

Food Functionality of *Opuntia ficus-indica* var. Cultivated in Jeju Island

– Review –

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Abstract

Opuntia ficus-indica, commonly known as prickly pear cactus, is commercially grown as a food and medicinal plant in Jeju Island, Korea. The crushed pads and fruits of *Opuntia ficus-indica* were dried in a freeze-dryer and ground into flour to be used for food materials. The major components of proximate compositions were part of a nitrogen free extract. The major minerals were Ca (4391.2 ~ 2086.9 mg %), K (1932.1 ~ 2608.7 mg %), and Mg (800.6 ~ 1984.8 mg %). The major amino acid was glutamic acid, comprising 16.3% of total amino acids in fruit and 25.2% in pad. Dihydroflavonols were identified as (+)-*trans*-dihydrokaempferol and (+)-*trans*-dihydroquercetin. Citric acid methyl esters extracted from fruits showed inhibitory activities against monoamine oxidase-B. The presence of trimethyl citrate has been reported in other plants, but 1,3-dimethyl citrate and 1-monomethyl citrate have not been previously reported. The results of pharmacological efficacy tests, including serum biochemical and hematological parameters, autonomic nervous system, anti-inflammatory, analgesic activity, anti-diabetic activity, antithrombotic, anticoagulant, dopamine beta-hydroxylase, monoamine oxidase activity, hyperlipidemia, the respiratory system, antigastic, and anti-ulcerative actions indicate that the fruit and pad of the *Opuntia ficus-indica* are rich sources of food and medicinal materials.

Key words: food, pharmacological efficacy, *Opuntia ficus-indica* var., Jeju

INTRODUCTION

Opuntia is the largest group of cacti in the world. This group also includes several edible of cacti. The plant is commonly known as a prickly pear, tuna, Indian fig, bunny ears, cholla, and barbary fig. *Opuntia* is native to North America, but it has also spread to Central South America, North Africa, Europe, Mediterranean countries, the Middle East, and Korea (1,2). *Opuntia* is an economically important crop in many arid and semi-arid areas of the world. Jeju Island in Korea has an area of over 2,000 ha (7,413 acres) under commercial cultivation of *Opuntia*, with an annual production of approximately 2,500 tons (3). *Opuntia ficus-indica* has been appointed as the Natural Monument number 429 by Bukjeju-gun province (Fig. 1). *Opuntia ficus-indica* is grown for commercial purposes as food and medicinal plant in Jeju Island. *Opuntia ficus-indica* is employed for the treatments of inflammation, burns, and edema as a folk medicinal plant in Jeju Island. Ground or pureed young pads can be used for first aid treatment like the aloe vera plant. In this paper, we review the characteristics including var-



Fig. 1. *Opuntia ficus-indica*, appointed as the Natural Monument number 429 by Bukjeju-gun province. Location: Seaside of Weollyeong-ri, Hallim-eup, Bukjeju-gun province, Jeju Island, Republic of Korea.

ety, compositions, food functionality, and pharmacological effects of *Opuntia ficus-indica* collected in Jeju Island, drawing from our published and unpublished lit-

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erature and data.

WHAT IS *OPUNTIA*

Opuntia is usually classified into two groups. The first group is *Platyopuntia*; those belonging to this group have round flattened joints, called pads. They are commonly known as prickly pears because they produce spiny, but usually edible fruits. Some are grown for their edible pads called nopales or nopalitos. The spines of these pads must be singed off before they can be prepared for eating. The second group is *Cylindropuntia*; those belonging to this group have long, cylindrical joints and are commonly called chollas. The sizes of *Opuntias* vary. They can be just a few inches and spreading, or grow up to 100 feet high and like a tree. Most varieties of these plants are covered with sharp, barbed spines that are difficult to remove without lacerating their skin.

Four characteristics distinguish *Opuntia* from other-cactus: firstly, they have jointed segments. However, though unlike chollas, the segments are grown in flat pads. Secondly the areoles (roundish pads which produce spines) have minute-barbed spines called glochids that are easily detachable. Thirdly rudimentary leaves are present on new joints. Fourthly, their seeds have a pale covering called an aril.

