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Review Article

Opuntia ficus-indica (L.): An Overview of the Recent Application and Opportunities in Food

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ABSTRACT

Opuntia ficus-indica (OFI, prickly pears, nopal cactus) has been used as a food, in beverages, besides prickly pears's natural betalain pigment serves as a food colorant. The abundant biological components of nopal cactus, including polyphenols, flavonoids, and other related compounds that exhibit therapeutic like, hypoglycemia management, anti-infection, anti-inflammatory, and antioxidation. Its versatility is remarkable, finding applications in pharmaceuticals, cosmetics, human and livestock nutrition, alternative fuels, construction, erosion control, and animal care. Recent studies highlight its potential to inhibit the growth of cervical, ovarian, and bladder cancer cells *in vitro*. *In vivo* tests on mice demonstrated decreased tumor growth in the ovarian cancer model. However, more meticulously designed clinical trials are required, utilizing phytochemically characterized preparations. *Opuntia ficus-indica* recast an exceptional safety and tolerability profile, underscoring its potential as a versatile and health-promoting resource.

Keywords: *Opuntia ficus-indica*, prickly pear, nopal cactus, anti-inflammatory, antioxidant

Introduction

Prickly pears (PP) or nopal cactus, also known as *Opuntia ficus-indica* (OFI), are members of the Cactaceae family of plants and are native to Mexico. This plant also grows in many places in America and is found worldwide, including in Australia, Africa, and the Mediterranean.[1,2] OFI is gaining popularity across the world because it can grow anywhere, particularly in dry and semi-arid countries.[3] Today, the prickly pear is a popular cuisine. According to experts, this is a "superfood" that helps you stay healthy from the inside out.

Numerous research articles in the scientific literature indicate that the fruits and cladodes of the PP plant hold the potential to serve as valuable sources of phytochemicals, vitamins, and minerals. Consequently, the PP plant is recognized for its ability to enhance a healthy diet by providing essential nutrients and a substantial content of beneficial compounds that can play a role in preventing a variety of diseases.[4,5]

The fruit and the "nopal" are two parts used for food. It can be consumed raw, dried in the sun, or made into marmalade. In Mexican regions, prickly pears are used as an ingredient for salads.[6] PP is becoming increasingly popular as an unusual, trendy, and healthy dish in many countries. The dishes made from this cactus are especially popular in Mexico, China, and America and may frequently be found on the daily menu of every family. Cactus is considered an unusual meal in some parts of the United States, especially healthy and only for gourmets. Prickly pear cactus is considered by the Spaniards as a food rich in iron, and vitamins B and C.

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It also has multiple quality that allow it to be used in a variety of applications, including pharmaceuticals, cosmetics, food for humans and livestock, alternative fuels, civil construction, soil erosion control, animal protection, and as a honey supply for bees.[7]

Botanical description

Morphology

The prickly pear cactus are roots, cladodes, leaves, flowers, and fruits. It has smooth, absorbent, extraordinarily spreading, succulent, and densely branching roots, and they may grow up to 5 meters tall. Horizontally, the root system extends up to 10 to 15 meters from the base of the tree.[7,8] Environmental factors such as soil type, water availability, and cultivation practices like as irrigation and fertilization all influence the length of the roots.

Cladodes, or stems, are soft and succulent. They have an ovoid or elongated form and weigh between 40 and 100 g. The dimensions of a cladode are length (30–50 cm), breadth (20–30 cm), and thickness (2–4 cm). The parenchyma which makes up around 50 to 70 percent of the cladode and stores water and organic acids, is located inside the cladode and between the chlorenchyma (green component), vital for photosynthetic activity.[9] Cladodes have areolas that can generate new cladodes, blooms, or roots depending on the environmental circumstances. Only the delicate cladodes have leaves that grow on the areolas and they are cylindrical, deciduous leaves last approximately a month.[7,8]

The huge, spectacular, and hermaphroditic blooms grow along the top leaf edge. They have attractive colors like yellow, orange, pink, purple, red, and white but do not have an aroma. Additionally, wind or insects pollinate them.[7] Few investigations on this plant's blooms have been conducted due to its short flowering season (March to June).[8,10]

The OFI fruit (called prickly pear) grows in the stem tissues from an inferior ovary. It matures around 110 to 120 days following blossoming and may vary in weight from 80 to 200 g. Prickly pears (PP) are cylindrical or ovoid in shape, with a length ranging from 5 to 10 cm and a width between 4 and 8 cm.[11] Peel, pulp, seeds are the three components of PP. The peel comprises 30 to 40% of the overall weight of PP, the pulp 60 to 70%, and the seeds 2 to 10%.[4,11]

The PP peel is separated into two parts: pericarp and mesocarp. The pericarp is rather slender and shaped similarly to cladodes, while the mesocarp is edible and nutritious. Conversely, when the fruit is peeled, the mesocarp is discarded and rarely consumed.[7,12] The peel is green during the early stages of fruit growth, changing to diverse colors ranging from greenish-white to purplish, and can be orange, purple, yellow, red, or purplish as the fruit matures. The reason that cactus has many different colors depends on their ecological and diversity.[12,13] The edible part is the PP pulp which is rated as soft, succulent, transparent, viscous and silky. It has multiple little seeds with robust integuments and is the same color as the peel. The seeds, which are evenly dispersed throughout the fruit, are black, edible, and have been widely researched.[12] Because PP has a limited shelf life (3-4 weeks), it is not suitable for long-term storage or worldwide distribution.[9]

