technology in arid and semi-arid areas: modelling the impact of spineless cactus in alley cropping in Central Tunisia. Agric Syst. 2007; 94:573–585.

[128] Golan-Goldhirsh A, Barazani O, Nepovim A, Soudek P, Smrcek S, Dufkova L, Krenkova S, Yrjala K, Schröder P, Vanek T. Plant response to heavy metals and organic pollutants in cell culture and at whole plant level. J Soils Sediments. 2004; 4:130–140.

[129] Figueroa JAL, Afton S, Wrobel K, Wrobelac K, Caruso JA. Analysis of phytochelatins in nopal (Opuntia ficus): a metallomics approach in the soil–plant system. J Anal At Spectrom. 2007; 22:897–904.

[130] Wojas S, Clemens S, Hennig J, Sklodowska A, Kopera E, Schat H, Bal W, Antosiewicz DM. Overexpression of phytoche-latin synthase in tobacco: distinctive effects of AtPCS1 and CePCS genes on plant response to cadmium. J Exp Bot. 2008; 59:2205–2219.

[131] Guo J, Dai X, Xu W, Ma M. Overexpressing GSH1 and AsPCS1 simultaneously increases the tolerance and accumulation of cadmium and arsenic in Arabidopsis thaliana. Chemosphere. 2008; 72:1020–1026.

[132] Couseloa JL, Navarro-Aviñób J, Ballester A. Expression of thephytochelatin synthase TaPCS1 in transgenic Aspen, insight intothe problems and qualities in phytoremediation of Pb. Int J Phytoremediat. 2010.

[133] Texeira G, Santana AR, Pais MS, Clemente A. Enzymes of *Opuntia ficus-indica*(L.) Miller with potential industrial applications-1. Appl Biochem Biotechnol. 2000; 88:299–312.

[134] Han YN, Choo Y, Lee YC, Moon YI, Kim SD, Choi JW. Monoamine oxidase B inhibitors from the fruits of*Opuntia ficus-indica* var. saboten. Arch Pharm Res. 2001; 24(1):51–54.

[135] Tovar-Puente A, Pando-Moreno M, González-Rodríguez H, Scott-Morales L, Méndez-Gallegos SDJ. Density of calciumoxalate crystals in 15 prickly pear cultivated species. J PACD. 2007; 9:91–98.

[136] Magallanes-Quintanar R, Valdez-Cepeda RD, Blanco-Macías F, Márquez-Madrid M, Ruíz-Garduño RR, Pérez-Veyna O, García-Hernández JL, Murillo-Amador B, López-Martínez JD, de Malainine ME, Dufresne A, Dupeyre D, Mahrouz M, Vuong R, Vignon MR. Structure and morphology of cladodes and spines of*Opuntia ficus-indica*. Cellulose extraction and characterisation. Carbohydr Polym. 2004; 51:77–83.

[137] Aliyu BS, Mustapha Y. Effect of different media on the in vitro growth of cactus (*Opuntia ficus-indica*) explants. Afr J Biotechnol. 2007; 6(11):1330–1331.

[138] Estrada-Luna AA, Martínez-Hernández JDJ, Torres-Torres ME, Chablé-Moreno F. *In vitro* micropropagation of the ornamental prickly pear cactus Opuntia lanigeraSalm-Dyck and effects of sprayed GA3 after transplantation to ex vitro conditions. Sci Hortic 117:378–385Tropical Plant Biol. 2008; 3:136–150 147.

[139] García-Saucedo PA, Valdez-Morales M, Valverde ME, Cruz-Hernández A, Paredes-López Pedro O. Plant regeneration of three Opuntiagenotypes used as human food. Plant Cell Tissue Organ Cult. 2005; 80:215–219.

[140] De Medeiros LA, de Ribeiro RCA, Gallo LA, De Oliveira ET, Dematte MESP. *In vitro* propagation ofNotocactus magnificus. Plant Cell Tissue Organ Cult. 2006; 84:165–169.

[141] Esparza ELI, Bustamante WJG, Cabral AFJ, Banuelos VR, Macias RFJ, Esparza FG, Valdez Cepeda RD, Reveles LRT. Molecular analysis of cactus pear cultivars. ISHS Acta Horticulturae 728: V International Congress on Cactus Pear and Cochineal. 2004.

[142] Souto Alves T, Vanusa da Silva M, Alves de Almeida CM, Oliveira Jordão do Amaral D, Cordeiro dos Santos D, Farias I, Tenório Sabino Donato VM, Da Costa AF (2009) Genetic diversity in cactus clones using issr markers. ISHS Acta Horticulturae 811: VI International Congress on Cactus Pear and Cochineal. 2009.

[143] Mangolin CA, Ottoboni LMM, de Fatima MMPS. RAPD Markers to evaluate callus tissue ofCereus peruvianusMill. (Cactaceae) maintained in different growth regulator combina-tions. Biochem Genet. 2002; 40:351–358.

[144] Tel-Zur N, Abbo S, Bar-Zvi D, Mizrahi Y. Clone identification and genetic relationship among vine cacti from the genera HylocereusandSelenicereusbased on RAPD analysis. Sci Hortic. 2004; 100:279–289.

[145] Luna-Paez A, Valadez-Moctezuma E, Barrientos-Priego AF, Gallegos-Vázquez C. Characterization ofOpuntiaspp. by means of seed with RAPD and ISSR markers and its possible use for differentiation. J PACD. 2007; 9:43–59.

[146] Collazo-Siques P, Valverde ME, Paredes-López O, Guevara-Lara F. Expression of ripening-related genes in prickly pear (Opuntiasp.) fruits. Plant Foods Hum Nutr. 2003; 58:317–326.

[147] Silos-Espino H, Valdez-Ortiz A, Rascón-Cruz Q, Rodríguez-Salazar E, Paredes-López O. Genetic transformation of prickly-pear cactus (*Opuntia ficus-indica*)byAgrobacterium tumefa-ciens. Plant Cell Tissue Organ Cult. 2006; 86:397–403.

[148] Mondragon-Jacobo C, Perez-Gonzalez S. Cactus (Opuntia spp.) as Forage. FAO Plant Production and Protection Paper 169. Rome: Food and Agri-culture Organization of the United Nations. 2001.

[149] Reynolds SG, Arias E. Introduction. In: Cactus (Opuntiaspp.) as forage. In: C Mondragón- Jaco-bo, S Pérez-González S (Eds.): FAO Plant Produc-tion and Protection Paper 169. Food and Agricul-ture Organization of the United Nations, Rome. 2001; 1-4.

[150] Orwa C, Mutua A, Kindt R, Jamnadass R, Simons A. Agroforestry Database: A Tree Reference and Selection Guide Version. 2015.

[151] Barceloux DG. Medical Toxicology of Natural Substances: Foods, Fungi, Medicinal Herbs, Plants, and Venomous Animals. ISBN-10: 047172761X. Hoboken USA: Wiley. 2008; 29: 837–840.