Opuntia stricta (Haw): A review on its chemical composition, putative in-vitro antidiabetic mechanism of action and potential pharmacological uses in chronic disease

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DOI: https://doi.org/10.22271/phyto.2022.v11.i2a.14359

Abstract

Opuntia species, which belong to the Cactaceae family, are well-known and have long been utilized in folk medicine. Scholars have been interested in the stems, fruits, and cladodes of Opuntia species in recent years because of their possible nutraceutical content and therapeutic properties. While Opuntia stricta (O. stricta) is a well-known Cactaceae family member, it is a relatively unknown herbal plant in Zambia, where it is viewed primarily as a flower and only a few local people use it as a complementary herbal medicine to manage chronic illnesses such as diabetes mellitus. Much is not known about its chemical composition and putative in-vitro antidiabetic pharmacological action. Therefore, this review provided experimental data regarding chemical composition, in-vitro pharmacological mechanism, and potential indications of O. stricta in the prevention and management of various chronic conditions.

Keywords: Opuntia stricta, antidiabetic mechanism, potential pharmacological

Introduction

Opuntia species (sp) (Cactaceae) are well-known and important, and are widely utilized in diverse indigenous systems of medicine to treat a variety of disorders such as asthma, inflammatory diseases, ulcers, and diabetes [1, 2]. The genus Opuntia contains about 200 species, mostly shrubby to low-growing clump-forming plants with flattened jointed stem segments called "pads" or "cladodes" that are usually covered with little prickly glochids with bigger spines every now and then [2, 3]. The majority of Opuntia species are native to North, Central, and South America, but they have also been introduced to Kenya, South Africa, Yemen, Ethiopia, and Madagascar [4-6].

The surge in demand for nutraceuticals has prompted further research into the chemical makeup and nutritional benefits of natural plants like Opuntia species [7]. The stem, fruit, and cladode of Opuntia species have been shown to contain significant levels of vital nutrients like antioxidants, betalains, and amino including taurine, vitamins, and minerals [6, 7].

Scientific, alternative and English names of Opuntia stricta

The scientific name for O. stricta is Opuntia stricta (Haw.) and it is also known by other alternative names (synonyms) like Cactus dillenii, Cactus Opuntia var. inermis, Cactus strictus Haw, Opuntia anahuacensis Griffiths, Opuntia dillenii (Ker Gawl.) Haw, Opuntia dillenii var. tehuantepecana, Opuntia inermis (DC.) DC., Opuntia horrida Salm-Dyck ex DC. Opuntia maritima Raf, Opuntia Opuntia vulgaris var. balearica and stricta var. dillenii. Opuntia stricta is also known by the common and English names: Sweet Prickly Pear, Erect Prickly Pear, Erect Prickly-Pear, Erect Pricklypear, Common Pest Pear, Coastal PricklyPear, Common Prickly Pear, Australian Pest Pear, Araluen Pear, Coastal Prickly-Pear, Elatham Indian-Fig,Cactus, Gayndah Pear, Pest Pear Of Australia, Pest Prickly-Pear,Sour Prickly Pear, Southern Spineless Cactus, Spineless Prickly Pear and Spiny Pest Pear [10]. O. stricta is also known in vernacular. In Germany, it is known as Feigenkaktus; Spain: Chumbera, Nopal Estricto, Afrikaan: Suurturksvy; Chinese: Xiang-Ren-Zhang, Hsian-Jen-Chang, Xian-Tao, Hsian-Tʻao; Mexico: Yaaxpakan (Spanish); Portuguese: Opúntia, Palmá-De-Espinho, Palmaróía and India: Nagajemudu, Nagadali (Andhra Pradesh), Nagphana (Bengal), Chorhathalo (Gujrat), Nagphan, Chhittarthor (Himachal Pradesh), Hathhathoria, Naghhana (Hindi), Papaskalli, and Chappatigalli (Karnataka) [9].
Origin and Distribution

*O. stricta* is widely distributed around the world and is endemic to Ecuador, the United States, the Caribbean, Mexico, Colombia, and Venezuela, among other places. Some *O. stricta* species, such as *O. stricta* var. *dillenii*, are only found in the drier Caribbean Islands, while their presence on the mainland USA has been confirmed (Louisiana and Georgia). Many more nations, including Spain, South Australia, Sri Lanka, Yemen, France, Italy, South Africa, Tanzania, Kenya, Namibia, Zambia, Zimbabwe, and Ethiopia, have been introduced to *O. stricta*. It has swiftly naturalized and grown invasive in several countries. *O. stricta* has been reported in significant invasions in Australia, South Africa, and Namibia [2, 6, 11].

