

Opuntia ficus-indica as Nutritious Food Ingredient; Prevalence for Therapeutic Specialty

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ABSTRACT

Background: It is predicted that the world's population, specifically in arid and semi-arid regions, usually with complications such as water scarcity, climate change, soil erosion, and wind erosion, is facing food insecurity issue. Moreover, the outbreak of several diseases is further a burden on the people living in such areas. The growth of improved crop varieties which is compatible with agro-climatic conditions of the site such as *Opuntia ficus-indica* is the ray of hope. Multipurpose native crops like *Opuntia ficus-indica* is cultivated owing to its drought tolerant ability and growth in different ranges of the environment. Furthermore, it has natural components that can not only be served as food but also the therapeutic ability for numerous diseases.

Objectives: The purpose of this review is concerning global issues such as food insecurity, malnutrition and their solution through natural products i.e. nutraceuticals. The target is to find one of the numerous approaches that can be adapted to focus on dealing with such problems.

Methodology: *Opuntia ficus-indica* has various nutraceutical uses that had been utilized in past but can further be accommodated for commercial utilization and public benefit. In this review, the therapeutic aspects of *Opuntia ficus-indica* have been elaborated with the utilization of its components to fight different diseases. Different studies from various scientists published in the form of research/review articles have been overviewed proving its physico-chemical elements to be beneficial in this aspect.

Results: *Opuntia ficus-indica* is not only a source of food but also has exponential components that serve as nutraceuticals including phytochemicals such as phenolics, vitamin C, flavonoids, betalains, and carotenoids. These components impart diverse beneficial effects on health and act as anti-ulcerogenic, anti-carcinogenic, antioxidant, hepatoprotective, anti-atherogenic, and immunomodulator.

Conclusion: *Opuntia ficus-indica* is a miracle of nature that has been bestowed upon us to reduce the risk of many calamities. It can not only be served as food but also imparts beneficial effects on health that not only reduces the chances of getting sick but also helps in alleviating the drastic effects of disease exposure.

Keywords

Antioxidant, Apoptosis, Hepatotoxicity, Fortified, Extract.

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INTRODUCTION

Cacti (singular Cactus) have unique and unusual properties that are adaptive to extremely hot and arid/semi-arid environments. They show a variety of functional and structural characteristics which make them

more interesting like water conservation and drought tolerance capabilities. As for drought tolerance ability, it comes from the phenomenon of CO₂ fixation capacity (CAM). Moreover, its leaves have the shape of spines,

while the stem is transformed into the succulent structure containing chlorophyll¹. Commonly, it is native to North America, Venezuela, Bolivia, South Africa, Argentina, Jordan, Israel, and West Indies, but now it is commonly growing in India, Italy, Spain, Mexico, Northern Africa, and the USA where they are now a significant part of people's dietary needs. It can be found in range of the environment from the dessert area below sea level to high altitude areas such as mountains of Peru². The genus *Opuntia* has approximately 300 different species which produces edible fruit varieties but the most important of these are *Opuntia ficus indica*, *Opuntia robusta*, *Opuntia streptocantha*, *O. amyclaea*, *Opuntia megacantha*, *O. hiptiacantha*, and *Opuntia ficus indica* (L) Mill. In different countries, a cactus pear is cultivated for different purposes e.g. to ensure food security (control the wind, water, and soil erosion, utilize as forage and as fence), use in the food processing industry (natural colorant, juice, jam, vinegar, flour, and food supplement), as a pharmaceutical product (essential oils, herbal extracts, in medicine), and in cosmetic industry (seed oil, soap, and shampoo)³.

Opuntia ficus-indica (L.) Mill., common name: prickly pear/nopal cactus, family: *Cactaceae* (dicotyledonous angiosperm) is an important cactus species in agriculture of non-irrigated lands due to its utility in food, fodder, dye, source of energy, ecosystem remediation, and prevention of soil erosion⁴. It is also recognized as "fruit for the poor", "treasure under spines", "future plant", "scared plant" and "monster tree" and these names depict its significance in human life⁵. The largest producer of *Opuntia ficus-indica* species in Mexico with 72000hectare (ha) area under fruit cultivation and 10,500 for nopalitos. In Brazil, North African countries (Morocco, Egypt, Tunisia, Algeria, and Libya) Italy, and Chile, the area under cultivation is 40000ha, 16000ha, 2500ha and 1100ha respectively^{6,7}. Without any technical involvements, the crop is produced in two seasons per year i.e. February-April and July-September with the covered area of 934.4ha in Chile. Among African Countries i.e. Algeria, Ethiopia, Morocco, South Africa, Tunisia where *Opuntia* species are grown, Ethiopia is the largest producer of cactus pear with the covered area of 360,000ha. The major purposes of its cultivation are fencing, delicious fruit, essential oil, pharmaceutical products, food products, cosmetics,