Ecology

Having an annual cycle, OFI is a perennial plant. Its cultivation is dependent on key factors such as climate, soil physicochemical characteristics, plant variety selection, soil preparation, planting distance, oriented crop rows, and irrigation systems, among others.[4] The harvesting process, diversity or ecotype, meteorological conditions and after -harvest procedures all affect the development of OFI. Depending on the above conditions, the physiological development of OFI takes 70 to 150 days after blooming. There are three stages of fruit development: pod dry matter development, seed dry matter development, and pulp development. During development, the color and texture of the rind and fruit change, colloidal seed drop occurs, and the total dissolved solids (TSS) concentration rises[7]. Fruit size, weight, and hardness, change in peel color, bloom depth, TSS content, minimum 14°Brix, dewdrop ratio, shell thickness, the pulp/shell ratio, and the ease of skin removal are factors that can assist in deciding the optimal time to harvest PP.[13]

Due to their glochids and spines, PPs are difficult to harvest; therefore, manual harvesting is done overnight and into the morning, when cutting is easier, the fruit tissues are more resistant to damage, and the glochids are still attached to the fruit, and more humid.[4] There are different methods for harvesting fruit, including turning or twisting (for processing), cutting flush to the insert (for consumption right away or sale with little conversation time), slicing off a tiny portion of the fruit-attached layer (for the commercialization of OFI because it increases the time of preservation).[7] Next, the glochids are mechanically removed while avoiding injuring the fruits' skin and then chosen according to the intended use. The fruits are then chlorinated with sodium hypochlorite or rinsed with drinking water to decrease the number of microorganisms. After that, they are coated with wax, either by immersion or by sprinkling, to prevent water loss through transpiration, lessen the intensity of gas exchange, enhance aesthetics, and extend fruit preservation. PPs are categorized manually or automatically according to their color and size. On the day of harvest, the fruits are often packed and delivered in refrigerated conditions. The fruits must be preserved in a certain way if they are handled a few days after harvest. Low temperatures (5-8°C), and relative humidity (85-95%) are suggested for PP storage, depending on several variables such as storage length, packing type, harvest season, and fruit variety. Under these circumstances, the shelf life ranges from 3 to 8 weeks.[7]

Infections with bacteria, viruses, and fungi are examples of biotic illnesses that can affect OFI, besides abiotic diseases brought on by hail, frost, pesticides, herbicides, and fruit breaking.[4] OFI in Portugal is relatively resistant to pests and illnesses. Phytopathogenic bacteria, fungi, and pests are the leading causes of the loss of OFI production. The insect that does the most harm in PP cultivation is the Mediterranean fly (*Ceratitis capitata*). In addition, some animals such as ants, slugs, snails, mealybugs, and fruit flies can also harm plants.[7]

Karyotype

Planting material can be created from cladodes as a whole or in parts by *in vitro* micropropagation or through straightforward asexual vegetative reproduction.[13] This method has a high rate of propagation, needs less space for cultivation, generates pathogen-free healthy plants, chooses certain genotypes, prevents physiological disruptions and morphological abnormalities, and generates plants with the necessary traits. Furthermore, OFI micro propagated from areolas can aid in delaying desertification in dry and semi-arid areas.[7]

Uses – economic botany

Use in food and traditional food

Cactus pear serves as a food source for both people and animals as well as a nutritional and medicinal agent in several dietary and value-added goods.[10] Different parts of cactus pear can be used as a variety of foods as listed in Table 1. Additionally, it has uses in the food business. Although the fruit of the PP is often eaten fresh, it can be even found in processed types like jams, syrups, juices, jelly, wine, and vinegar. These products are widespread in Latin America. Recent research has shown that the quality and health advantages of stirred yogurt milk were greatly enhanced by the addition of cactus pear and pomegranate juices.[14] Moreover, juice from OFI has been studied to produce alcoholic beverages with biological functions[15] and some authors have used prickly pear for alcohol production.[16] Prickly pear juice and fruit have a short harvest period of three to four weeks and a high tendency to deteriorate, which is a challenge for the marketing of fresh goods.[17] Therefore, a recent study has developed a prickly pear juice fermented beverage using *Saccharomyces cerevisiae* yeast to prolong shelf life and improve the sensory qualities of this beverage.[16]

During the dry season, *Opuntia* fruits are the major food source in the village close to the Mukogodo forest, where humans and domestic animals rely on them. Because of their flavonoid, ascorbic acid, and carotenoid content, they are also a good source of natural antioxidants for food. Being fleshy and sweet, they are also used as a source of refreshment and are used to produce jams and juices.[18] In Mexico and the countries of the Americas, dishes from cacti are very popular and are considered a green vegetable, included in the daily menu of every family. Today, many restaurants in the UK are starting to use the leaves, stems, and fruits of cacti to make salads, sandwiches, or juice. Cactus juice and jam began to appear on many shelves in supermarkets.

Use in medicine

According to various studies, cardiovascular disease and numerous types of cancer have been shown to be less common among those who eat a diet rich in fruits and vegetables.[4] Several studies in the scientific literature demonstrate the potential use of PP fruits and cladodes as an abundant supply of phytochemicals, vitamins, and minerals. Thus, OFI is regarded for its contribution to a nutritious diet as well as its high concentration of health-promoting compounds employed in the prevention of many diseases.[4,5] Some of the beneficial features of OFI are illustrated in Figure 1.