Taxonomic classification and description

*O. stricta* var. *stricta* and *O. stricta* var. *dillenii* are the two varieties (or sub-species) of *Opuntia stricta* Haworth that are now widely considered as a single species [5, 10]. Plants are spreading or erect succulent shrubs with many branches that reach a height of 1-2 m and shallow fibrous roots. The stems are green to bluish-green, with a succession of flattened cladodes that are around 30 cm long by 15 cm wide and commonly 7-15 cm wide, as illustrated in figure 1. The cladodes’ border appears scalloped between elevated areoles from which strong, somewhat curved yellowish spines emerge, ranging in number from completely missing to groups of one or more or clusters [5]. The spine clusters in *O. stricta* var. *dillenii* are yellow and small, measuring about 2-5 mm long. The vivid yellow blooms, which resemble those of a cactus, bloom during the summer months. With yellowish inner tepals, filaments, anthers, and style and stigma lobes, the flowers are about 6-8 cm across [10]. *O. stricta* Haworth is most recognized by its barrel-shaped skin and red to purplish fruit, which is typically 4-6 cm long and 2-3 cm wide, as illustrated in figure 2. Except for a few glochids lodged in the little areoles, its outer surface is smooth and spineless. Seeds with a diameter of 4-5mm are embedded in a purple-colored pulp. The pulp has a sour flavor and approximately 60 hard-coated seeds [6, 10].

Chemical Composition of Cladodes

*Opuntia* species have a high nutritional value, owing to their mineral, vitamin, dietary fiber, and phytochemical content [13, 14]. The cladodes of *O. stricta* include essential oils, dietary fibers, antioxidants, carbohydrates, different flavonoids, vitamins, free radical scavengers, and certain phytochemicals, according to the body of knowledge [14, 15]. The chemical composition of cladodes is currently known to be affected by harvest season, maturity stage, postharvest treatment type of species, and environmental circumstances [8, 16]. According to one study, medium-aged cladodes of *Opuntia ficus indica* contained more total saponins, phytosterols, and indigestible fiber than younger and older cladodes, while young cladodes contained the most hydrolyzable and condensed tannins [8]. Cladodes of *Opuntia* species have been found to be a good source of dietary fibers [14, 17], which have been associated to lowering blood glucose levels by binding to dietary lipids and boosting excretion [18, 19]. The calcium (Ca) content of *Opuntia* cladodes has also been reported to be higher than that of vegetables, fruits, and nuts [20, 21]. Vitamin A, E, and C levels of *O. stricta* cladode per 100g of dry extract were 711.2 mg, 231.4 mg, and 2.9 mg, respectively, according to one study [15].
### Table 1: Some chemical composition and their pharmacological properties of *Opuntia stricta* cladodes [15]

| Name            | Structure | Pharmacological action                     |
|-----------------|-----------|--------------------------------------------|
| Alpha-ocimene   | ![Alpha-ocimene Structure](image)         | Anti-inflammatory                          |
| Alpha-Pinene    | ![Alpha-Pinene Structure](image)         | Antineoplastic, anti-inflammatory. Antioxidant |
| beta-Phellandrene | ![beta-Phellandrene Structure](image) | Antineoplastic, anti-inflammatory. Antioxidant |
| Sylvestrene     | ![Sylvestrene Structure](image)          | *                                           |
| Linalool oxide  | ![Linalool oxide Structure](image)       | Antineoplastic, anti-inflammatory. antioxidant |
| Cycloheptane    | ![Cycloheptane Structure](image)         | *                                           |
| Terpinolene     | ![Terpinolene Structure](image)          | Antineoplastic, anti-inflammatory. Antioxidant |
| beta-Ionone     | ![beta-Ionone Structure](image)          | Antineoplastic, anti-inflammatory. Antioxidant |
| delta-Amorphene | ![delta-Amorphene Structure](image)      | Antineoplastic, anti-inflammatory           |

*Pharmacological action not reported at the time of the study*

### Chemical Composition of Fruits

The fruit of *O. stricta* is one of the edible portions of the plant. Protein, calcium, nitrogen, moisture, energy, fat, copper, iron, magnesium, zinc, sodium, phosphorus, niacin, and vitamin are among the nutrients found in **Stricta fruit** [10, 22]. The nutritional value of *O. stricta* fruit per 100g was also recorded in one study. Proteins, oil, fiber, and carotenoids were found in larger concentrations in the seeds than in the
pulp and peal [22, 23]. Cactus pulp is also high in ascorbic acid, phosphate, calcium, iron, salt, sucrose, glucose, and fructose, according to the study [23].