livestock feed, and forage⁸. It is a cheap source of food i.e., nopal/cladodes and prickly pear, fodder, and ornamental use. Cladodes are used as salads. Prickly pear is an elongated and fleshy berry having different sizes, color, and shape which can be consumed in the fresh, dried, and preserved form such as syrups, jams and candy-like products⁹. In most of the West Asian countries, the cactus is established for food and feed production, also utilized as hedges around the houses for enhancing aesthetic value. The modern cactus pear production in Australia is very small around 200ha and most established in the home gardens. Among the European countries, Italy is famous for its appreciation of *Opuntia ficus-indica* and it was recognized as "bread for poor" and also being used as an emergency fodder. Portugal has also promoted the production of cactus pear and planned to plant on more than 500ha which was before 200ha and also made the plan to engage the unemployed persons².

Opuntia ficus-indica contains 92% moisture in addition to 4-6% total fiber and 1-2% protein¹⁰. It is of great nutritional profile having high sugars i.e., glucose, fructose, and sucrose, other macronutrients like protein, lipid, ash, fiber, and minerals. Moreover, there is an increased amount of free amino acids including glutamine, proline, serin, methionine, arginine, aminobutyric acid, and histidine. There is considerable amount of bioactive compounds available in *Opuntia ficus-indica* for example ascorbic acid, carotenoids, and taurine^{11,12}. It is known to have pigments and molecules which are usable in nutritive and medicinal aspects that make it among the list of functional foods¹³. These pigments can be classified according to the chromophore structure such as chromophores with conjugated systems i.e. carotenoids, caramel, betalains, lakes, and synthetic pigments, and metal coordinated porphyrins such as chlorophyll and myoglobin. The amount of bioactive compounds in the pulp of cactus pear varies with the variety and place of growth¹⁴.

THERAPEUTIC PROPERTIES

Anti-oxidant Activity

The oxidation process in the body is the stimulant of various diseases. Polyphenols present in *Opuntia ficus-indica* possesses anti-oxidant activity which is divided into flavonoids, stilbenes, phenolic acids, and lignin &

suberin. Through the interaction of flavonoids with carbohydrates, lipids, and proteins, the oxidation process is inhibited¹⁵. According to Slimen¹⁴, the mechanisms behind the antioxidant activities of polyphenols are given in Fig 1.

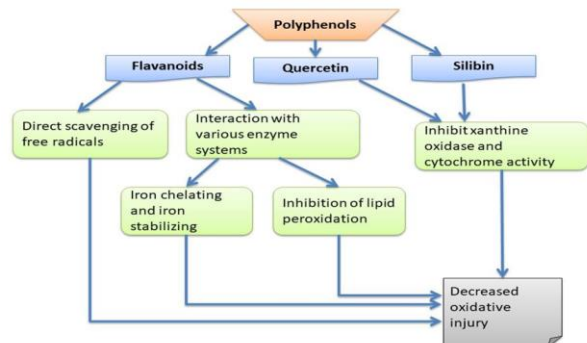


Fig 1. Polyphenols of *Opuntia ficus-indica*: flavonoids, quercetin and silibin working as antioxidants. (Slimen *et al.*, 2016).