In Mexico, OFI is used as a folk medicine to treat burns, wounds, edema, and indigestion. Its alcoholic extract is said to have anti-inflammatory, hypoglycemic, and antiviral effects. Furthermore, for centuries the stems of prickly pears have been utilized medicinally to treat obesity, hyperlipidemia, and diabetes. Nowadays, it would be acceptable to develop OFI and its ingredients as a medication due to their outstanding biological activity.[19]

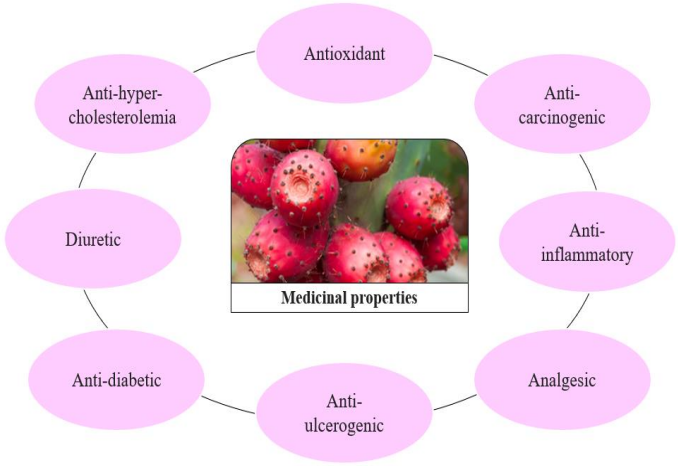


Figure 1: The health benefits of OFI

Table 1: Food products, by-products, and additives obtained from cactus pear fruit and cladodes[13]

Products	From fruit	Juices and nectars
		Jams, gels, and jellies
		Dehydrated fruits and fruits leathers
		Sweeteners
		Wines, alcohols, and vinegars
		Frozen fruit and pulp
		Canned fruit
		Juices
		Pickled and brine-cured products
	From cladodes	Jams and jellies
		Flours
		Alcohol
		Confectionery
		Sauces
		Oil from seeds
		Mucilage from cladodes
By-products	From fruit and cladodes	Coloring agents from the peel and fruit
		Dietary fiber from cladodes
		Animal feed derived from the pulp, peel, and seeds

Source of fiber

According to the literature, cactus pears are a notable source of fiber, which provides the juice with a pleasant mouthfeel and decreases blood sugar levels,[2] including a content of 3.0-5.0 g/100 g, which is greater than the comparable fiber levels of 2.4 g/100 g, 2.0 g/100 g, and 2.6 g/100 g found in fruits like apples, oranges, and bananas. Moreover, the fiber content of cactus is also higher than the fiber content of broccoli (2.6 g/100 g), rice (0.4 g/ 100 g) and wheat (1.2 g/100 g).[20] The cactus fruit and pad are both rich in fiber, which can lower cholesterol levels in the blood,[21] found that cactus-pear fruit pulp fibers had the greatest impact on the digestibility of a casein-based diet when compared to Arabic gum, carrageenan alginic acid, locust bean, and citrus pectin fibers.[21]

In addition, fiber also attracts the most attention among dietary supplements. In a recent study, cactus peel powder was used in cake production as a natural source of dietary fiber. Large concentrations of dietary fiber, ash, carbohydrates, phenolic compounds, flavonoids, or antioxidant activity may be found in prickly pear peel powder. When added to another sample, dietary fiber, total polyphenols, flavonoids, and minerals were considerably higher than in the control group. Mixing powdered prickly pear by-products with wheat flour is thought to have enhanced the nutritional quality and function of baked goods like bread and cookies.[22]

Animal feed

Cactus has been used successfully as a source of feed in nations spanning from South Africa and Tunisia to Brazil and Mexico, where research and extension programs on cacti are given attention and strongly organized. The animal feed business is expanding, and there are fewer risks than the produce market, implying greater opportunity for involvement in entrepreneurship. Animal feed may be made from trimmed fruit orchard cactus cladodes in some areas, boosting the farmer's earnings. The potential for foraging of cacti is generally neglected in semi-arid environments. There are numerous prospects for building cactus-based livestock production systems that will promote human life while minimizing the impact on natural rangelands.[4]

Cosmetic

Herbal goods are becoming increasingly popular, and sales of herbal cosmetics are increasing. OFI is a plant whose cladodes are mostly made up of water (80-95% of the total) and carbohydrates (3-7%). Some of the substances present in the chemical composition of the PP include phenolic components (kaempferol, quercetin) and carbohydrates (galacturonic acid, glucose, rhamnose, and arabinose), and the cosmetic industry is interested in these substances as moisturizers and anti-aging products.[5] Cactus cladodes are used to make a wide range of goods in Mexico, containing face masks, soaps, shampoos, and other kinds of creams and lotions.[13]

The current importance of Opuntia ficus-indica

Opuntia fruit is frequently used to produce a variety of foods, including tortillas, bread, nachos, juice, jam, and biscuits.[23,24] Additionally, some writers have attempted to create a novel functional pasta using Opuntia, and they have demonstrated that it might be regarded as a nutritious meal without modifying the physical and organoleptic qualities of the finished food.[25] Instead, other researchers examined the 3% *Opuntia* enrichment of pasta, noting that this is a great functional diet for maintaining a healthy weight and reducing age-related metabolic issues.[26]

Cactus pear has betalain, a natural colorant that is commonly applied in the food industry. Betalains in cactus pear are both betacyanins (red-violet colour) and betaxanthins (yellow color), in quantities equivalent to the most betalain-rich red beet hybrids.[2] It was looked at using a purple concentrated prickly pear juice, for example, as a food coloring for dairy goods (like yogurt)[4]. Other investigations concentrated on spray-drying or freeze-drying cactus pear pulp to create colorant powders.[13]