**Opuntia stricta** fruit juice was discovered to be a possible source of betacyanin pigments and could be used as a natural red-purple food colorant in one of the studies. Only betanin and isobetanin (betacyanins) were found in *O. stricta* fruits, but no betaxantins [24]. The primary components of *O. stricta* fruit peels were likewise discovered to be trans-linalool oxide, cis-linalool oxide, and linalool [25].

**Nutritive and medicinal uses**

**Nutritive properties**

The fruits of *O. stricta* are edible raw and are widely cultivated [23]. Commercially, the fruits are used to make alcoholic beverages, candies, juices, teas, and jellies. Flowers produce a good amount of honey. *O. stricta* platyclads have been used to produce candy. Betacyanin pigments are found in *Opuntia stricta* fruit juice and are utilized as a natural red-purple culinary colorant [6, 10, 26]. The young leaves of *O. stricta* are commonly used in salads and as healthy vegetables. Mock-gherkins are made from the immature fruits [26].

**Pharmacological properties of *Opuntia stricta* and other *Opuntia* species**

The body of knowledge has suggested that *Opuntia* species might be of value in the management of certain chronic diseases.

**Antidiabetic effects**

As shown in table 2, studies that have been conducted so far have shown that *Opuntia* species extract reduces blood glucose levels in diabetic induced rats [9, 23]. Therefore, these studies have supported the traditional use of *Opuntia* species in the treatment of diabetes mellitus type 2 by local people in many parts of the world [16, 27]. In one study, stems of *Opuntia ficus indica* stems reduced postprandial levels of glycemia in wistar rats and polysaccharides were identified to be responsible for the hypoglycemic effect [28]. It was also reported that the cactus acid fruit (xoconostle) that contained phenols and flavonoids bioactive compounds had inhibitory activities against alpha amylase and alpha glucosidase enzymes suitable for absorption of carbohydrates in the gastrointestinal tract (GIT) [29]. Very few studies have investigated, putative *in-vitro* antidiabetic mechanism of action of *Opuntia* species.

| Authors               | Evidence                                                                 | Mechanism of action                                      |
|-----------------------|--------------------------------------------------------------------------|----------------------------------------------------------|
| Kunyanga et al., 2014 [23] | *Opuntia stricta* cladode aqueous extract (1 mg/kg) significantly reduced blood glucose levels *in vivo* | **                                                      |
| Manzano et al., 2017 [28] | *Opuntia ficus indica* stems reduce postprandial levels of glycemia in wistar rats | **                                                      |
| Hwang et al., 2017    | *Opuntia ficus indica* showed anti diabetic activities in low-dose streptozotocin induced diabetic rats fed a high-fat diet | Inhibition of α-Glucosidase enzyme                        |
| Abdallah, 2008 [41]  | *Opuntia, dillenii* fruit juice reduced bold glucose levels on streptozotocin induced diabetic rats | Proliferation of cells of Langerhans islets might have explained hypoglycaemic activity due to antioxidant activity |
| Patel et al., 2017    | *Opuntia elatior* fruit juice reduced blood glucose levels in diabetic induced albino rats | Not conducted                                            |
| Leem et al., 2016 [27] | *Opuntia ficus indica* var. saboten significantly reduced blood glucose levels in wistar rats | inhibiting glucose absorption from the intestine and enhancing glucose uptake from insulin-sensitive muscle cells through the AMPK/p38 MAPK signalling pathway |
| Hassan et al., 2011 [33] | *Opuntia ficus indica* fruit juice possessed hypoglycaemic effects in in alloxxon-induced diabetic rats | **                                                      |
| Mokua et al., 2016    | prickly pear cactus cladode extracts lowered blood glucose levels in alloxxon induced diabetes rats | **                                                      |
| Nunez-Lopez et al., 2013 | Medium and small cladode flours of *Opuntia ficus indica* lowered postprandial blood glucose in streptozotocin-induced diabetic rats | **                                                      |
| Bournims et al., 2019 [30] | Seed oil of *Opuntia dillenii* reduced blood sugar levels in streptozotocin-induced diabetic rats [30] | **                                                      |
| Halmi et al., 2012    | *Opuntia ficus indica* cladodes aqueous extract reduced blood sugar levels in diabetes induced albino rabbits | **                                                      |

**Anti-hyperlipideamic effects**

The ability of various *Opuntia* species to minimize the risk of atherosclerotic diseases has been proven [31]. 160 dyslipidemia patients were placed into two groups in one study: a control group and an experimental group. For a month, an experimental group's diet was supplemented with 100g of *Opuntia* cactaceae. The results showed that the group receiving *Opuntia* cactaceae in their diet had considerably lower cholesterol and triglyceride levels [32]. Another study looked at the nutritional value, antioxidant activity, and effect of cactus pear (*Opuntia ficus indica*) fruit juice on biochemical parameters, enzyme activities, and lipid peroxidation in alloxxon-induced diabetic rats. Cactus pear fruit juice was also found to have hypcholesterolemic and antiatherogenic characteristics in this study [33].