The genus *Opuntia* is the largest species of the family comprising more than 300 species. Major varieties of genus *Opuntia* included *O. compressa*, *O. arenaria*, *O. fragilis*, *O. imbricate*, *O. phaeacantha*, *O. polyacantha*, *O. invicta*, *O. lindheimeri*, *O. tunicate*, *O. vestita*, *O. aurantiaca*, *O. basilaris*, *O. cylindrical*, *O. dillenii*, *O. ficus-indica*, *O. leucotricha*, *O. pentlandii* (boliviana), *O. pottsii* (filipendula), *O. spinosissima*, *O. whipplei*, *O. neoargentina* (tree opuntia), and *O. paraguayensis* (riverina Pear). Among these, *Opuntia ficus-indica*, *O. amy-claea*, *O. streptacantha*, *O. megacantha*, and *O. inermis* are cultivated as fruit plants. *Opuntia ficus-indica*, one of those plants, is considered as an economically important cactus. The most popular variety, *Opuntia ficus-indica* var. is cultivated in Jeju Island.

Prickly pear cactus, form *Opuntia*, is considered to be an important nutrient and food source in many parts of the world. Mexico, Chile, Italy, and a number of regions in the USA farm prickly pears for commercial purpose. The fruits are called "prickly pears" and "cactus pears" in the southwestern part of the United States, or "tunas" in Latin America, "ficodindia" or "fig of India" at Italy, "tzabba" at Israel, or "sabar" in Arab nations around the Mediterranean Sea. In Jeju Island, Korea, *Opuntia ficus-indica*, is called sonbadak cactus (meaning hand-like) cactus or baeknyuncho (meaning a plant

living for a hundred years). The pads are "cladodes" or "nopales" when they are whole, and "nopalitos" when diced.

PROCESSED FOODS

Opuntia ficus-indica is cultivated for both food and medicinal purposes. The pads and the fruit are harvested for many different food dishes and processed foods. The pads of *Opuntia ficus-indica* have been grown as a traditional vegetable in Central Mexico. Nopalitos (sliced or cubed pads) have been used as a food ingredient in omelettes, jelly, bread, and cookie. They taste something like green beans. Today, the pads are available in that country throughout the year for specialty produce sections. The smaller young pads in the early spring are the most succulent and delicate in their flavor, and have the fewest spines. Fresh pads are full of water and should be bright green and firm. They can be eaten raw in salads, boiled and fried like eggplant, pickled with spices, or cooked with shellfish, pork, chilies, tomatoes, eggs, coriander, garlic, and onions. In Jeju Island, the crushed pads are freeze-dried and ground into flour (180~200 mesh) to be used as food ingredients in noodles, drinks, jam, tea, baked products, and tablets (4,5).

Such fruit as tuna or prickly pear has been used for appetizers, soups, salads, vegetable dishes, and breads to desserts, beverages, and candies over the world. The flavor of a ripe prickly pear cactus fruit depends on the variety, but comprises the scents of strawberries, watermelons, honeydew melons, figs, bananas, and citrus. They can be cooked into jams and preserves or cooked down into syrup as a base for jelly or made into a candy called "cactus candy" in some Mexican food stores and "neck candy" in some Korean food stores. The crushed fruits (usually a purple red colors) are also freeze-dried and ground into flour (180~200 mesh) to be used as food ingredients in noodles, drinks, jam, tea, baked products, yogurt, and tablets in Jeju Island. The fruit pulp is also extracted by in boiling water and then packing it into a retort pouch for drinking (4,5).

CHARACTERISTICS OF *OPUNTIA FICUS-INDICA* CULTIVATED IN JEJU ISLAND

Opuntia ficus-indica cultivated in Jeju Island is one of varieties of *Opuntia*. Authors have thought the taxonomy of the group to be confusing, no doubt due to the asexual propagation of interspecific hybrid swarms, as well as its propagation as a crop in so many arid and semiarid regions. Usually, *Opuntia ficus-indica* is cultivated on stony soil in Jeju Island. As shown in Fig. 2, *Opuntia ficus-*



Fig. 2. The prickly pear *Opuntia ficus-indica* grown in well-organized plantations at stony soil in Jeju Island.

indica is grown in well organized plantations for fruit production in Jeju Island. The pads are newly sprouted in early spring through late summer in Jeju Island. As shown in Table 1, flowers bloom from late spring through early summer and fruits mature in the winter season (5). Fruits are the best for eating after ripening in December (5).