With the current food-related healthcare trend, the cactus is a potential bioactive plant species that is beginning to be explored by the industry. Besides, it is possible to consider using cactus as food for humans, increasing economic value from this plant for dry and semi-arid regions as well as lessening the impact of global climate change. Additionally, it is necessary to explore further applications of cactus in the field of probiotic foods. Besides, one of the industries with the largest growth is probiotic foods, providing probiotic-related benefits through food. Therefore, to expand and diversify functional foods made from cactus, new studies on the use of cactus components in the development of probiotic, postbiotic, and para probiotic foods need to be carried out.[20]

Economical-botanical aspects

Opuntia spp. can resist extended periods of drought, extreme temperatures, wind, and water erosion. This capacity, along with their diverse economic applications, makes them appropriate for farming growth in places impacted by the world's two most serious ecological concerns: changes in climate and desertification. The benefits of OFI incorporate control of soil and water erosion, climate conditioning through carbon sequestration, biodiversity protection, ecosystem for wildlife, pharmacological and industrial advantages, and their visual attractiveness as evergreen plants. In spite of their ecological, financial, and societal importance, cactus plant get little both popular and scientific attention. This is primarily owing to a concentrated cactus application for animal feed and fruit production. A multifaceted strategy is required, with a focus on environmental protection, agricultural production, and socioeconomic growth. It would be very helpful to promote the cacti's ecological, economic, and social benefits and to improve the technical proficiency of the human resources dedicated to these species.[4]

Phytochemistry

Nutritional value

A variety of research has been conducted on prickly pear species and fruits based on an assessment of nutritional composition, chemical properties, and antioxidant activity. Prickly pear fruit generally comprises around 85% water, 15% sugar, 0.3% ash, and less than 1% protein.[27] The fruit does not have a particular scent, but the pulp is quite

sweet, and the sugar component is primarily glucose and fructose (in comparable proportions), with concentrations ranging from 10° to 17° Brix. Given its significant water content, this fruit has a caloric value of 50kcal/100 g, which is equivalent to more fresh fruits such as pears, oranges, and apricots.[28] Table 2 displays the chemical composition of the fruit's edible portion in plants grown in some regions of the globe, including Chile, Argentina, Egypt, Mexico, and Saudi Arabia.[13]

The mineral composition of the edible parts of cactus pear fruits grown in various nations is shown in Table 3. The plant's location, cultivation practices, fertilizer and irrigation usage, temperature, and genetic variations among different types can collectively contribute to variations.[29]

Phytochemistry

Antioxidant substances (betacyanin, betaxanthin, flavonoids, and phenols), ascorbic acid, vitamin E, carotenoids, fiber, and amino acids are all present in large concentrations in cactus fruit.[30] Flavonoids and phenolic acids are plentiful throughout all parts of the cactus plant, both belonging to the polyphenol family. Isorhamnetin glycosides have a high quantity (50.6 mg/100g) in comparison to other flavonoids, while the total phenol content in fruit pulp is 218.8 mg/100g [31] (Table 6). The antioxidant and radical-scavenging activities of cactus polyphenols may have an impact on their capacity to promote health.

Vitamins are significant nutritional components of cactus pear fruit (Table 4). Lipid components from cacti fruit and seeds include tocopherols or fat-soluble vitamin E. The antioxidant properties of vitamin E are well known to increase the stability of fatty oils. Next, the second and third most important vitamins in cactus pears are vitamin K and ascorbic acid (Table 7).[32]

Sterols are precursors of brassinosteroids, a class of plant hormones that govern plant growth and development. The predominant sterols in plants are β-sitosterol, campesterol, and stigmasterol.[33] β-sitosterol and campesterol are the primary sterols derived from various portions of fruit oils such as pulp, peel, and seeds. Other sterols identified in cactus fruit include stigmasterol, lanosterol, 5-avenasterol, and 7-avenasterol.[30]

Table 2: Chemical composition of the pulp of cactus pear fruit (g/100g)

Parameter	(1)	(2)	(3)	(4)	(5)	(6)
Protein	0.8	0.6	1.4-1.6	0.21	0.82	0.99
Moisture	85.1	91	85-90	85.6	83.8	84.2
Fat	0.7	0.1	0.5	0.12	0.09	0.24
Fiber	0.1	0.2	2.4	0.02	0.23	3.16
Ash	0.4	-	-	0.44	0.44	0.51
Total sugars	-	8.1	10-17	12.8	14.06	10.27
Vitamin C (mg/100g)	25	22	4.6-41	22	20.33	22.56
B-carotene (mg/100g)	-	-	Trace	Trace	0.53	-

Source: (1) [58]; (2) [29]; (3) [59], (4) [60]; (5) [61]; (6) [62]

Table 3: Mineral composition of the pulps of cactus pear fruit (mg/100g)

Mineral	(1)	(2)	(3)	(4)	(5)
Iron	-	2.6	1.5	0.4	-
Magnesium	98.4	85	27.7	16.1	-
Calcium	24.4	49	27.6	12.8	-
Potassium	90	220	161	217	78.72
Sodium	1.1	5	0.8	0.6	1.64
Phosphorus	28.2[a]	-	15.4	32.8	-

[a]Phosphate PO_4 (mg/100g)
Source: (1) [58]; (2) [29]; (3) [59], (4) [60]; (5) [62]

Table 4: Mineral composition of cactus pear fruit pulps (mg/100g edible part)

Mineral	Green fruit	Orange fruit	Purple fruit
Magnesium	16.1	11.8	11.5
Calcium	12.8	35.8	13.2
Potassium	217	117.7	19.6
Iron	0.4	0.2	0.1
Phosphorus	32.8	8.5	4.9
Sodium	0.6	0.9	0.5