Moreover, Betalains also plays a vital role in antioxidant properties owing to their hydroxyl, imino, and tetrahydropyridine groups. Betalains are pigments present in the vacuole in the form of betalamic acid which condenses and convert into betacyanins (violet color) and betaxanthins (yellow color). In *Opuntia ficus-indica* these are present in pulp and peel. In the pulp fruit, betanin, betanidin, neobetainin, isobetainin, and indicaxanthin are detected¹⁶. While in the peel portion, betanin and indicaxanthin are present. The two pigments betanin and indicaxanthin have the ability to donate their electrons that help in the inhibition of lipid peroxidation and heme disintegration. Betanin is more effective in the radical scavenging process rather than indicaxanthin¹⁷. Betanidin is another potent antioxidant that acts against nitric acid and peroxy radical and has additive interaction with α -tocopherol^{18,19}. Yahia & Mondragon-Jacobo⁷ have concluded during their study that tocopherols and carotenoids are not responsible for the antioxidant activity but phenolic compounds, betalains, and vitamin C are the ones to carry out the antioxidant property. During experimental studies, it has been observed that *Opuntia ficus-indica* is effective for a decrease in lipid oxidation and an increased amount of antioxidant i.e. reduction in glutathione. This ultimately results in improving the erythrocyte's redox potential. Hence, 500g of prickly pear supplement on daily basis is effective for lowering the

oxidative stress in a healthy person within two weeks²⁰. Similarly, Siriwardhana²¹ also showed that *Opuntia ficus-indica* (whole fruit) extract has the potential effect as an antioxidant which helped in 60% decrease in impaired lymphocytes DNA. Hence, the utilization of prickly pear and its products are effective in free radical's reduction that leads to alleviation in the development of chronic ailments.

Anti-inflammatory and Anti-thrombogenic Properties

The flavonoids present in *Opuntia ficus-indica* helps in the prevention of inflammation. The mechanism behind this is that they inhibit arachidonic acid metabolism which results in anti-thrombogenic and anti-inflammatory characteristics¹⁴. Moreover, isorhamnetin glycosides flavonoids namely isorhamnetin-3-O-glucosyl-rhamnoside (IGR) and isorhamnetin-3-O-glucosyl-rhamnosyl-rhamnoside (IGRR) regulates anti-inflammatory activities by inhibition of the NF κ -B activation and the COX-2 (Cyclooxygenase-2) gene expression with suppressing the TNF- α production as well. Antunes-Ricardo²² has done the study using alkaline extraction and purification through semi-preparative chromatography of *Opuntia ficus-indica* and the results suggest that it significantly affects COX-2 and decreased secretion of cytokines and nitric oxide thus exhibiting the anti-inflammatory properties (Fig 2).

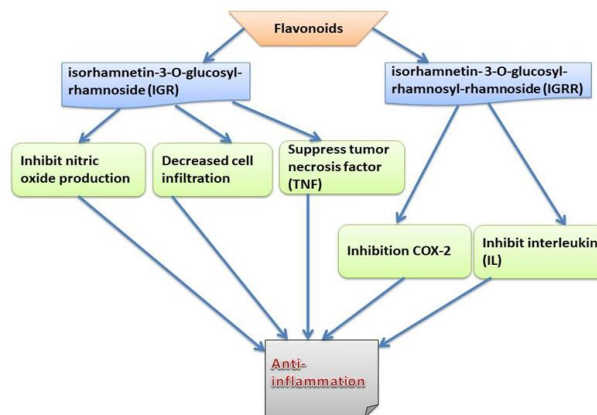


Fig 2. Flavonoids exhibiting anti-inflammation characteristics in the human body. (Antunes-ricardo *et al.*, 2015).

Tesoriere²³ observed that indicaxanthin from cactus pear (*Opuntia ficus-indica* L. Mill) fruit prevents eryptosis (programmed cell death of erythrocytes) induced by oxysterols. Eryptotic erythrocytes may contribute to

thrombotic complications; as if phosphatidylserine (PS) is exposed to the surface of eryptotic cells may activate coagulant enzymes which can cause thrombosis and thrombo-occlusive disease. Further, it will also attach to the endothelial cells and can cause vascular damage. This problem can be prevented by cactus pear (*Opuntia ficus-indica*) fruit because polyphenol such as betalamic acid and indicaxanthin obtained from it have the reducing potential and amphipathic in nature, interacts with membranes, enters various cells, including erythrocytes and counteracts oxidative damage induced by various events such as the presence of reactive oxygen species (ROS), the release of prostaglandin (PGE2), the opening of prostaglandin dependent calcium channels and exposure of phosphatidylserine (PS). The indicaxanthin of prickly pear fruit in the concentration range of (1.0-5.0mm) can eliminate the PS externalization and cell shrinkage.