Proximate compositions of *Opuntia ficus-indica* are presented in Table 2. The major component of the freeze-dried *Opuntia ficus-indica* was the nitrogen free extract, 58.02~69.20% (6). Components of the pad and fruit were 9.30~5.94% water, 1.20~1.35 crude fat, 8.52~4.24% crude protein, 20.05~12.12% crude ash, and 3.79~6.27% crude fiber, respectively (6). The fibrousness of the fruits increased as the fruits matured and nitrogen free extracts related to dietary fiber contents (7).

Mineral compositions of *Opuntia ficus-indica* are presented in Table 3. The calcium contents were relatively high compared to the other minerals. The calcium contents (4391.2~2086.9 mg%) were considerably higher than those of the commonly consumed fruits such as citrus, strawberry, jujube, persimmon, and apple (8). The major minerals were Ca (4391.2~2086.9 mg%), K (1932.1~2608.7 mg%), and Mg (800.6~1984.8 mg%),

Table 3. Mineral compositions of *Opuntia ficus-indica* var. in Jeju Island (Unit: dry basis, mg%)

Minerals	Pad	Fruit
Ca	4391.2	2086.9
Mg	1984.8	800.6
Na	985.4	539.7
K	1932.1	2608.7
Fe	11.3	12.9
Mn	1.4	2.2
P	93.0	99.6
Total	9399.2	6150.6

respectively. Total mineral contents of pad and fruit of *Opuntia ficus-indica* were 9399.2, and 6150.6 mg%, respectively.

Information on the amino acid content of a food protein provides a useful indication of its nutritive value as compared to other foods with high quality proteins. Compositions of total amino acids of *Opuntia ficus-indica* are listed in Table 4. The major amino acid was glutamic acid, accounting for 16.3 mg% in fruit and 25.2% in pad of the total amino acid content. The contents of glutamic acid, arginine, asparatic acid, leucine, and proline were

Table 4. Compositions of total amino acid of *Opuntia ficus-indica* var. in Jeju Island (Unit: dry basis, mg%)

Amino acids	Pad (%)	Fruit (%)
Asp	453.742 (7.4)	258.424 (7.0)
Glu	1543.155 (25.2)	605.788 (16.3)
Ser	219.817 (3.6)	118.790 (3.2)
Gly	245.066 (4.0)	128.105 (3.5)
His	188.540 (3.1)	150.896 (4.1)
Arg	361.728 (5.9)	306.088 (8.3)
Thr	199.319 (3.3)	97.791 (2.6)
Ala	163.310 (2.7)	93.668 (2.5)
Pro	294.235 (4.8)	242.270 (6.5)
Tyr	228.108 (3.7)	314.067 (8.5)
Val	264.000 (4.3)	104.887 (2.8)
Met	24.075 (0.4)	5.432 (0.2)
Cys	55.394 (0.9)	57.636 (1.6)
Ile	249.127 (4.1)	131.149 (3.5)
Leu	373.521 (6.1)	121.220 (3.3)
Phe	276.887 (4.5)	153.856 (4.2)
Lys	281.268 (4.6)	108.269 (2.9)
Total	6130.047 (100)	3706.449 (100)

Table 1. Seasons for growing stages of *Opuntia ficus-indica* var. in Jeju Island

Sprouting stage			Blooming stage		Fruiting stage	
First	Second	Third	Beginning	Completion	Beginning	Completion
20 May \pm 2 ^{b)}	1 July \pm 2	23 Aug \pm 3	10 June \pm 4	1 July \pm 5	1 Nov \pm 5	5 Dec \pm 10

^{b)}The date \pm day.

Table 2. Proximate compositions of *Opuntia ficus-indica* var. in Jeju Island

(Unit: %)

Samples	Moisture	Crude fat	Crude protein	Crude ash	Crude fiber	Nitrogen free extract
Pad	5.94	1.20	8.52	20.05	6.27	58.02
Fruit	9.30	1.35	4.24	12.12	3.79	69.20

relatively high compared to the other amino acids (6).

Compositions of free sugars of *Opuntia ficus-indica* are presented in Table 5. The major free sugar in pad was fructose, but the major free sugar in fruit was sucrose (6). Fructose content was 40.8% in pad and 18.0% in fruit, while sucrose content was 31.8% in pad and 68.7% in fruit. Mannose was less than 2%. Sawaya et al. (9) also reported that the sugars of prickly pear consisted of mainly glucose and fructose (60:40).

