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Review Article

Chemical Composition of Prickly Pads from (*Opuntia ficus-indica* (L.) *Miller* Related to Maturity Stage and Environment

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Abstract

Cactus of the genus *Opuntia* is native to several arid regions, around the world such as Africa, Australia and in the Mediterranean. This cactus is a peculiar plant; their chemical composition, depend on the interaction with the climatic conditions and stages of maturity, their anatomy and physiology permits it survive under stress of extreme climate conditions, being an alternative harvest for regions where the availability of water is limited. Cactus prickly pads also can prevent or ameliorate the soil erosion and deforestation, because their adaptation to the water scarcity, also. The present review has been carried out to achieve and analyze the main knowledge in the implicated factors for the establishment of structural and chemical content of *Opuntia. ficus-indica (L.) Miller*. Prickly pads when fresh young are, have been consumed in Mexico and Unites States, cooking by different methods. Furthermore, the older prickly pads are frequently used as forage for livestock, especially when other fresh forage is scarce in dry station. Organic foods i.e. prickly pads, maintained without chemical substances like pesticides and insecticides treatments are alternative food sources since they contribute to human health maintenance, i.e. for prevent diabetes, and hypercholesterolemia. The Cactus offer an opportunity to carry out studies related to their environmental interactions, nutritional values. Taking benefit of the fiber content of young prickly pads or the mineral content from oldest one pads, because their fluctuations along the life cycle at extremely environmental conditions, related with the plants sense a stressful environment conditions.

INTRODUCTION

The Cactaceae are one of the most interesting plant families of the world's arid and semi-arid regions, the latter covering about 30% of the world's continental surface [1]. The prickly pads cactus (*Opuntiaficus-indica (L.)Miller*), is a vegetable also known as prickly pads, cactus pad, or cladode, native to the American Continent and is extensively distributed in Mexico in the extreme environmental conditions [2-4]. From Mexico, was propagated to other regions like the Mediterranean region and North Africa [5].

The anatomic and morphologic adaptation to arid environments have relationship with the adaptations of its roots surface which turn extended to capture the scarce rain water in these environments, the water limitations induce the formation of secondary roots than increase the surface of contact with the soil which facilitates the absorption of water and nutrients. The modified stems botanically called cladodes or prickly pads; replace the leaves and realize the photosynthesis and have a large capacity to store water, in the parenchyma allowing plants to resist long periods of drought. Additional have a protection by a cuticle thick, covered with wax or hair that prevent the loss of water [6,7].

Their peculiar adaptations to water scarcity and sun irradiation included Crassulacean acid metabolism (CAM), the reduction of leaf tissues and cuticular waxes covering the cladodes and fruit surfaces, which allow them to grow year-round and stay evergreen despite harsh environmental conditions.

Geographical distribution

The genus *Opuntia* is most widespread, presumably due to its capacity to regenerate either from root calluses, pads, fruits, tissue culture and grafting [8,9].

It can be encountered from temperate (Italy, Israel), subtropical African and American zones, Asia (China, South Korea) as well as in cold regions with winter snowfalls as in Canada and Argentina [9-11]. However, due to their remarkable genetic bulk variability, this vegetable possesses great adaptability and is found in diversity of geographic regions and habitats [12]. Around the word, *Opuntia. ficus-indica (L.) Miller* is the most important and extensive genera of cactus plants and represent a considerable economical resource [2,13]. The most common and widespread *Opuntia sp*., including more than 300 species, among which over 100 have been found in Mexico, 60 of them being endemic. The prickly pear or cactus pear, and the *CylindrOpuntia spp*. represent the main divisions of *Opuntia spp*. cactus [14,15].