Anti-carcinogenic and Anti-ulcerogenic Characteristics

Opuntia ficus-indica also possesses chemo-preventive activity. It was found effective against the inhibition of cancerous cells. Zou²⁴ has studied the effect of prickly pear extract on tumor cell growth²⁴. He made a comparison of the effects of prickly pear extract and retinoid N-(4-hydroxipernil) retinamide (4-HPR) on cancer cells of cervical, bladder, and ovary. The results showed that there is an obvious increase in cellular apoptosis and inhibition in cancerous cells development (Fig 3).

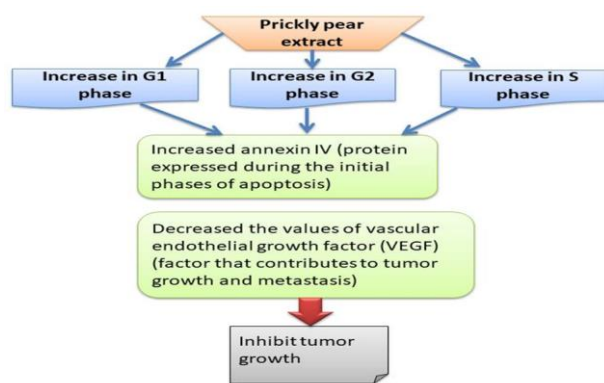


Fig 3. Prickly pear’s extract working in tumor growth prevention. (Zou *et al.*, 2005).

Furthermore, betanin extract from *Opuntia ficus-indica* is also beneficial in terms of cellular apoptosis induction. In myeloid leukemia, betalains impose inhibitory action on

the cellular growth²⁵. Gastric mucous is a protective layer of gastric cells but if any damage occurs to it, it results in the impairment of cells and many problems such as ulcers, gastritis, and cancer take place. Nonetheless, antioxidants present in the *Opuntia ficus-indica* have the ability to prevent such problems to arise. Galati²⁶ has studied anti-ulcerogenic effect of *Opuntia ficus-indica* during a trial on wistar mice. Moreover, the mechanism behind such activity is demonstrated by Jiménez-Aguilar²⁷ that is shown in Fig 4.

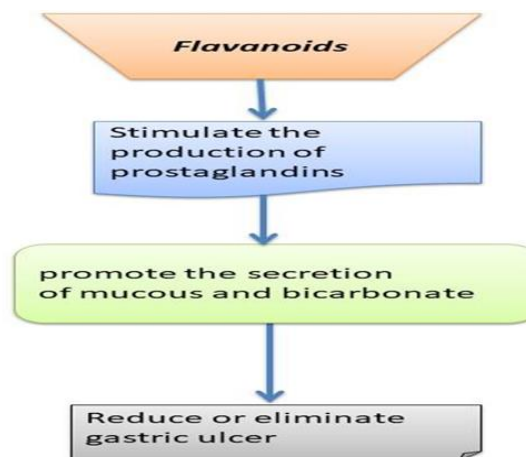


Fig 4. Flavonoids bioactivity in gastric ulcer reduction. (Aguilar *et al.*, 2014).

Another study based on the lyophilized cactus pear fruit juice reported that it has certain constituents that work against the stress-induced gastric lesions particularly betanins and *Opuntia ficus-indica* var. saboten fruit juice and maltodextrin (OFSM). It was proven that it is effective against the prevention of gastric lesions and gastric mucosal tumor (TNF-a factor)²⁸ (Fig 5).

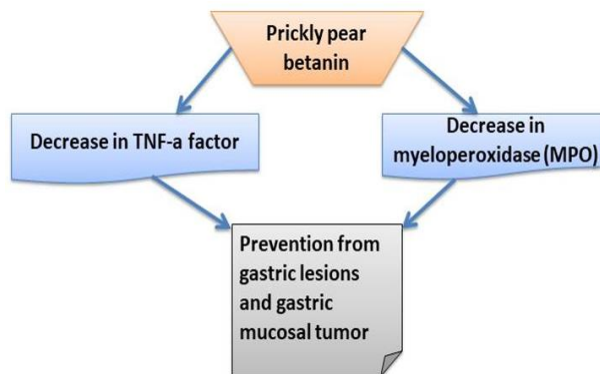


Fig 5. Betanin bioactivity to prevent tumor growth. (Kim *et al.*, 2012).

