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Review

Nutritional pharmacological and toxicological characteristics of pitaya (*Hylocereus undatus*): A review of the literature

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Studies on the cacti of the genera, Hylocereus Tropical and Subtropical America are scarce. Cultivation and consumption of different species and varieties of pitaya (*Hylocereus undatus*) may represent a source of diversified agricultural activity since these species contain rich bioactive compounds that add a rustic beauty to the cultivation of the fruit in addition to the benefits they bring to the health of the population. The functional attributes assigned to this fruit, prompt the need to study its physical, chemical, nutritional, pharmacological and toxicological characteristics. The objective of this study was to review the literature on the pitaya, investigating the relationship between post-harvest production, technological and pharmaceutical applications, in addition to nutritional properties, and the chemical components that are beneficial and toxic to health. Hence, a literature search at the PubMed and SciELO Medicine® sites, with descriptors "Hylocereus" and "pitaya" was held. Recent studies on the bioactive compounds in pulp and peel, antioxidant activity and the relationship between use and health were mainly selected, based on *in vivo* studies. Based on the articles studied, observation showed that the intake of bioactive compounds present in pitaya boosts immunity in individuals, thus inducing better health and improving physical and mental performance. However, additional research is necessary to obtain consistent and reliable data to explore unrestricted use by the food, pharmaceutical and cosmetic industry.

Key words: Cactaceous, pitaya, *Hylocereus undatus*.

INTRODUCTION

Brazil is the world's third largest fruit producer, ranked behind China and India (Duarte, 2013). According to Kist (2012), the estimated Brazilian production in 2011 involved 20 species of fruit at 42,101 million tons. However, Brazil's potential for fruit farming is even greater due to a large land area and good weather

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conditions, which favor the planting of species of tropical, subtropical and temperate climate as well as special situations that allow year round production.

Fruit consumption in Brazil, according to the Ministry of Agriculture, was 125 kg per person/year^{-1} in 2009. In some European and North American countries, average fruit consumption ranges between 140 and 150 kg per person/year^{-1}, respectively. Although, Brazilian data are far from desirable, a growing awareness of the health benefits provided by the regular intake of fruits has portrayed an increasing demand for fresh fruits (Brazil, 2011).

Introducing fruits in daily dietary practices has made room for different, even exotic fruit species with distinctive flavor and interesting mineral, fiber and antioxidant contents. Among the various options of exotic fruit species with good prospects for commercialization, is the pitaya (also known as dragon fruit), a native cactaceae fruit from the tropical forests of Central and South America, India and Malaysia, (Canto, 1993; Nerd and Mizrahi, 1997).

Pitaya (*Hylocereus undatus*) is among the lesser-known tropical fruits, but has high economic potential in domestic and foreign markets, which justifies intensifying research aimed primarily at obtaining basic information on farmer cultivation (Lima, 2013). In this context, the purpose of the study was to review literature on pitaya (scientific name), relating the general aspects of post-harvest production, the technological and pharmaceutical applications, in addition to the chemicals that are beneficial and toxic to human health.

MATERIALS AND METHODS

The literature review was conducted at the PubMed, SciELO Medicine® research sites with the descriptors "Hylocereus", "dragon fruit" and *"Hylocereus undatus."* Articles were selected on the cultivation of pitaya, the bioactive compounds in pulp and peel, antioxidant activity, the toxicological, as well as the pharmacological aspects and the relation between the potential use of pitaya, within the health context, through *in vivo* and *in vitro* studies.

The pitaya species

The plant that produces the fruit called pitaya (*Hylocereus undatus*), originates from tropical and Subtropical America and belongs to a group of fruit trees considered promising for farming, which are distributed in Costa Rica, Venezuela, Panama, Uruguay, Brazil, Colombia and Mexico (Canto, 1993). Until recently, this fruit was unknown and, more recently, represents a growing niche market of exotic fruits (Moreira et al., 2012).

Pitaya is a rustic fruit, which belongs to the Cactaceae family, known worldwide as "Dragon Fruit" because it presents a bright red shell with overlapping green scales covering the fruit (Jaafar et al., 2009). Plants of this family are able to tolerate extreme heat and cold in addition to dry periods and low-nutrient soils. The structure of these plants present stem modification for water storage, reduction or the absence of leaves, surfaces coated with natural waxes and nighttime stomata opening to absorb carbon dioxide (CAM metabolism), which allows the plants to tolerate the most difficult conditions (Marenco and Lopes, 2011).