The amount of each type of amino acid found in cactus fruit is displayed in Table 5. The two major amino acids, comprising 46% and 15.78% of the total amino acid content, are proline and taurine, respectively. [30]

Organic acids

Cactus pears are classified as low-acid food (pH>4.5) since the pH of the pulp ranges from 5.8 to 6.4. The primary organic acid in prickly pears is citric acid (62 mg/100g), which is followed by malic acid (23.3 mg/100g). Only trace quantities of isocitric, fumaric, glycolic, and succinic acids were detected. Meanwhile, quinic acid (19.1 mg/100g) and shikimic acid (2.8 mg/100g) were found in quite significant concentrations.[34]

Biological and pharmacological activities

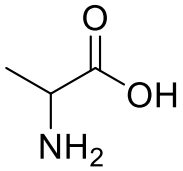
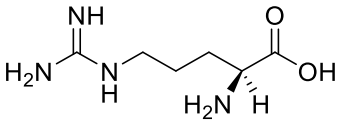
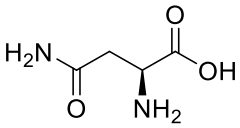
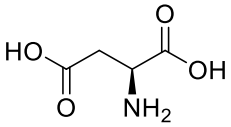
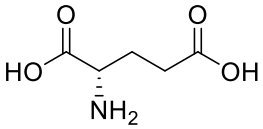
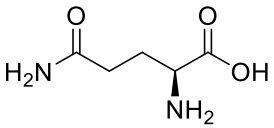
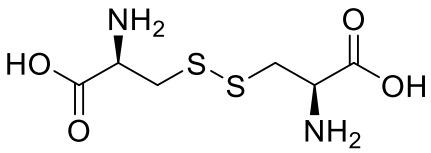
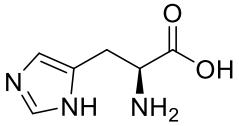
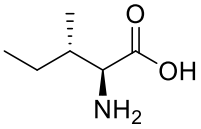
Anti-cancer effect

Recent research has shown that the fruit extract from cactus pears inhibits the growth of cervical, ovarian, and bladder cancer cell lines *in vitro* and decreases tumor growth in the nude mice ovarian cancer model *in vivo*.[32] These investigations have shown that different doses of cactus pear extract (1, 5, 10, and 25%) inhibited cancer cells *in vitro*-cultured for 1, 3, or 5 days. When mice were given a cactus extract solution intraperitoneally, the animals gained weight, demonstrating that the cactus had no harmful effects. More significantly, similar to N-(4-hydroxyphenyl) retinamide, a synthetic retinoid currently used as an ovarian cancer prevention drug, inhibition of tumor growth was observed using cactus extract.[35,36]

Anti-oxidant properties

Natural antioxidants have received a lot of attention lately due to their connection to health benefits provision.[37] Fruits and vegetables are potential sources of natural antioxidants. It creates various antioxidant molecules to combat reactive oxygen species (ROS).[38] There are several types of activated oxygen, or ROS, including free radicals like superoxide anion radicals (O_2), hydroxyl radicals (-OH), and nonfree radical species like H_2O_2 and single oxygen.[39] According to Cano et al. (2017), the antioxidant activity of prickly pear is on par with that of red oranges and grapes. Its biological benefits may result from the combined action of betalains (tyrosine-derived pigments), flavonoids, and other physiologically active ingredients.[40]

Table 5: The distribution and amino acid composition of OFI fruit juice [30,63]

Amino acid	Structure	Molecular formula	Content in g/100g
Alanine		$C_3H_7NO_2$	3.17
Arginine		$C_6H_{14}N_4O_2$	1.11
Asparagine		$C_4H_8N_2O_3$	1.51
Asparaginic acid		$C_4H_7NO_4$	Trace
Glutamic acid		$C_5H_9NO_4$	2.40
Glutamine		$C_5H_{10}N_2O_3$	12.59
Cystine		$C_6H_{12}N_2O_4S_2$	0.41
Histidine		$C_6H_9N_3O_2$	1.64
Isoleucine		$C_6H_{13}NO_2$	1.13

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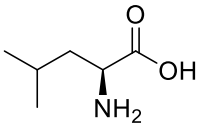
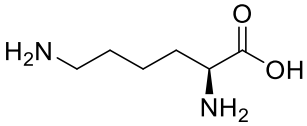
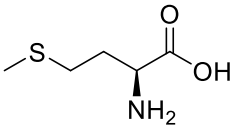
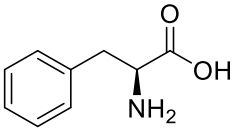
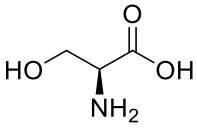
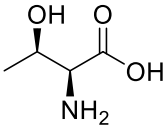
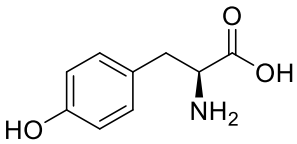
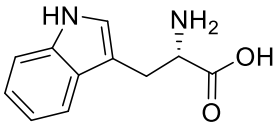
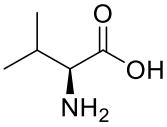
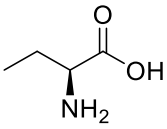
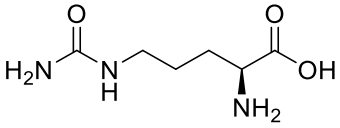
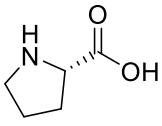
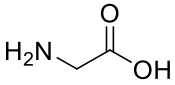
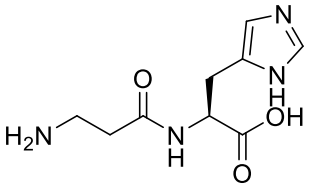
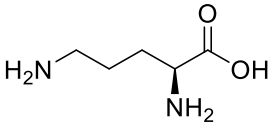
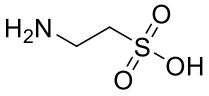
Leucine		$C_6H_{13}NO_2$	0.75
Lysine		$C_6H_{14}N_2O_2$	0.63
Methionine		$C_5H_{11}NO_2S$	2.01
Phenylalanine		$C_9H_{11}NO_2$	0.85
Serine		$C_3H_7NO_3$	6.34
Threonine		$C_4H_9NO_3$	0.48
Tyrosine		$C_9H_{11}NO_3$	0.45
Tryptophane		$C_{11}H_{12}N_2O_2$	0.46
Valine		$C_5H_{11}NO_2$	1.43
α-Aminobutyric acid		$C_4H_9NO_2$	0.04
Citrulline		$C_6H_{13}N_3O_3$	0.59
Proline		$C_5H_9NO_2$	46.00
Glycine		$C_2H_5NO_2$	Trace