Immunomodulatory Activity

Human body defence system has the ability to fight the disease causing factors and prevent the body, but there are some causalities like an autoimmune disease where the immune system starts to act against the body organs and tissues for example psoriasis, atopic dermatitis, Type I diabetes and rheumatoid arthritis. Aires²⁹ has conducted the study to find the solution to such a problem and results showed that *Opuntia ficus-indica* has immunomodulatory effects which are attained by minimizing Jurkat T cell multiplication (Fig 6).

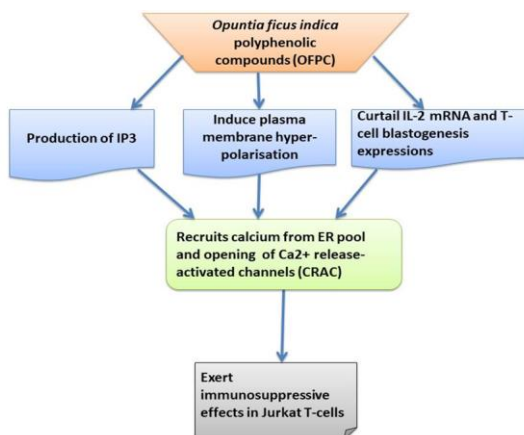


Fig 6. Pathway of polyphenolic compounds of *Opuntia ficus-indica* acting as immunity boosters. (Aires *et al.*, 2004).

Hepatoprotection

Liver is a fundamental human body organ as its major role is to detoxify, bile excretion, protein and fat metabolism, and storage of carbohydrates and vitamins. *Opuntia ficus-indica* has proven to be effective for the protection and cure of liver functionality. Galati³⁰ has worked on the *Opuntia ficus-indica* fruit juice for its evaluation of protective working against carbon tetrachloride (CCl₄) induced hepatotoxicity and found that injury caused by CCl₄ was cured in 72hrs. Similarly, Djerrou³¹ find out that CCl₄ induced hepatotoxicity, can be cured by using aqueous extract of *Opuntia ficus-indica*. In the results, it was prominent that there was a raised value of aspartate ammonia transferase and alanine ammonia transferase in the groups intoxicated with CCl₄ dose which indicate *Opuntia ficus-indica* aqueous extract's hepatoprotective capability.

Cellular Membrane Protection

Cladodes of *Opuntia ficus-indica* are identified for having three carotenoids including β -carotene, lutein, and α -cryptoxanthin. The highest content of carotenoids was detected in orange color cultivars. While in the case of young cladodes the values fall in 0.047 to 0.077mg/100g range and for fruits, the concentration varies between 1.77mg/100g and 2.65mg/100g. The peeling part contains 2.97mg/100g of carotenoids³². Carotenes and xanthophylls like zeaxanthin, cryptoxanthin, s-carotene, lycopene, and α -carotene are potential singlet oxygen (¹O₂) and peroxy radical quenchers. They scavenge the peroxy radical and make them stabilized in the form of carbon-centered radical. Moreover, they possess lipophilic properties. Both of these characteristics make them vital for the protection from oxidative impairment of cellular membranes and lipoproteins¹⁴. Cactus pear was used in traditional medicine for their cicatrisant activity. The cladodes of *Opuntia ficus-indica* have carbohydrate polymers such as a mixture of mucilage and pectin. The results showed that its cladodes, particularly pectic polysaccharide has the crypto-protection phenomenon by breaking the epithelial cell, increased mucus production, and enhance the number of secretory cells. Ulcer healing is either through regeneration or migration of cells which results in thickening the mucus membrane³³.

Gastrointestinal Tract

Recently, cactus cladodes are considered as fiber source for human consumption as its powder contains 43% fiber including 28.5% of insoluble fiber. Soluble fibers can impose potential health benefits as they stabilize the intestinal food transit. Moreover, insoluble fibers such as hemicellulose, cellulose, and lignin are beneficial for microbiota, water retention, bile acid absorption, and ionic exchange¹⁴. Sánchez-Tapia³⁴ has checked the prebiotic effect of Nopal (*Opuntia ficus-indica*) and the results of the study suggest that more consumption of high fat and high sugar food, enhance the chances to get affected with the conditions such as obesity, gut dysbiosis, inflammation, and gut barrier disruption. The reason is the disturbance in the balance of gut microbiota. Nopal is a rich source of dietary fibers, vitamin C, and polyphenols which are effective in the reduction of obesity by

regulating the gut micro-biome and prevent metabolic endotoxemia.