Biological characterization

Cactus plant have the vegetative region, namely pads, also considered modified stems instead of classical leaves in their photosynthetic function, the outer cladode, the chlorenchyma, is crucial for its photosynthetic action, and in contrast the inner part is formed of a medullar parenchyma with the main function is for water storage. Cactus absorb water even from steam or a light rain, this permits the vegetable to take in water and store it in the parenchyma, even under adverse climatic conditions [16]. Prickly pads (cladodes) has an opaque green color, its oblong cladodes are 30–60 cm long, 20–40 cm wide and 1.9-2.8 cm thick approximately [17-20] dominances between cladodes along a branch of *Opuntia ficus-indica (L.) Miller* have a cross-sectional area equal to 22% of the area at mid cladode [21].

The *Opuntia ficus-indica (L.) Miller* is extremely efficient at converting water into biomass (Kluge and Ting, 1978). The cladode in early development present C3 metabolism, that changes to CAM [21,22]. The cladode that show CAM metabolism present changes in the content of malic acid during the day, with high values in the morning and decrease in the afternoon because this acid is accumulate in the night and in the existence of light diffuse to the cytoplasm, where is decarboxylase by the malic enzyme that depend of nicotine adenine diphosphate NADP+ and CO_2 thus ingress to Calvin cycle for the carbohydrate synthesis [23-25]. This process cause the acid fluctuation affecting the flavor, for that reasons the harvest is between 5:00 a 7:00 in the morning. This peculiar adaptation to water scarcity and sun irradiation is due to CAM metabolism. CAM is characterized by high water use efficiency and the ability to store considerable quantities of water, which help the plant to survive against severe environmental conditions [21].

The prickly pear plants are known for their flattened stems and their fruits exhibit considerable variations in form, size, structure, and color. Several studies reported a great variation in the number of fruit seeds per fruit [26-33]. This variation is observed depending on age, plant size, and the number of flowers per plant between species. For their classification studies on *Opuntia spp*. search of potential indicators are being investigated to understand genetic variability [12,34,35].

Chemical composition and fiber content

The main constituent of *O. ficus-indica* cladodes is water (80-95%), followed by small amounts of carbohydrates (3-7%), fiber (1-2%), and protein (0.5-1%); other compounds are only partly known [36-41]. Mucilage is present in the characteristic fluid secreted by cladodes and fruits and set up about 14% of the cladode dry weight. 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. (*Opuntia ficus-indica (L.) Miller* cladodes also imply a source of phytochemicals, such as phenols, flavonoids, minerals, and other nutrients, and because indicating inside in improved when vegetables are under a stressful environment conditions [42].

The bioactive antioxidant compounds that contain *Opuntia sp*ecies, includes phenolic acids, flavonoids, flavonols, carotenes, ascorbic acid, phytosterols, and chlorophyll, indicate the antioxidant properties previously reported [43-45]. Polyphenols, which have varied molecular structures, another is common constituents of plants include also stilbenes and ligands [46]. Phenols and flavonoids are bioactive compounds that have been related to restorative processes by their antimicrobial properties and abilities to reduce free radical formation and to sift free radicals [47,48].

Secondary metabolites

Secondary constituents are remaining residues in plants, their role in to ensure them survive protecting the plants of herbivorous and microorganisms damage. Secondary pathways also may participate physiological processes in the removing and storing carbon compounds, as results of photosynthesis, under nitrogen scarcity or absence of leaf growth. Wide increment in the concentration of secondary metabolites in response to the physical damage caused by insects. Secondary metabolites are established drought ontogeny, such as occurs as general rule the most protected are the vulnerable plant organs. Also, toxins are distributed indiscriminately, to protect the plants for diseases or physical dangerous. Several studies demonstrated the content of at least 14 know secondary metabolites in *Opuntia*ficus-*indica (L.) Miller* and they were extracted and identified [49-58]).

Developmental stage and chemical content

The fresh young pads also known as cladodes are an excellent source of proteins including essential amino acids, and vitamins. Several studies have reported that high levels of amino acids especially proline, taurine and serine can also be found in prickly pads [12,59-63]. Protein content is low and maintained along age, like those found of other comestible plants [64]. The chemical composition is related to environmental conditions for instance water availability, temperature, and which changes along the four seasons of the year, in example light/dark periods are mainly involved in protein synthesis. Another explanation can be because protein synthesis increasing as a cellular protection when the soil is too acid or saline [65-67].