Carnosine		$C_9H_{14}N_4O_3$	0.21
Ornithine		$C_5H_{12}N_2O_2$	Trace
Taurine		$C_2H_7NO_3S$	15.79

Anti-inflammatory effect

The juice of OFI was investigated as a possible source of natural antioxidant and anti-inflammatory compounds against intestinal inflammation. Flavonoids-rich concentration derived from cactus pear juice has been shown to alter intestinal oxidative stress indicators and inflammatory mediators, indicating that it might be a promising natural component for attenuating and preventing chronic intestinal inflammation.[41] Another study found that a cactus pear diet reduced pro-inflammatory indicators including tumor necrosis factor and erythrocyte sedimentation rate while increasing anti-inflammatory markers. Furthermore, the diet reduced the proportion of pro-inflammatory biomarkers to anti-inflammatory biomarkers. Cactus pear supplementation increased cutaneous carotenoids, which are an indicator of the body's antioxidant level. Because of the present modulation of both inflammatory indicators and antioxidant balance, OFI fruit is a special and useful component that should be added to existing healthy dietary habits.[42]

Antimicrobial activities

OFI fruits were tested for antimicrobial action against harmful organisms in humans suchs as *Enterococcus faecalis* ATCC 29212, *Staphylococcus aureus* ATCC 6538, *Pseudomonas aeruginosa* ATCC 10145, and *Escherichia coli* NRLL B-3008 using a broth microdilution technique. The minimal non-reproductive concentrations were identified, with 500 g/mL inhibiting *S. aureus* the most effectively.[43] In addition, [44] discovered that various OFI cultivars might be employed for its antibacterial or antioxidant qualities against *Clostridium perfringens*, *Vibrio cholera, and Campylobacter jejuni* to prevent or regulate food contamination. The antimicrobial properties of ethanolic, methanolic, and aqueous extracts of OFI against *Vibrio cholerae* were also examined, the most effective extract is the methanolic one.[45] OFI extract disrupts membranes, as a result, membrane permeability increases and pH and ATP levels drop significantly.

Safety

Toxicology

The toxicity of prickly pear cactus is not well researched. However, a toxicity study of OFI seed oil was performed in 8-week-old Mus musculus rats weighing 20-30g each. The results indicate that the high values of the lethal oral and intraperitoneal doses of OFI fixed oils indicate their low acute toxicity.[46]

In Korea, to treat constipation, *Opuntia ficus-indica var. saboten* (OFIS) is frequently utilized although its safety is unknown. As a result, a study was carried out to assess the genotoxicity and recurrent oral toxicity of OFIS extract (OE). Experiments were done on female and male white *Sprague Dawley* rats that were given OE orally for a week at doses of 0, 500, 1000, and 2000 mg/kg per day. The findings revealed that OE did not affect the regular behavior of the rats, resulting in increased body weight as well as food and water consumption as compared to the conventional controls. The ophthalmic test revealed no harmful effects, and the hematological and serum biochemical results, together with the organ weight and urinalysis parameters, were similar to those shown in the normal control group. As a result of the findings in this study, OE may be regarded as a trustworthy and safe herbal medication or dietary supplement.[47]

Interactions

Several clinical trials on the application of cactus fruit have been studied. It has been shown that juice from the whole fruit of Sicilian OFI reduces liver damage in rats. In addition, it suppressed ovarian tumor growth in naked mice. In Korea, a methanol extract from the whole dried fruit of OFI is used to protect against perioperative global ischemic injury. This finding may indicate that OFI extract can help reduce excitatory neuronal damage brought on by global ischemia.[48]

In another study, the hypoglycemic effect and *in vitro* pancreatic lipase inhibitory activity of OFI extract were tested in rats. The results showed that OFI extract containing polyphenolic compounds could prevent hypercholesterolemia by inhibiting the enzymatic function of pancreatic lipase responsible for fatty acid hydrolysis. Thus, the total cholesterol level in the blood also decreases. This is the basis for using OFI extract to develop a hypoglycemic agent or functional food for people with high cholesterol levels.[49] Besides, OFI extract also can remove reactive oxygen species *in vitro* and enhance antioxidant capacity in human plasma. The current research shows that the *in vitro* and *in vivo* antioxidants in OFI can remove H_2O_2, •OH, O_2•−, ONOO−, and HOCl *in vitro* tests. Polyphenols and vitamin C were shown to have antioxidant action. Even though OFI extract was used to achieve these findings, they also showed an increase in antioxidant activity *in vivo* in the blood of subjects consuming them. Thus, cacti can be regarded as a food with antioxidant activity and employed as a tactic to lessen problems associated with diseases.[50]

Future research

The cactus fruit has a lot of potential and promise for the future. In the food industry, yellow-orange and purple prickly pear varieties are used as a source of red-violet and yellow-orange pigments, instead of synthetic colorants, for food coloring and functional properties.[51] In a recent study,[52] cladode mucilage, microparticles of yellow-orange prickly pear cactus pulp, and maltodextrin were utilized as an additional food coloring for yogurt.