**Antibacterial effects**

Moosazadeh et al. found that the essential oil of *Opuntia stricta* F. had antibacterial efficacy against standard strains of Pseudomonas aeruginosa, Bacillus cereus, Escherichia coli, Candida albicans, and Bacillus licheniformis in a fascinating study. The presence of thymol, which was identified as the primary component, was linked to the antibacterial activity, although the mechanism of action was unknown [12]. In another investigation, *Opuntia ficus-indica* cladodes were found to inhibit the growth of gram-positive bacteria and the generation of Staphylococcus aureus biofilms. There were a lot of phenolic chemicals in the cladodes, particularly p-hydroxybenzoic acid derivatives [34]. When compared to aqueous extracts of stem and fruit, methanol fruit extracts of *Opuntia ficus-indicas* cladodes displayed strong bacterial
inhibitory activity against Bacillus subtilis, Pseudomonas aeruginosa, and Escherichia coli [133].

Anti-viral effect
At concentrations of 25 g/ml and 20 g/mL, Opuntia dillenii floral extract showed potent antiviral activity against herpes simplex 1 and vaccinia [106]. The cactus plant Opuntia streptacantha was utilized in another investigation to stop intracellular virus replication and inactivate extracellular viruses. Viruses like the Equine herpes virus, pseudorabies virus, influenza virus, respiratory syncitial illness virus, HIV-1, and Herpes simplex virus Type 2 had both RNA and DNA replication inhibition [37]. Both research didn’t look into the exact mechanism of action or the active inhibitory bioactive components in the extracts of the two Opuntia species.

Anti-oxidant properties
The antioxidant capabilities of vegetables and fruits have been considered to be responsible for their beneficial health effects [32, 38, 39]. Several antioxidants have been discovered in Opuntia species, including ascorbic acid, vitamin E, betacarotene, carotenoids, betain, indoxanthin, quercetin, kaempferol, isorhamnetin, beta-Phellandrene, cysteine, reduced glutathione, and taurine [115, 33, 36]. Extracts of Opuntia stricta were shown to be high in phenolic biochemical components and to have good antioxidant activity in a recent study [13]. Another study used a 1, 1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging assay to reveal that the isolated non-polar chemicals from O. stricta fruit peels had substantial antioxidant activity [29]. Extracted polysaccharides from O. stricta fruit peels were found to have excellent antioxidant activity, and chemical analysis of the fruit peel extract revealed arabinose, mannose, galactose, galacturonic acid, rhhamnose, and glucose [40]. The antioxidant capabilities of Opuntia species have been linked to antibacterial, hypoglycemic, and anti-inflammatory effects in some studies [25, 33, 41].

Anti-inflammatory properties
Plants from the Opuntia genus have been used for generations to treat inflammatory disorders like rheumatism and asthma [15, 42]. RAW 264.7 cells were used in a South Korean investigation to investigate the anti-inflammatory effect of O. stricta cladodes. Aqueous, ethanol, and acetone extracts of O. stricta cladodes were found to have anti-inflammatory effects [15]. The pharmacological effects of ethanol extracts of the fructus and stem of Opuntia ficus-indica were investigated in another investigation. In the CMC-pouch model in rats, the results demonstrated suppression of carrageenan-induced rat paw edema as well as a substantial inhibition of leukocyte migration [43]. In a follow-up study, the anti-inflammatory activity of Opuntia elatior Mill fruits was assessed in Albino wistar rats utilizing carrageen-induced paw edema and neutrophil adhesion assays. Opuntia fruits were discovered to have anti-inflammatory activities that were dose-dependent [44].

Analgesic action
Writhing and tail-immersion tests in Albino wistar rats were used to assess the analgesic qualities of Opuntia fruit juice (OFJ). When compared to the control group, the OFJ at doses of 5, 10, and 15 ml/kg per oral inhibited the writhing responses of rats caused by intraperitoneal acetic acid administration, and at the dose of 15 ml/kg established a significant reduction in painful sensation caused by tail immersion in warm water [44]. In another study, hot plate and tail flick procedures were used to test extracts from Opuntia ficus-indica cladodes for their most popular application as an analgesic. Cladode extracts demonstrated significant analgesic effect at intraperitoneal dosages of 300, 500, and 1000 mg/kg body weight, according to the findings [45]. This data gives credence to the traditional use of Opuntia ficus-indica cladodes as an analgesic.