The fat content of the powders decreased as increasing age, were perhaps associated to plant physiological variations under climatic conditions such as water availability around the cultivar. Carbohydrate content increases of old prickly pads, such as typical structure of vegetables, being their main component [65].

Fiber content depends of the age, in the case of dietary soluble fiber (pectin, gums and mucilage) a decrease from 100 until 200g of weight. In disparity, insoluble fiber (cellulose, hemi cellulose, and lignin) which increases from 200 to 250g of weight. The variation in soluble and insoluble fiber in cladode per maturation stage could influence its potential uses, improving insulin sensitivity, decreasing LDL-cholesterol levels as young [68]. Nonetheless, in the instance of mineral content there is a significant increase in calcium content as according cladode age increasing, and decrease in the typical outlines of oxalate, with a clear tendency to diminish along age. Because the oxalates [67] could limit the calcium absorption, diminish oxalate crystals related to age represent a benefit for the bioavailability of calcium. In contrast, the content of P, Mn and Zn not showed changes as maturity stage increase. The microelements the vanadium, cobalt and selenium showed no important changes related to the age were observed. Suggesting that the prickly pads powders might be a potential source for essential microelements. Further that prickly pads chemical composition depends of environmental factors such as water availability, soil properties (pH, texture and salinity), which determine the variety of cladodes content of minerals for example carbonates, chlorides, sulfates and phosphates [69,70].

The tannins which have anti nutrimental activity, findings suggest that have a role of enzyme inhibition, since they form complexes with protein and human obstruct the assimilation of this macronutrient [71]. Studies was demonstrated an increase according age enlarge and identified a higher content of tannins in the older prickly pads 500-550 g of weight. The tannins have little relevance in the human diet and are mainly found in coffee, tea and some fruit [72]. In this regard, has established that a high concentration of these ant nutrimental substances in food can give tan astringent palate, in addition also being a chelating agent and sequestrate heavy metals, consequently serves for prevent or diminish the presence of toxic substances [72]. However, old prickly pads have the benefit for their antioxidant activity, supporting the benefits for include prickly pads in the diet per maturity stage according the feeding requirement at each human phase of living cycle.

The chemical and mineral compositions of several maturity stages in the prickly pads (*Opuntiaficus-indica (L.) Miller*) changes per age. The mineral content of prickly pads for their high calcium availability is at old maturity stage (135 days-age). Findings suggests that older prickly pads products can be a good source of calcium for human nutrition as an alternative of dairy products and in people with lactose intolerance [66,68]. Being the old prickly pads recommended for the health benefit associated to the calcium requirements and the young prickly pads due to their insoluble fiber content, associated with hypoglycemic properties or diminishes circulating cholesterol.

The prickly pads products, in example, the prickly pads powders are an exceptional form for preserve and storage because their scarcity in humidity inhibits the growth of dangerous microorganisms to conserve the pads powders as a healthy food [73]. Results from previous research report where compare the compound diverse in dry process versus fresh samples, showed that total flavonoid content was preserved at more 80% of that of the fresh sample after drying at 45°C. Although total flavonols were affected by the dehydration process, approximately 25% of their original content remained after convective drying at 45°C. Among the three flavonols studied, isorhamnetin was found at the highest concentrations, followed by kaempferol and finally quercetin. Ascorbic acid was the bioactive compound that was most severely affected by the dehydration process, with more than 80% of the original content being lost during dehydration, while for carotenes the loss was about 50%.

Respect to the dry prickly pads product, an exhaustive study report that a drying method preserve the nutrimental values [73]. Because *Opuntia* cladodes contain several nutritional mineral elements, the dry prickly pads represent an alternative source for elaboration of prickly pads foods because diminish at minimum the humidity; this procedure take the advantage for prevents the proliferation of microorganisms and keep the powder inalterable.