Contents of vitamin C, total polyphenols, and flavonoids of *Opuntia ficus-indica* are presented in Table 6. Vitamin C contents of pad and fruit were 71.2 and 163.8 mg%. Vitamin A was not present in pad and fruit. Total polyphenols of fruit were more than those of pad. Total flavonoids of fruit were similar to those of pad. However, Lee et al. (6) have been reported that the contents of total polyphenols and flavonoids were changed by extraction solvent and temperature. In the methanol extract of the fruits, two dihydroflavonols were isolated and identified as (+)-trans-dihydrokaempferol and (+)-trans-dihydroquercetin by spectroscopic methods (10). Kuti (11) also identified conjugated flavonoids (quercetin, kaempferol, and isorhamnetin) in extracts from cactus (*Opuntia* species) fruits. Polyphenolic flavonoids are metabolic products widely distributed in foods of plant origin and they have numerous biological and pharmacological properties. Also they could potentially afford protection against chronic diseases. The results indicate that fruit and pad of *Opuntia ficus-indica* are rich

Table 5. Contents of free sugar of *Opuntia ficus-indica* var. in Jeju Island (Unit: dry basis, mg)

Free sugars	Pad (%)	Fruit (%)
Fructose	4327.639 (40.8)	7359.003 (18.0)
Glucose	2722.767 (25.7)	5243.173 (12.8)
Sucrose	3364.785 (31.8)	28101.118 (68.7)
Mannose	180.481 (1.7)	208.286 (0.5)
Total	10595.672 (100)	40911.610 (100)

Table 6. Contents of vitamin C, total polyphenols, and flavonoids of *Opuntia ficus-indica*

Vitamic C (mg%)		Polyphenols (mg/g)		Flavonoids (mg/g)	
Pad	Fruit	Pad	Fruit	Pad	Fruit
71.2	163.8	1.858	4.976	1.290	1.590

Table 7. Hematological values of rats intraperitoneally treated with fruit and pad of *Opuntia ficus-indica*

Samples	Parameter/Dose (mg/kg)	0	500	1,000	1,500	2,000
Fruit	WBC ($\times 10^3$ μ L)	13.7 \pm 2.1	14.3 \pm 2.0	13.5 \pm 3.2	15.2 \pm 4.0	15.7 \pm 2.7
	RBC ($\times 10^3$ μ L)	7.6 \pm 0.2	7.7 \pm 0.3	7.5 \pm 0.4	7.5 \pm 0.3	7.8 \pm 0.3
	Hb ($\times 10^3$ μ L)	14.9 \pm 0.6	15.3 \pm 0.5	14.2 \pm 0.6	14.7 \pm 0.3	15.2 \pm 0.6
Pad	WBC ($\times 10^3$ μ L)	14.6 \pm 3.7	15.2 \pm 3.0	14.6 \pm 2.3	15.6 \pm 4.0	15.9 \pm 2.6
	RBC ($\times 10^3$ μ L)	7.8 \pm 0.7	7.6 \pm 0.3	7.8 \pm 0.4	7.5 \pm 0.5	7.7 \pm 0.5
	Hb ($\times 10^3$ μ L)	15.0 \pm 0.7	14.9 \pm 0.6	15.2 \pm 0.5	15.3 \pm 0.6	14.9 \pm 0.5

sources of flavonoids and polyphenols (6). Therefore, their components may also lead to food functionalities such as antioxidant, biological and pharmacological effects.

PHARMCOLOGICAL EFFICACY

Serum biochemical and hematological parameters

The activities of serum biochemical and hematological parameters were not affected in rats orally treated for 4 weeks with fruit and pad of *Opuntia ficus-indica* (5). Hematological values such as white blood cell (WBC), red blood cell (RBC) and hemoglobin (Hb) showed no significance in the experimental rats intraperitoneally treated with the fruit and pad of the *Opuntia ficus-indica* (Table 7). There were also no significant differences in SDH, ALT, AST, GGT, ALT, T.Pro, uric acid and creatine (Data not shown. Refer to Ref. No 5). On the other hand, there was no acute toxicity from administration of either the fruit or pad of *Opuntia ficus-indica* in rats orally treated for 4 weeks. All rats survived the experimental period (Data not shown. Refer to Ref. No 5). The results indicated that the fruit and pad of *Opuntia ficus-indica* are considered to be the good and safe sources of food materials.

As shown in Table 8, serum lipid components were also unaffected in the normal rats (5). Hepatic lipid peroxide content, superoxide dismutase and glutathion peroxidase activities were not affected significantly by treatment with the fruit and pad of the *Opuntia ficus-indica*.