Antiulcerogenic effect
Antiulcerogenic abilities have been discovered in Opuntia species [13]. The juice of full Opuntia ficus indica (L.) Mill. fruits was studied in one study. Ascorbic acids, polyphenols, and flavonoids were found in the juice, according to the data. The researchers also discovered that preventing the ulcerogenic activity of ethanol in rats with the juice of Opuntia ficus indica (L.) Mill. increased mucus production and restored normal mucosal architecture using light microscopy [46].

In another study, the protective Opuntia ficus indica var. saboten fruit juice and its main constituent, betain, were evaluated against stress-induced acute gastric lesions in rats. Gastric mucosal lesions with bleeding were induced in Sprague-Dawley rats after six hours of water immersion restraint stress. The results showed that lyophilized powder that contained Opuntia. ficus indica var. saboten fruit juice, and maltodextrin, and betain at a dose of 800–1600 mg/kg considerably exerted gastro protective activity against stress-induced gastric lesions by maintaining gastric mucus [47]. In addition, the methanolic floral extract (OMFE) of Opuntia ficus indica f. inermis was tested in rats to see if it might prevent ethanol-induced stomach ulcers. The results demonstrated that pre-treatment with OMFE (250, 500, and 1000 mg/kg) protected against ethanol-induced gastric ulcers by preventing the deep necrotic lesions of the gastric epithelium in a dose-dependent manner [48].

Antispermatogenic properties
The weights of seminal vesicles, ventral prostate testes, and epididymides were significantly reduced after oral administration of Opuntia dillenii phylloclade extract at a concentration of 250 mg/kg to male rats. Rats treated with Opuntia dillenii had their spermatid production reduced by 88.06%, preleptotene spermatocytes reduced by 59.7%, spermatagonia reduced by 61.65%, and secondary spermatocytes reduced by 63.32%, according to the findings. The Opuntia dillenii phylloclade extract was found to have a 100% reduction in male rat fertility [49].

Male rats were given the methanol fruit extract of Opuntia elatior Mill orally at doses of 300 and 900 mg/kg body weight for 60 days in another study. The epididymal sperm count, blood testosterone levels, spermatogenesis, and testicular hydroxysteroid dehydrogenase activity were all used to assess fertility. Mating treated rats with normally cycling virgin females was used to test fertility, and the reversal of infertility in male rats was tested by stopping treatment for two weeks. The researchers discovered that in male rats treated for 60 days, epididymal sperm count and motility were lowered by up to 75% to 80%. The results also demonstrated that stopping the medication for two weeks resulted in infertility reversal [50].

Antineoplastic properties
Opuntia species have anticancer effects, according to the body of knowledge. Betain, which is present in most Opuntia species, is thought to cause apoptosis in K562 cells.
via the intrinsic mechanism. Betanin is thought to work by causing the release of cytochrome c from mitochondria into the cytosol and the cleavage of ADP ribose polymerase [51]. Another study used the trypan blue assay to evaluate the anticancer activities of various Opuntia ficus indica peel extracts. The results showed that chloroform and ethanol extracts caused the largest percentages of antineoplastic activity, with 96 and 83 percent, respectively [52].

Toxicology of Opuntia stricta
Opuntia species have been reported to be typically well tolerated when given orally [53]. An acute toxicity research was carried out in one of the investigations in accordance with the report obtained from Kumar et al. [54]. The mice were put into three groups of six mice each, aged 6 to 8 weeks, and fasted overnight. The control group received 33.3 ml/kg of distilled water, whereas the second and third groups received 5g/kg of mucilage suspension of Opuntia ficus-indica and O stricta. The test mice did not demonstrate any changes in behavior for 4 hours after receiving mucilage dispersions from two Opuntia species, and no death was observed after two weeks of follow-up [55]. This study, however, didn’t report the very low acute toxicity that was observed. In books of traditional folk medicines and case studies, Opuntia ficus-indica has been reported to cause headache, abdominal fullness, increased stool frequency, mild diarrhoea, nausea, and low colonic obstruction [56, 57]. Even though most people believe that herbal medicines are comparatively safe since they are “natural”, there is unusually little data to give credence to this assumption [53]. Nevertheless, there is a huge possibility that side effects may also occur because of contamination of herbal products due to heavy metals such as arsenic, copper, lead, mercury, and other undisclosed pharmaceutical ingredients added to the herbs to produce a desired effect. Microorganisms, microbial toxins, and genetic factors are among other factors that can affect the content of active biochemicals in herbal products [53, 57]. It is against that background that more investigations are launched to assess the risks and benefits of using Opuntia stricta.