The cactus as a natural resource

Prickly pad played a vital ecological role to diminish the soil erosion, considering the portion of arid or semi-arid land it is suitable for cultivating these species that require little water, can understand their ecological importance. With the high degree of environmental disturbance, the Cactus can be a potential alternative to capture part of the increase in CO_2 because the peculiar acidic metabolism. The increasing changes of the CO_2 related to the growing deforestation which effects on the world's major ecosystems cactus can establish themselves successfully in damaged lands [74-79].

The plant is used as a vegetable for human consumption and as forage and for prickly pear (fruit) production. The high season for harvesting *Opuntia* cactus fruits are variables per the environmental condition being specific for each continent.

Medical applications

In Mexico, prickly pads have been part of the human and animal diets for centuries, being consumed as salad at different stages of from 24 to 48 days (60 to 150g, respectively) but mainly as fresh that corresponds to the first stage of development less than 32 days of harvest (100g weight) maturation [65].

Prickly pads are also used in traditional medicine to treat several diseases condition due to their hypoglycemic properties in the diabetes, reduce weight on obesity and diminish the cholesterol levels [77,78,80]. Prickly pads also content nutrimental substances with dairy diet values such as vitamins and several minerals. The cactus pear reportedly shows medicinal properties, including antiulcer, anti-inflammatory, diuretic, cardiac, and diabetic effects [3,81].For nutritional deficiencies associated to degenerative disease are currently widespread in countries of low economy and developing ones, attention should be focused on alternative economical options of regional food resources. Returning to customs of the precedent cultures, combined with the global tendency on the habits of feeding and thus to improve food, respecting at all times their habits and cultural trends. Prickly pads powders can be an alternative for their low-slung cost, and can be used on powders as dietary supplement in all seasons, taking advantage of the better harvest station and storage when the scarcity coming. The dried prickly pads signified several advantages for their management, transport and storage for long periods and ensure supreme nutritional values [82]. Many chronic and degenerative diseases (cancer, hypertension, obesity, cardiovascular diseases) are related to ordinary nutritional disorders [83]. Scientific studies support the importance of bioactive compounds in the diet namely functional foods for their additional health benefits to the individual. Additionally, the isolated β-sitosterol as an active anti-inflammatory principle from the pads extracts [84]. Their elevated content of pectin and fibers can improve peristaltic motility, which in turn can help to the adjustment of cholesterol and glucose plasma ranks [12,85].Functional foods are defined as those which, additionally to nutritive components, small amounts of other compound that give additional benefits to human health. Fiber and antioxidants are some complexes included in functional foods; prickly pads accomplish with both, being better products in dehydrated form. Functional and organic foods that have additional benefit for health are desired for human diet instead off other cultivated foods concerning their exposure for agricultural chemical products [77,86]. Prickly pads are good option for people with hyperglycemic for their benefits for ameliorating the health damage effects of inadequate nutritional habits. For prevent and cure nutrition-related diseases synchronized team effort is required, that includes the health care professionals and patient for ameliorate or resolve the health problem.

Environmental adaptability, utilization and production

Livestock in semi-arid and arid regions is strongly affected by droughts and irregularities in rainfall, causing low forage availability, which generates that farmers use foods of high cost that increases the costs of production. The products and derivative products (Table 1) from cacti are an alternative resource to these regions due to its high efficiency in the use of water (Torres-Sales, 2010). Succulence cactus *Opuntiaficus-indica (L.) Miller* maintains photosynthetic activity five months once the rains cease [87] and it has been noted that the proportion of biomass with limited soil moisture is significantly increased [88]. These crops adequately managed through traditional or intensive farming technologies are transformed into source of good quality forage to low-cost and water, allowing affordability in livestock production systems. In a study findings permits establishes that the method of use of cactus cladodes for livestock differs depending on the circumstances, such as the available workers, facilities and availability of the material [89]. While the cladodes *in-situ* grazing is the best place, is not recommended and must take care for over use of place grazing and cultivar fields. The most common practice is to cut and eat in-situ, but another method implied the cladodes can be silage and utilize when it is necessary, being more economical to store the cladodes for their posterior use when scarcity of grazing occurs [90] emphasized that cacti are important elements in the structure and the dynamics of the ecosystems of the semi-desert areas and its disappearance involves a process of biological poverty, soil erosion causing loss of useful resources for human benefits. There are areas where the soils are inadequate for traditional farming, but the climate conditions are appropriate, if soil contamination can be eliminated, the production of cactus is possible, using resources for ameliorate the soil composition [91].