Furthermore, mucilage derived from the peel of OFI fruits is used as a byproduct with possible health advantages. It was used as the material for the wall of anthocyanin microencapsulation of blueberry from Colombia (*Vaccinium meridionale Sw.*) using a spray drying procedure, demonstrating great oxidation and thermal durability and a smooth, crack-free surface.[53] Mucilage extracted from OFI cladodes and aloe leaves were also incorporated as wall material in the microencapsulation of pink guava carotenoid (*Psidium guajava*) by spray drying method.[54] This type of microcapsules is proposed as a promising alternative that combines natural colorants with high antioxidant capacity and fiber content in the production of cosmetics as well as new functional products.

In addition, OFI is also used as an edible film in food preservation with value-added functions. Fruit that has been harvested is prone to rotting, losing nutrients, and becoming brown during storage. Researchers are

currently developing bioactive edible cactus mucilage films to improve quality and prolong fruit shelf life[55] combined this mucilage and the probiotic strain *Enterococcus faecium* FM11-2 to create an edible film to preserve freshly cut apple slices.[55] Another study also used cactus fruit mucilage as a coating on loquat fruit. The obtained results showed a significant effect of mucilage coating on the preservation of quality, nutritional value, and sensorial parameters and showed significantly lower microbial growth compared to uncoated loquat fruits during cold storage. [56,57] Furthermore, edible coatings made from OFI cladodes and chitosan were used to assess the quality and antioxidant capability of cherries during storage.[57]

Conclusion

Cactus fruits have been used in many semi-arid areas of the world for food and animal feed due to their low water requirements compared to more traditional crops. They have high nutritional content and can help improve health and prevent some diseases. Besides being consumed as food, prickly pear cactus can also be processed into pharmaceuticals and cosmetics, contributing to diversifying products and increasing the commercial value of prickly pear cactus. Recently, cacti have also been focused on research on their ability to inhibit cancer cells and exploit them for application as potential functional foods for health.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

Acknowledgments

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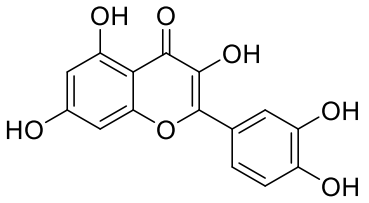
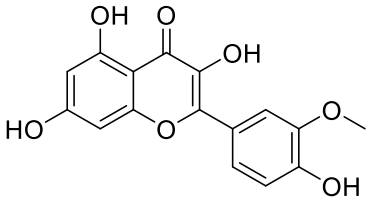
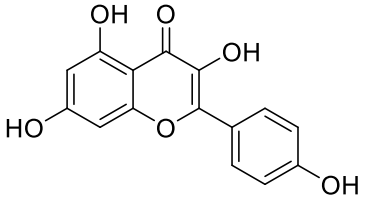
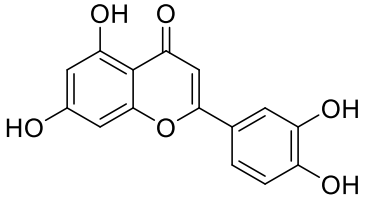
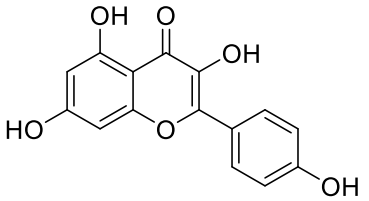
Table 6: The distribution and contents of phenols and flavonoids in the pulp and skin fruits of OFI

Plant tissue	Main component identified	Structure	Molecular formula	Content in mg/100g
Pulp	Total phenolic acid	-	-	218.8
	Quercetin		$C_{15}H_{10}O_7$	9
	Isorhamnetin		$C_{16}H_{12}O_7$	4.94
	Kaempferol		$C_{15}H_{10}O_6$	0.78
	Luteolin		$C_{15}H_{10}O_6$	0.84
	Kaempferol	-	-	2.7
	Isorhamnetin glycosides	-	-	50.6
	Total phenolic acid	-	-	45.7
	Total Flavonoid	-	-	6.95
Skin fruits	Kaempferol		$C_{15}H_{10}O_6$	0.22

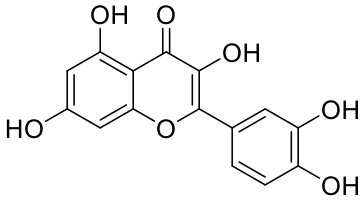
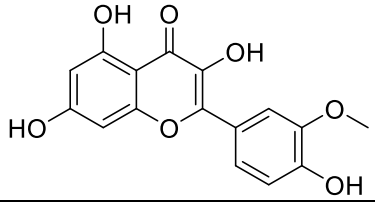
Quercetin		$C_{15}H_{10}O_7$	4.32
Isorhamnetin		$C_{16}H_{12}O_7$	2.41-91