Conclusion
Contemporary medicine may be available in most parts of the world for the treatment of many chronic degenerative ailments. However, most people around the world are still relying on the use of folk medicine. This review article revealed that while Opuntia species are among the most widely studied plants in the world, there is an in-depth gap in information regarding the isolation of the active ingredients responsible for the reported pharmacological properties and their postulated mechanism of action. Furthermore, there is generally insufficient data on the pharmacodynamics and pharmacokinetics of Opuntia stricta. Therefore, more studies are required to characterize the reported pharmacological properties and the safety of Opuntia species, keeping in mind that the reported pharmacological properties in different studies, both in-vitro and in-vivo, may differ as a result of the different geographical environments and species. This review also revealed that O. stricta has been domesticated in some parts of the world, a situation which may further cause the exhibition of variations in both the biochemical composition and properties.

References
1. Chauhan S, Sheth N, Jivani N, Rathod I, Shah PJ, Sri P. Biological actions of Opuntia species. 2010;1(2):146.
2. Shackleton RT, Witt AB, Pirors FM, Van Wilgen BW. Distribution and socio-ecological impacts of invasive alien cactus Opuntia stricta in eastern Africa. Biological Invasions. 2017;19(8):2427-41.
3. Novoa A, Kaplan H, Wilson JR, Richardson DMJEM. Resolving a prickly situation: Involving stakeholders in invasive cactus management in South Africa. 2016;57(5):998-1008.
4. DeFELICE MSJW. Prickly pear cactus, Opuntia spp.—a spine-tingling tale. 2004;18(3):869-77.
5. Novoa A, Le Roux JJ, Robertson MP, Wilson JR, Richardson DMJAP. Introduced and invasive cactus species: a global review. 2015, 7.
6. Pawar AV, Killedar SG, Dhuri VGJJoAR, Ideas, Technology II. Opuntia: medicinal plant. 2017;3(2):148-54.
7. Feugang JM, Konarski P, Zou D, Stintzing FC, Zou CJFB. Nutritional and medicinal use of Cactus pear (Opuntia spp.) cladodes and fruits. 2006;11(1):2574-89.
8. Figueroa-Pérez MG, Pérez-Ramírez IF, Paredes-López O, Mondragón-Jacobo C, Reynoso-Camacho RJJoFP. Phytochemical composition and in vitro analysis of nopal (O. ficus-indica) cladodes at different stages of maturity. 2018;21(1):1728-42.
9. Kalungia AC, Mataka M, Kaonga P, Bwalya AG, Prashar L, Munkombwe D. Opuntia stricta Cladode Extract Reduces Blood Glucose Levels in Alloxan-induced Diabetic Mice. 2018.
10. Lim T. Opuntia stricta. Edible Medicinal and Non-Medicinal Plants: Springer, 2012, 687-92.
11. Larsson P. Introduced Opuntia spp. in southern Madagascar: Problems and opportunities: Swedish University of Agricultural Sciences Upsalla, 2004.
12. Moosazadeh E, Akhgar MR, Kariminik AJJoB, Sciences E. Chemical composition and antimicrobial activity of Opuntia stricta F. essential oil. 2014;4(5):94-101.
13. Stintzing FC, Carle RJMn, research f. Cactus stems (Opuntia spp.): A review on their chemistry, technology, and uses. 2005;49(2):175-94.
14. Díaz MdSS, de La Rosa A-PB, Héliès-Toussaint C, Guéraud F, Nègre PB, Héliès Camacho R, Longevity C. Opuntia spp.: characterization and benefits in chronic diseases. 2017.
15. Izuegbuna O, Otunola G, Bradley GPo. Chemical composition, antioxidant, anti-inflammatory, and cytotoxic activities of Opuntia stricta cladodes. 2019, 14(1).
16. Hernández-Urbiola MI, Pérez-Torero E, Rodríguez-García MEJ, Ijoer, health p. Chemical analysis of nutritional content of prickly pads (Opuntia ficus indica) at varied ages in an organic harvest. 2011;8(5):1287-95.
17. Peña-Valdivia CB, Trejo C, Arroyo-Peña VB, Sanchez Urdaneta AB, Balois Morales RJC. Biodiversity, Diversity of unavailable polysaccharides and dietary fiber in domesticated nopalito and cactus pear fruit (Opuntia spp.). 2012;9(8):1599-610.
18. Alarcon-Aguilar FJ, Valdes-Arzate A, Santiago Xolalpa-Molina TB, Jimenez-estrada M, Hern E, Roman-ramos R. Hypoglycemic activity of two polysaccharides isolated from Opuntia ficus-indica and O. streptacantha, 2003.
19. Uebelhack R, Busch R, Alt F, Beah Z-M, Chong P. WICTR. Effects of cactus fiber on the excretion of dietary fat in healthy subjects: a double blind, randomized, placebo-controlled, crossover clinical investigation. 2014;76:39-44.