Blood circulatory system

Neither the fruit or pad extracts of the *Opuntia ficus-indica* influenced the normal mean blood pressure in anesthetized rat (Table 9). Samples were administered orally to 3 rats. This results showed no significant actions on blood circulatory system, which implies that they had no toxic effects in animals (5).

Autonomic nervous system

The fruit and pad extracts of the *Opuntia ficus-indica* combined with acetylcholine and histamine stimulation exhibited measurable non-contractility in the isolated rat ileum (Table 10 and 11). Each 15 μ L/mL of extracts was added to the isolated organ after cumulatively

Table 8. Effects of fruit and pad of *Opuntia ficus-indica* on the lipid peroxidation, superoxide dismutase (SOD) and glutathione peroxidase (GP) activities in normal rats

Samples	Dose (mg/kg)	Lipid peroxidation ¹⁾	SOD activity	GP activity
Fruit	0	16.8 ± 0.8	9.6 ± 0.2	120.9 ± 16.7
	250	20.2 ± 2.1	9.7 ± 0.4	140.8 ± 23.2
	500	21.9 ± 4.2	9.9 ± 0.5	138.7 ± 20.4
	1,000	18.9 ± 0.9	10.3 ± 0.4	129.6 ± 18.4
Pad	0	18.3 ± 1.2	10.1 ± 0.5	123.7 ± 20.4
	100	21.4 ± 2.7	9.8 ± 0.6	139.4 ± 19.6
	250	20.6 ± 3.1	9.7 ± 0.4	119.6 ± 18.7
	500	22.9 ± 4.1	9.7 ± 0.4	140.3 ± 35.4

¹⁾Lipid peroxidation unit: MDA nmole/g of tissue.

Table 9. Effects of fruit and pad of *Opuntia ficus-indica* on blood pressure in rat

Time (min)	Mean blood pressure (mmHg)					
	Control	Fruits		Control	Pad	
		15 mg/kg	30 mg/kg		15 mg/kg	30 mg/kg
0	119 ± 2.6	115 ± 1.2	112 ± 3.1	113 ± 3.8	115 ± 3.2	112 ± 3.1
5	106 ± 3.1	108 ± 9.1	116 ± 4.2	103 ± 3.2	108 ± 5.1	111 ± 3.4
10	107 ± 2.4	111 ± 8.7	107 ± 3.4	115 ± 6.7	113 ± 4.7	110 ± 3.5
30	114 ± 3.1	104 ± 4.5	113 ± 3.9	114 ± 1.4	114 ± 3.2	112 ± 4.2
60	108 ± 3.1	113 ± 9.4	118 ± 2.1	113 ± 5.4	102 ± 3.9	106 ± 5.3
90	115 ± 2.9	118 ± 4.2	117 ± 5.3	99 ± 2.7	101 ± 5.4	108 ± 3.5
120	117 ± 1.4	109 ± 3.1	108 ± 5.2	101 ± 2.4	105 ± 4.1	112 ± 2.6

Table 10. Effects of fruit and pad of *Opuntia ficus-indica* and acetylcholine of isolated rat ileum

Acetylcholine concentration (M)	Contraction (%)				
	Ach	Fruit + Ach	Ach	Pad + Ach	
10 ⁻⁹	7.3 ± 1.3	1.4 ± 0.0	7.4 ± 2.1	2.1 ± 0.1	
2 × 10 ⁻⁹	15.2 ± 1.7	5.8 ± 3.2	7.4 ± 2.1	6.2 ± 2.2	
5 × 10 ⁻⁹	17.9 ± 1.8	15.7 ± 2.3	18.2 ± 2.0	19.3 ± 2.4	
10 ⁻⁸	28.3 ± 1.4	43.0 ± 7.5	30.4 ± 1.4	40.2 ± 8.5	
2 × 10 ⁻⁸	81.6 ± 3.5	80.8 ± 1.4	89.2 ± 2.2	84.3 ± 2.2	
5 × 10 ⁻⁸	98.8 ± 0.3	99.3 ± 0.3	100.0 ± 0.0	99.1 ± 0.4	

Table 11. Effects of fruit and pad of *Opuntia ficus-indica* and histamine of isolated rat ileum