Blood Glucose and Cholesterol

Opuntia ficus-indica cladodes have soluble fibers including gums, pectin, mucilage, and hemicellulose that help in the lowering of cholesterol level and glycemic index in humans¹⁴. Polysaccharides, alkaloids, neobetanin, indicaxanthin, and flavonoids extracted from cladodes are capable with special effects of antidiabetic and antiglycation³⁵. The redox imbalance is one of the main factors leading to the induction of a genetic basis for diabetes³⁶. Berraouan³⁷ suggested that *Opuntia ficus-indica* seed oil have a high amount of polyunsaturated components and antioxidant compounds which are useful against the diabetes mellitus (DM) as it increased the survival rate by 78% against the diabetes mellitus. According to Milán-Noris³⁸ prickly pear is the fruit which is enriched with many phytosterols, betalains, phenolic acids, and flavonoid. Especially, its peel has many bioactive compounds which can be extracted and used as a functional ingredient. His observation proved that the prickly pear peel is enriched with total phytosterols (65.65±1.5mg/g) such as, sitosterol (76.6%), campesterol (19.5%), and stigmasterol (3.9%) which show the strong hypocholesterolemic effect. Also, it contains the highest phenolic content which will produce a synergistic effect also.

Benign Prostatic Hypertrophy

The prostate is a part of the mammalian male reproductive organ which contributes to secretions. It surrounds the bladder and proximal portion of the urethra. Usually, these glandular muscles enlarge and press the urethra which causes hindrance in urination. *Opuntia ficus-indica* is thought to cure such complications especially the decoction made from the flowers of cactus pear. In North Africa, the flowers of *Opuntia* combined with barley seeds and corn-silk is used to treat urine obstruction. During a study on clinical trials of its 250mg capsules by Palevitch³⁹, results have shown that patients got relief from the symptoms of obstruction during urination and there was no change in urino-dynamics and kidney functions of the patients. Moreover, flowers of *Opuntia ficus-indica* are also effective in the cure of benign prostatic hypertrophy⁴⁰.

Wound Healing

Traditionally, *Opuntia ficus-indica* cladodes were used to promote wound healing through the formation of a scar. An ointment prepared by using 15% lyophilized cladodes has shown that it produces more organized tissue reconstruction, fibroblast and fibers will arrange in derma properly and piliferous bulbs will recover in 5 days⁴¹. For wound healing, it is mandatory to keep the area well hydrated. So, *Opuntia ficus-indica* oil stimulates the scarring process by the development of epithelium over the granulation muscle and prevents the wound from dehydration as well⁴².

USES AS FOOD

Opuntia ficus-indica has found its place in a variety of products to utilize in daily routine. This was possible due to its contents that are beneficial for health and also its production is easy and adaptive to the environment. The young tender stem is called “nopalitos” which are used in diverse dishes including salads, soups, snacks, pickled and desserts⁴³. Indigenous people utilize the nopal cactus seed extract in tea, juice, jam, or consume as dry or fresh fruits. Moreover, peeled and sliced pads are dried and called as leather britches that help add texture and fibrous material in soups and stews³⁵. The cactus pear pulp with effective natural colors is utilized for the preparation of additive-free i.e. artificial color/flavor toppings⁴⁴. It is used in the fortification purpose to make high quality products with high contents of phenolics and antioxidants such as stirred yogurt⁴⁵. The fruit wine is also obtained by the blend of *Opuntia ficus-indica* and *Lantana camara*⁴⁶. Furthermore, Cactus pear peel extraction can be successfully used in the substitution of wheat flour biscuits⁴⁷. Its pulp is also utilized in the production of fortified rice milk product⁴⁸. In the Southwestern United States, cactus pear is commonly added to the omelets which are very famous over there.