Table 7: The distribution and contents of vitamins in the pulp from OFI fruit

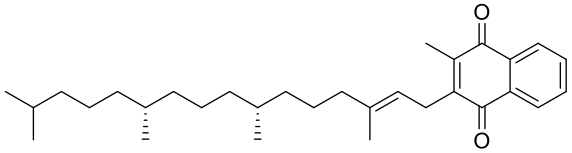
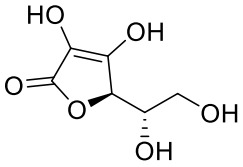
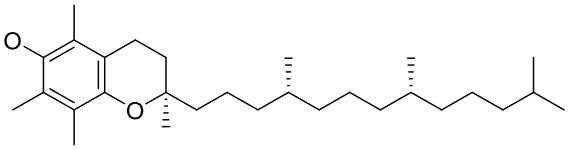
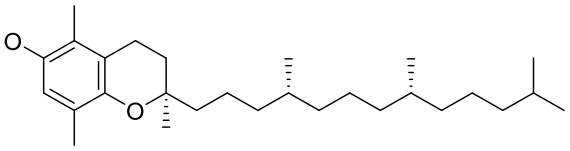
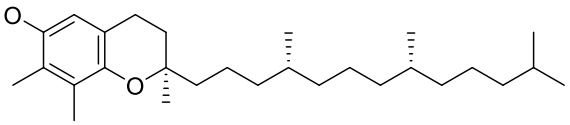
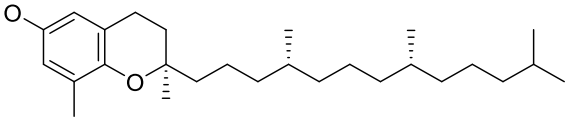
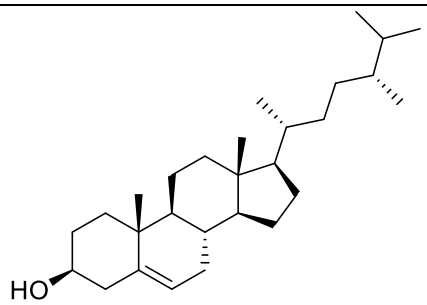
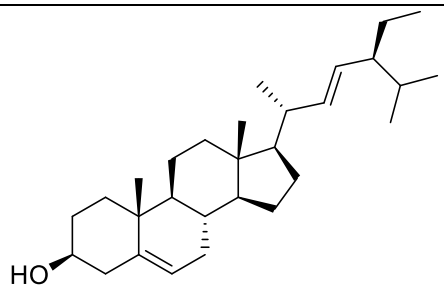
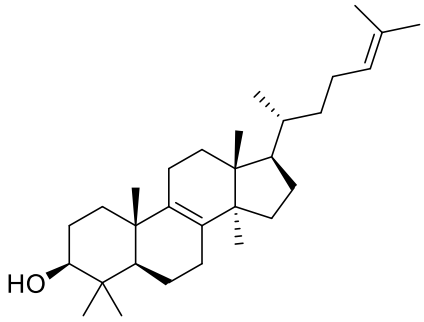
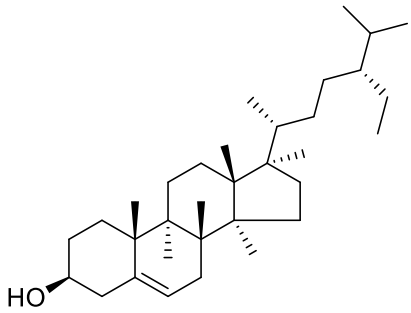
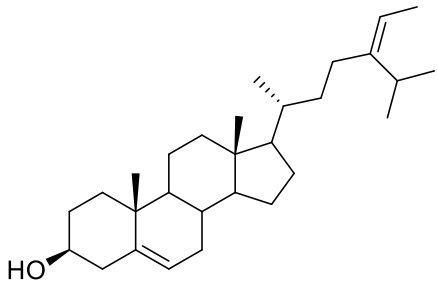
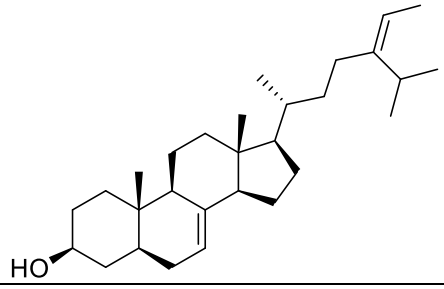
Vitamin	Structure	Molecular formula	Content in mg/100g
Vitamin K1		$C_{31}H_{46}O_2$	53.2
Vitamin C		$C_6H_8O_6$	34-40
α-Tocopherol		$C_{29}H_{50}O_2$	84.9
β-Tocopherol		$C_{28}H_{48}O_2$	12.6
γ-Tocopherol		$C_{28}H_{48}O_2$	7.9
σ-Tocopherol		$C_{27}H_{46}O_2$	422
Total vitamin E	-	-	527.4

Table 8: The distribution and ceontents of sterols in the pulp of the OFI fruit [64,65]

Sterol	Structure	Molecular formula	Content in g/kg
Campesterol		$C_{28}H_{48}O$	8.74

Stigmasterol		$C_{29}H_{48}O$	0.73
Lanosterol		$C_{30}H_{50}O$	0.76
β-Sitosterol		$C_{29}H_{50}O$	11.2
Δ5-Avenasterol		$C_{29}H_{48}O$	1.43
Δ7-Avenasterol		$C_{29}H_{48}O$	1.43

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