Histamine concentration (M)	Contraction (%)			
	Histamine	Fruit + His	Histamine	Pad + His
5 × 10 ⁻⁸	4.9 ± 0.5	6.3 ± 1.4	5.1 ± 0.4	6.2 ± 1.3
10 ⁻⁷	9.1 ± 0.9	16.8 ± 1.8	10.2 ± 1.2	15.3 ± 2.8
2 × 10 ⁻⁷	48.0 ± 4.0	47.2 ± 4.0	52.3 ± 5.2	48.2 ± 6.0
5 × 10 ⁻⁷	83.7 ± 9.2	77.8 ± 5.2	88.2 ± 8.3	79.2 ± 7.2
10 ⁻⁶	87.6 ± 3.4	90.7 ± 1.9	87.4 ± 7.2	90.2 ± 2.4
2 × 10 ⁻⁶	100 ± 0.0	95.7 ± 0.5	99.2 ± 0.2	98.8 ± 0.4

adding acetylcholine and histamine and then washing them. They showed no significant differences from each other. This results showed no significant affects on the autonomic nervous system (5,12).

When we measured phenobarbital-induced sleeping time, locomoter activity, rotarod test, body temperature, MES-induced, strychnine-induced and pentylene-tetrazol-induced seizures which influence CNS, it was found that they were not affected by treatment with the fruit and pad extracts of *Opuntia ficus-indica* (Data not shown.

Refer to Ref. No 5 and 12). Considering the above results, *Opuntia ficus-indica* showed no significant reactions on the central and autonomic nervous, and blood systems, which imply no toxic effects in animals. The results indicated that fruit and pad of the *Opuntia ficus-indica* can be regarded safe and good sources of food materials.

Anti-inflammatory

Carrageenin-induced hind paw edema in rat was uti-

lized as animal models to screen for anti-inflammatory activities (5,12). As shown in Table 12, the cactus fruit and pad were orally administered to 10 rats 30 minutes prior to carrageenin injection. Treatment with cactus fruit (500, 1,000 mg/kg) and pad (100, 250, 500 mg/kg) showed an inhibitory effect on carrageenin-induced paw edema, indicating that both of the cactus fruit and pad exhibited the anti-inflammatory activity. Moreover, Park et al. (13) demonstrated that the ethanol extracts of *Opuntia ficus-indica* suppressed the release of glucuronidase, a lysosomal enzyme in rat neutrophils. It was also noted that the ethanol extracts showed a protective effect on gastric mucosal layers. Based on these results, it is suggested that the ethanol extracts of *Opuntia ficus-indica* cultivated in Jeju Island contain anti-inflammatory agents that may protect against gastric lesions.

Analgesic activity

Author and coworkers (5,12) found that of *Opuntia ficus-indica* showed anti-inflammatory and analgesic activities. Hot plate and acetic acid induced writhing tests in mice were utilized as animal models to search for analgesic activities (Table 13, 14). The cactus fruit and pad were administered orally for 30 minutes prior to the intraperitoneal injection of 0.7% acetic acid-saline (0.1 μ L/10 g) to 10 ICR mice according to Whittle's method. The treatment of the cactus fruit (250, 500, 1,000 mg/kg) and pad (100, 250, 500 mg/kg) inhibited acetic acid-

Table 14. Effects of fruit and pad of *Opuntia ficus-indica* on hot-plate test in mice

Treatment	Dose (mg/kg)	Onset time (sec)
Fruit	0	15.4 \pm 0.1
	250	18.7 \pm 0.1
	500	25.4 \pm 0.2
	1,000	30.6 \pm 0.3
Aminopyrine	100	50.2 \pm 0.5
Pad	0	16.5 \pm 0.2
	100	20.3 \pm 0.2
	250	30.7 \pm 0.3
	500	33.6 \pm 0.4
Aminopyrine	100	49.8 \pm 0.4

induced writhing and hot-plate responses. These results indicate that both cactus fruit and pad had analgesic activity. The activity of pad was stronger than that of fruit.

Anti-diabetic activity

Diabetes mellitus is chiefly classified into two categories: type 1 (insulin-dependent diabetes mellitus, IDDM) is usually characterized by a chronic disorder that results from autoimmune destruction of the insulin-producing pancreatic beta-cell and type 2 (non-insulin-dependent diabetes mellitus, NIDDM) is a major metabolic abnormality characterized by the impairment of insulin action (insulin resistance). There are several kinds of microvascular and macrovascular complications in diabetics.