NUTRACEUTICAL USES

NeOpuntia prepared by Bio Serae Laboratories is an innovative functional food product that is made of dehydrated leaves of *Opuntia ficus-indica* containing soluble and insoluble fibers. This product is effective against lipid metabolism disorder and has hypolipidemic characteristics¹. Furthermore, cactus preparation is also

proved to be useful for the prevention of alcohol addiction⁴⁹. Traditionally, phytochemical rich products were prepared from *Opuntia ficus-indica* extracts for herbal medicines³⁵. Pharmacopeia, traditional medicine of sub-Saharan is prepared from cactus. Its flowers are effective anti-hemorrhoid medicine while fruits and flowers are antidiarrheal and anti-ulcerogenic mediators. Its cladode sap is the remedy for whooping cough. It involves heating the pads and places it on the chest of the patient which helps in relieving the congestion⁵⁰. Alcoholic extracts of *Opuntia ficus-indica* is used as an antiviral, hypoglycemic, and anti-inflammatory. Similarly, it has been a part of traditional medicine and curative for various ailments like catarrhal gastritis, hyperlipidemia, edema, burns, wounds, and obesity in different countries⁵¹. *Opuntia ficus-indica* cladodes were used by Sicilian folk as cicatrizant (promote the healing through the formation of the scar)⁴¹. Dehydrated nopal of cactus pear has also served in the nutraceutical market as dietary supplements for having high nutritional value⁵². Not only the extract of cactus pear is helpful in the remedy of high blood sugar level, but also the cooked form plays a significant role in lowering the blood sugar level. It may be due to the presence of high fiber content as pectin absorbs sugar and supports the body in slow release of sugar throughout the day. Similarly, the stem portion of this plant is found to be useful in use for traditional medicine for edema and indigestion⁵³. Tea made from the pad has been utilized for the cure of lung diseases⁵⁴. Moreover, it is a traditional cure for various ailments like diuretic action, gastritis, antiulcer activity, arteriosclerosis, antioxidant property, diabetes, cartilage alteration protection, and hyperglycemia⁵⁵. A process known as Chinese medicine is the "moxibustion". In this process, plant material is burned on the skin to cure the infection and irritation. Likewise, the Lakota tribe prepares tea from prickly pear that is found to be helpful in childbirth¹³. *Opuntia ficus-indica* has been utilized as a treatment for the ailments such as bronchial asthma, diabetes, abdominal ache, indigestion, and burns in South Korea⁵⁶.

OTHER USES

Extract of *Opuntia ficus-indica* cladodes is found to be useful in the reduction of salt stress in the agriculture sector^{57,58}. It is also utilized as cattle fodder which imparts

quality characteristics in milk. In addition, to enhance the flavor and color of the milk, it also brings nominal changes in the medium and longchain fatty acids in milk profile⁵⁹. Oil extracted from prickly pear seeds are utilized in cosmetics as well³⁵. Biogas is an essential energy source in the rural and agricultural areas. Cactus pear cladodes are served for the production of biogas as it has a high potential of biomass production². The cactus pear (both spiny and spineless) was utilized as ruminant feed in Zimbabwe which was imported from South Africa⁶⁰. The juice prepared by nopal is used as a hair massage which results in soft and shiny hair. *Opuntia ficus-indica* is utilized in the formation of moisturizers for skin⁵⁵. For many centuries in Mexico, it was utilized in the formation of waterproof paints that are used to paint houses, churches, and marking of property lines. Moreover, it is also useful as a protective barrier against predators. In Central Africa, its juice is proved to be nominal mosquito repellent. It has its ornamental use as well due to its attractive colors and desert landscape. The gum obtained from cactus is usually used for stiffening the clothes. It is also a good source of dye. Additionally, essential oils obtained from its flowers and seeds are consumed as perfumes and oils¹³.

CONCLUSION

In this modern era, industrialization has made everything possible and we get many alternates of natural products. there are some natural elements have also proven to be effective as well. Global food insecurity, natural resources shortcomings and increase in population are the issues that have already targeted our globe but will become drastic in the future. To avoid such a situation, we need to find the solutions within nature. *Opuntia ficus-indica* is a natural product that can grow without many natural resources consumption. Moreover, it is proven that it has therapeutic effects for various diseases. Hence, it can become one of the major nutraceutical product in near future owing to its marvelous physical and chemical characteristics.

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None.

LIST OF ABBREVIATIONS

CAM	Crassulacean acid metabolism (Carbon Fixation Pathway)
CCl ₄	Carbon tetrachloride
COX-2	Cyclooxygenase-2
DM	Diabetes mellitus
ha	Hectare
hrs	Hours
IGR	Isorhamnetin-3-O-Glucosyl-Rhamnoside
IGRR	Isorhamnetin-3-O-Glucosyl-Rhamnosyl-Rhamnoside
PGE2	Prostaglandin
PS	Phosphatidylserine
ROS	Reactive Oxygen Species

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