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20. Ramírez-Moreno E, Marques CD, Sánchez-Mata M, Goñi IJI-FS, Technology. In vitro calcium bioaccessibility in raw and cooked cladodes of prickly pear cactus (Opuntia ficus-indica L. Miller). 2011;44(7):1611-5.

21. Astello-García MG, Cervantes I, Nair V, del Socorro Santos-Díaz M, Reyes-Agüero A, Guérada F, et al. Chemical composition and phenolic compounds profile of cladodes from Opuntia spp. cultivars with different domestication gradient. 2015;43:119-30.

22. Miller JB, James KW, Maggiore PMA. Tables of composition of Australian Aboriginal foods: Aboriginal Studies Press. 1993.

23. Kunyangja C, Vellingiri V, Imungi KJAJoF. Agriculture, Nutrition, Development. Nutritional quality, phytochemical composition and health protective effects of an under-utilized prickly cactus fruit (Opuntia stricta Haw.) collected from Kenya. 2014;14(7):9561-77.

24. Castellar M, Obón J, Alacid M, Fernández JJJo, chemistry f. Fermentation of Opuntia stricta (Haw.) fruits for betalains concentration. 2008;56(11):4253-7.

25. Koubaa M, Krata A, Bouaziz F, et al. Solvent extract from Opuntia stricta fruit peels: Chemical composition and Biological activities. 2015, 5(2).

26. Shetty AA, Rana M, Preetham SJJoFs, technology. Cactus: a medicinal food. 2012;49(5):530-6.

27. Leem K-H, Kim M-G, Haem Y-T, Kim H. Hypoglycemic effect of Opuntia ficus-indica var. saboton is due to enhanced peripheral glucose uptake through activation of AMPK/p38 MAPK pathway. Nutrients. 2016;8(12):800.

28. Manzano PI, Pesantes OG, Sarmiento GM, Chávez-Guerranda I, Burbano ZC, Duran GM, et al. Chemical analysis and normo-glycemic effect of Opuntia ficus indica. 2017;1:19-27.

29. Medina-Pérez G, Zaldívar-Ortega AK, Cenobio-Galindo ADJ, Afanador-Barajas LN, Vieyra-Aldo Alberto R, Estevez-Duarte JA, et al. Antidiabetic Activity of Cactus Acid Fruit Extracts: Simulated Intestinal Conditions of the Inhibitory Effects on α-amylase and α-glucosidase. 2019;9(19):4066.

30. Bouhrim M, Ouassou H, Loukili EH, Ramdani M, Mekhfi H, Ziyat A, et al. Antidiabetic effect of Opuntia dillenii seed oil on streptozotocin-induced diabetic rats. 2019;9(9):381.

31. Brinker FJJJoDs. Prickly pear as food and medicine. 2009;6(4):362-76.

32. Zoraïda AS, Sánchez JML, Ayala ERg, Flores C, Domínguez EFRI, Montaño LEJJDMDC. The Effect of Complementing Opuntia Cactaceae in Normocalic Diet in Patients with Dyslipidemia. 2017;4(2):34-8.

33. Hassan F, El-Razeek A, Hassan A. Nutritional value and hypoglycemic effect of prickly cactus pear (Opuntia ficus-indica) fruit juice in alloxan-induced diabetic rats. Australian Journal of basic and applied sciences. 2011;5(10):356-77.

34. Blando F, Russo R, Negro C, De Bellis L, Frassinetti SJJA. Antimicrobial and antifilm activity against Staphylococcus aureus of Opuntia ficus-indica (L.) Mill. cladode polyphenolic extracts. 2019;8(5):117.

35. Gnanakalai K, Gopal Rijjocp R. In Vitro Antibacterial Activities of Opuntia ficus indica Stem and Fruit Extracts Using Disc Diffusion Method. 2016;8(2):68-9.

36. Jang HT, Kumar AS, Ganesh M, Peng MMJJBoP. Phytochemical, anti-oxidant, antiviral and cytotoxic evaluation of Opuntia dillenii flowers. 2014;9(3):351-5.

37. Ahmad A, Davies J, Randall S, Skinner GJAJo. Antiviral properties of extract of Opuntia streptacantha. 1996;30(2-3):75-85.

38. Tesoriere L, Fazzari M, Allegra M, Livrea MJJoA, chemistry f. Biothiols, taurine, and lipid-soluble antioxidants in the edible pulp of Sicilian cactus pear (Opuntia ficus-indica) fruits and changes of bioactive juice components upon industrial processing. 2005;53(20):7851-5.