Table 12. Effects of fruit and pad of *Opuntia ficus-indica* on the carrageenin-induced hind paw edema in rat

Treatments	Dose (mg/kg.p.o)	Time (hr) course of swelling percent (%)			
		0.5	1	2	3
Control	0	67.0 \pm 7.2	63.7 \pm 5.7	76.6 \pm 4.2	79.0 \pm 7.8
Fruit	250	60.9 \pm 3.2	59.8 \pm 3.6	61.3 \pm 6.2	72.3 \pm 4.9
	500	51.8 \pm 4.3	49.9 \pm 5.3	53.6 \pm 4.7	67.4 \pm 5.5
	1,000	45.3 \pm 2.4	43.4 \pm 3.6	50.8 \pm 5.5	70.3 \pm 6.2
	Indomethacin	20	39.7 \pm 6.2	37.3 \pm 5.0	47.3 \pm 6.6
Control	0	66.0 \pm 5.7	68.9 \pm 6.2	78.8 \pm 5.2	81.3 \pm 6.2
Pad	100	52.3 \pm 2.3	54.0 \pm 3.4	58.4 \pm 4.2	69.8 \pm 5.3
	250	50.8 \pm 8.6	48.6 \pm 3.5	55.9 \pm 3.6	71.3 \pm 6.2
	500	43.7 \pm 3.9	42.7 \pm 5.2	51.6 \pm 3.7	68.8 \pm 4.2
Indomethacin	20	37.3 \pm 3.3	36.7 \pm 4.0	40.7 \pm 3.4	53.9 \pm 4.3

Table 13. Effects of fruit and pad of *Opuntia ficus-indica* on acetic acid-induced writhing syndrome in mice

Treatments	Dose (mg/kg)	Fruit		Pad	
		Writhing lag (sec)	Writhing syndrome (sec)	Writhing lag (sec)	Writhing syndrome (sec)
Control	0	220.4 \pm 16.5	18.4 \pm 1.8	230.6 \pm 17.4	19.4 \pm 1.6
<i>Opuntia ficus-indica</i>	100	243.6 \pm 17.9	16.4 \pm 1.7	260.7 \pm 18.9	15.1 \pm 1.8
	250	307.4 \pm 22.7	10.7 \pm 2.2	310.9 \pm 24.4	10.3 \pm 2.5
	500	324.9 \pm 30.1	9.8 \pm 1.9	330.4 \pm 29.8	8.7 \pm 1.6
Aminopyrine	100	398.9 \pm 39.4	5.3 \pm 0.7	404.2 \pm 41.2	4.8 \pm 1.2

There is evidence that the hyperglycemia acts through a common mechanism to cause early functional alterations in peripheral nerves, kidney, and retina that antedate the development of characteristic diabetic pathology. Anti-diabetic activities (*in vitro* alpha-glucosidase inhibitory and ability to lower blood glucose levels in alloxan-induced streptozotocin-induced diabetic *db/db* mice) of *Opuntia ficus-indica* were investigated by author and co-workers (14). The urinary total glucose and blood total glucose were exhibited in *db/db* mice (Table 15, 16). The other results were omitted in this review. *Opuntia ficus-indica* was administered along with the diet for 5 weeks to *db/db* diabetic mice. The pads of *Opuntia ficus-indica* inhibited the glucose elevation in blood and urine. The results suggest that *Opuntia ficus-indica* could reduce the postprandial blood glucose levels in normal and diabetic mice. Also, the results seemed to indicate that it could prevent various symptoms of diabetics and other diseases originating from hyperglycemia. *Opuntia ficus-indica* pads could be more effective than fruit for the treatment of insulin-independent type 2 diabetes mellitus.

Other activities

In order to isolate pharmacologically active constituents from *Opuntia ficus-indica*, the author and coworkers (15) screened with several bioassays including antithrombotic, anticoagulant, dopamine beta-hydroxylase and monoamine oxidase (MAO) activities. Among these, it was

found that the fruit and pad of *Opuntia ficus-indica* inhibited MAO activity. Citric acid methylesters, particularly dimethylester, are major components of the MAO fraction found in a fruit. The presence of trimethyl citrate has been reported in other plants, but 1,3-dimethyl citrate and 1-monomethyl citrate have not been previously reported. In addition, some Korean researchers (16) studied the effects of *Opuntia ficus-indica* on the dietary and alcoholic hyperlipidemia, the respiratory system, antigastic and anti-ulcerative actions.