Table 1: Food products and sub products from pear fruit and cladodes of Prickly pads [92,93].

Pears fruit	Cladodes
Juices and Nectars	Juices
Marmalades	Pickles and brine
Gels	Marmalades
Jellies	Jellies
Fruit and dried blades	Flours
Sweeteners	Liquors
Alcohols, wines and Vinegars	Candy
Canned fruit	Sauces
Frozen fruit and pulp	Dietary fiber
Pigments	Salads (young Prickly pads)
Forage pulp (peel and seeds)	Mucilage (insoluble fiber)
	Pigments
	Roasted for cattle forage

CONCLUSION AND PERSPECTIVES

The prickly pads present metabolic adaptation, for the desert environmental conditions with excesses environmental conditions, such as hot and dry climates, warm around all year, and extremely hot in the summer. The desert climate is associated to low pluvial precipitation, being the environment drastic for the plants. There are little plants adapted to the hard desert condition, the cactus plants have special adaptations for survive in dry conditions, being the main vegetable resources in these ecosystems.

The importance for include the prickly pads in the dairy diet are mainly by their high content of dietary fiber. Drying process are excellent alternative methods, It is should be possible to use young prickly pads in powders instead of other vegetables as fiber sources, can be prepared in uncommon manner, candied cladodes and jams could be consumed [94]. However, the demand for tender young prickly pads is limited to Mexican populations [95]consumed as salads and other cooking forms. However, an increasing demand is observed in other countries, considered an exotic food [95]. Also, exists the possibility to introduce these products to several countries to stimulate their inclusion in the diet for their nutritional values, due to their considerable content of fiber and minerals. The refined analytical studies and inventive of new technologies, will offers new ways for processing and encourage the use of cactus, their fruits and flowers as food, medicine, cosmetic, and pharmaceutic products, also for support farmers to remediate the soil erosion [79]. Although much research still needs to be done, concerted actions of biologist, and agriculture engineers, nutritionists and pharmacologists will help discover and understand the using potential of the *Opuntia* cactus. The growing location and time of harvest, maturity date are basics for validation of analytical and pharmacological studies. The precise plant portions used in the extraction and processing conditions need to be accurately documented to allow proper data evaluation.

The globalization of markets offers new opportunities for development of the field especially to underutilized resources in some countries, such as cacti, due to that in each country, cultivar models are different. Climate change is creating new dynamics in those models that can be sustainable or disruptive and the cacti ensure in certain aspects alternatives for the sustainability.

New possibilities are being explored in the expansion of the potential of cacti benefits. In some cases, aimed at a better use and productivity, the conservation of the environment and the genetic diversity, and in others, the studies and practices are aimed at giving added value. In General, the information contributes to sustainable development in the regions. These strategies can be followed by public and health professionals, alimentary legislation, food processers for safe that correct nutrimental information be included in the food tagging. Only transnational researches will be adept of manifest their significance and the underlying interactions environmental factors such as diet and healthy life style [91]. Efforts for ameliorate or prevent health damage can be followed by the professionals of health care, government representatives, the nutrition experts and food superiors to conduce the human populations to adequate food election. In addition to involve patients in training, to drive appropriately in their health care's. Only wide multifaceted efforts will be capable of give the directions for conduce to adequate feeding selection, and together promote the improvement of food choice. Future studies are necessary to obtain data about nutrimental values of prickly pads along the four-year stations, to rationalize their uses collecting the prickly pads during the year station which represent the better nutritional value taking advantage the dry processes for storage the powder or elaborated products. These data also can help to select the phases of prickly pads maturity, per the health problem that is intended to resolve, so much for humans as cattle.

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