39. Berrabah H, Taïbi K, Abderrahim LA, Boussaid MJJoFM, Characterization. Phytochemical composition and antioxidant properties of prickly pear (Opuntia ficus-indica L.) flowers from the Algerian germplasm. 2019;13(2):1166-74.

40. Koubaa M, Krata A, Barba FJ, Grimi N, Mhemdi H, Bouaziz F, et al. Water-soluble polysaccharides from Opuntia stricta Haw. Fruit peels: recovery, identification and evaluation of their antioxidant activities. 2015, 29(3).

41. Abdallah IZ. Evaluation of Hypoglycemic Activity of Opuntia dillenii Haw Fruit Juice in Streptozotocin-Induced Diabetic Rats. Egyptian Journal of Hospital Medicine. 2008, 33.

42. Allegra M, Tesoriere L, Livrea M, Janaro A, Panza E, editors. Cactus pear fruit extract exerts anti-inflammatory effects in carrageenin-induced rat pleurisy. VIII International Congress on Cactus Pear and Cochineal. 2013, 1067.

43. Park E-H, Kahng J-H, Paek E-AJAopr. Studies on the pharmacological actions of cactus: identification of its anti-inflammatory effect. 1998;21(1):30-4.

44. Chauhan SP, Sheth NR, Suhagia BNJJJoA, Medicine I. Analgesic and Antinflammatory action of Opuntia elatior Mill fruits. 2015;6(2):75.

45. Moughaddach A, El-hadi A, Taghzhouti K, Bendaou M, Hassikou RJJoP. Assessment of Opuntia ficus-indica in vivo following ethnobotanical survey: confirmation of its analgesic activity. 2018;16(S1):S191-S6.

46. Galati EM, Mondello MR, Giuffrida D, Dugo G, Miceli N, Pergolizzi S, et al. Chemical characterization and biological effects of Sicilian Opuntia ficus indica (L.) Mill. fruit juice: antioxidant and antiulcerogenic activity. 2003;51(17):4903-8.

47. Kim SH, Jeon BJ, Kim DH, Kim TI, Lee HK, Han DS, et al. Prickly pear cactus (Opuntia ficus indica var. saboten) protects against stress-induced acute gastric lesions in rats. 2012;15(11):968-73.

48. Alimi H, Hfaiedh N, Bouoni Z, Sakly M, Rhouma KBJEt, pharmacology. Evaluation of antioxidant and antioxideric activities of Opuntia ficus indica f. inermis flowers extract in rats. 2011;32(3):406-16.

49. Gupta R, Sharma R, Sharma A, Chaudhury R, Bhatnager A, Dobhal M, et al. Antispermatogenic effect and chemical investigation of Opuntia dillenii. 2002;40(6):411-5.

50. Shivabasavaya STJIJoR, Contraception, Obstetrics, Gynecology. Reversible antifertility effect of Opuntia elatior Mill. Fruit extract. 2015;4(2):393.
52. Abou-Elella FM, Ali RFMJB, Biochemistry A. Antioxidant and anticancer activities of different constituents extracted from Egyptian prickly pear Cactus (*Opuntia ficus-indica*) Peel. 2014;3(2):1.

53. Osuna-Martínez U, Reyes-Esparza J, Rodríguez-Fragoso LJOf-i. Cactus (*Opuntia ficus-indica*): A Review on its Antioxidants Properties and Potential Pharmacological Use in Chronic Diseases. Nat Prod Chem Res 2: 153. doi: 10.4172/2329-6836.1000153 Page 2 of 8 and protein (0.5-1%); other compounds are only partly known and have not been quantitatively determined [9]. The sugar moiety includes mucilaginous components containing polymers, such as chains of (1-4)-linked β-D-galacturonic acid and R (1-2)-linked L-rhamnose residues [10, 11]. The physiological role of the plant mucilage is to regulate the cellular water content during prolonged drought and to regulate the calcium fluxes of the plant [12, 13]. 2014.

54. Kumar R, Patil M, Patil SR, Paschapur MSIJJoPR. Evaluation of *Abelmoschus esculentus* mucilage as suspending agent in paracetamol suspension. 2009;1(3):658-65.

55. Gebresamuel N, Gebre-Mariam T. Comparative physicochemical characterization of the mucilages of two cactus pears (*Opuntia* spp.) obtained from Mekelle, Northern Ethiopia. 2011.

56. Kleiner O, Cohen Z, Mares AJAp. Low colonic obstruction due to *Opuntia ficus indica* seeds: the aftermath of enjoying delicious cactus fruits. 2002;91(5):606.

57. Gagnier JJ, DeMelo J, Boon H, Rochon P, Bombardier CJTAjom. Quality of reporting of randomized controlled trials of herbal medicine interventions. 2006;119(9):800. e1-, e11.