CONCLUSION

Opuntia is the largest group of cacti in the world. Jeju Island in Korea has an area of over 2,000 ha (7,413 acres) under commercial cultivation with *Opuntia*, with an annual production of approximately 2,500 tons. *Opuntia ficus-indica* is grown in commercial quantities as a food and medicinal plant in Jeju Island. The crushed pads and fruits of *Opuntia ficus-indica* are freeze-dried and ground into flour (180~200 mesh) to be used as food ingredients for noodles, drink, jam, tea, baking, beverages, candy, yogurt, and tablets in Korea. The results of pharmacological efficacy testing, such as serum biochemical and hematological parameters, autonomic nervous system, anti-inflammatory, analgesic activity, anti-diabetic activity, antithrombotic, anticoagulant, dopamine beta-hydroxylase, monoamine oxidase (MAO) activity,

Table 15. Changes of urinary total glucose in *db/db* mice treated with the fruit and pad of *Opuntia ficus-indica*

Group ¹⁾	Changes of urinary total glucose (mg/20 h)				
	0 wk	1 wk	2 wk	4 wk	5 wk
Lean	1.2 ± 0.4	2.5 ± 1.5	2.1 ± 1.0	1.3 ± 0.7	1.1 ± 0.7
Nontreated	286.8 ± 5.6	318.0 ± 4.6 [#]	572.0 ± 9.6 [#]	572.0 ± 5.3 [#]	586.8 ± 2.0 [#]
Acarbose	532.4 ± 2.6	499.0 ± 3.8	108.4 ± 4.2 [*]	108.4 ± 6.9 [*]	495.2 ± 5.2 [*]
Pad	444.0 ± 4.2	532.0 ± 7.6	452.4 ± 0.4 [*]	452.4 ± 6.4 [*]	488.0 ± 7.1 [*]
Fruit	342.0 ± 0.8	791.6 ± 3.7	521.6 ± 6.3 [*]	521.6 ± 4.4 [*]	506.4 ± 2.4 [*]

¹⁾Lean, C57BLKS/J-control group for *db/db*; nontreated, group treated with normal diet on C57BLKS/J-m+/+Lepr^{db}; acarbose, group treated with 0.1% acarbose-mixed diet on C57BLKS/J-m+/+Lepr^{db}; Pad, group treated with a 1% pad of cactus-mixed diet on C57BLKS/J-m+/+Lepr^{db}; Fruit, group treated with a 1% cactus fruit diet on C57BLKS/J-m+/+Lepr^{db}.

[#]Significantly different from the lean group. ^{*}Significantly different from the nontreated group.

Table 16. Changes in blood total glucose in *db/db* mice treated with the fruit and pad of *Opuntia ficus-indica*

Group ¹⁾	Changes of urinary total glucose (mg/20 h)				
	0 wk	1 wk	2 wk	4 wk	5 wk
Lean	47.5 ± 2.1	75.0 ± 21.1	64.0 ± 5.6	71.5 ± 10.6	80.0 ± 2.8
Nontreated	94.5 ± 22.5	161.5 ± 40.5 [#]	205.0 ± 34.0 [#]	258.0 ± 14.0 [#]	199.5 ± 45.5 [#]
Acarbose	134.5 ± 56.5	68.5 ± 4.5	244.5 ± 51.5 [*]	358.0 ± 43.0 [*]	230.5 ± 23.5 [*]
Pad	138.0 ± 41.2	65.0 ± 30.8	199.0 ± 37.1 [*]	178.0 ± 34.0 [*]	138.0 ± 23.8 [*]
Fruit	221.0 ± 44.0	123.5 ± 47.5	188.0 ± 26.0 [*]	171.0 ± 45.4 [*]	74.5 ± 2.5 [*]

¹⁾Lean, C57BLKS/J-control group for *db/db*; nontreated, group treated with normal diet on C57BLKS/J-m+/+Lepr^{db}; acarbose, group treated with 0.1% acarbose-mixed diet on C57BLKS/J-m+/+Lepr^{db}; Pad, group treated with a 1% pad of cactus diet on C57BLKS/J-m+/+Lepr^{db}; Fruit, group treated with a 1% cactus fruit diet on C57BLKS/J-m+/+Lepr^{db}.

[#]Significantly different from the lean group. ^{*}Significantly different from the nontreated group.

hyperlipidemia, the respiratory system, antigastic and anti-ulcerative actions indicate that the fruit and pad of the *Opuntia ficus-indica* are good sources of food materials.

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