Depending on the species, the fruit may take on diverse characteristics, such as size, the presence of thorns, color of pulp and skin, thus reflecting high genetic variability (Junqueira et al., 2010).

According to Le Bellec et al. (2006), the dragon fruit can be grouped into four botanical genera: *Stonecereus* Briton & Rose, *Cereus* MiLL, *Selenicereus* (A. Beger) Riccob and *Hylocereus* Briton and Rose. The variability of species is related mainly to the size and color of fruit and production time (Marques, 2010). The most common and commercialized species are: *Selenicereus megalanthus*, yellow pitaya with white flesh, known as "Colombian pitaya"; *Hylocereus polyrhzius*, pitaya with red rind and flesh; *H. undatus*, red pitaya with white pulp (Donadio, 2009). The *Selenicereus setaceus* species, also known as bush land pitaya, is commonly found in Brazil, displays thorny small fruits (Junqueira et al., 2010).

Pitaya pulp is delicate, juicy and contains numerous dark edible seeds of approximately 3 mm in diameter (Nerd and Mizrahi, 1997). From a nutritional standpoint, this fruit is considered highly nutritious, with high water content, sugars and minerals, antioxidants and low calories (Molina et al., 2009). However, the red rind pitaya has great potential to be used as natural pigment, due to the presence of betacyanin (Harivaindarn et al., 2008), in addition to the interesting antioxidant activity of this pigment (Kim et al., 2011).

PITAYA PRODUCTION IN BRAZIL

For a long time, the consumption of pitaya fruit was restricted to North American, European and Australian regions. It arrived in Brazil in the 1990s through imports from Colombia, which triggered the interest of Brazilian fruit producers (Lima, 2013).

The farming areas of this fruit in Brazil are small and located mainly in the state of São Paulo, specifically in Catanduva County. However, increased consumption of exotic fruits and their commercial value have sparked the fruit grower's interest in cultivating the fruit. In the Southeast, the fruit production occurs from December to May (Bastos et al., 2006).

According to Junqueira et al. (2010), there is no cultivar released to the market which meets the climate needs for

production. All seedlings sold in recent years do not come from selected matrices and present a large variation in production such as fruit size and shape, as well as the physicochemical characteristics, reflecting the need for cultivars that are appropriate for the bush land region of the Central Plateau.

Pitaya harvest and post-harvest conditions

Pitaya is a perennial plant that commonly grows on trees or rocks, due to abundant fibrous roots and that develops numerous adventitious roots, which assist in setting and obtaining nutrients; the cladodes are triangular, juicy, exhibiting 2 to 4 mm wide spines. The flower is large (measuring about 20 to 30 cm wide) hermaphroditic, white-colored, night-blooming flower (Canto, 1993).

The harvest usually occurs when the fruit has reached full maturity, that is, 30 to 40 days after blooming, in which the shell acquires pink to deep red coloring and a still quite-firm creamy-white pulp texture (Marques, 2010).

Post-harvest surveys show that the dragon fruit, under environmental conditions deteriorates with relative ease. As a result, the post-harvest life for commercialization is short, approximately six to eight days at room temperature (Nerd and Mizrahi, 1997). Studies by Hoa et al. (2006) show that the fruit may have a shelf life of upto ten days without any chemical treatment.

In a study conducted by lim et al. (2010), the authors demonstrated that *Salmonella* spp. could grow on freshly harvested pitaya under inadequate storage conditions, indicating that the harvest of fresh fruit could act as a potential vehicle for salmonellosis. Therefore, the study conducted by the authors suggested that fresh (minimally processed) pitaya harvests should be stored at 4°C to ensure food product safety and to extend the shelf life of recently harvested fruits.

Nutritional and pharmacological aspects of pitaya

Due to its sweet taste, the pitaya fruit, which has emerged with great potential to be used in Brazilian cuisine, can be used in jams, juices, ice cream and candy or be enjoyed *in natura* (Donadio, 2009). Its nutritional properties and pulp color make the fruit to become an attractive raw material for various types of drinks, including fermented drinks or beverages produced using enzymes (Yien Ong et al., 2012).

Further, for nutritional importance and culinary applications, pitaya can be utilized in the pharmaceutical and cosmetic industry (Molina et al., 2009). Ancient Mayas traditionally used the leaves and flowers of *H. undatus* for hypoglycemic purposes, as a diuretic and healing agent (Arquete et al., 1994). The pitaya is also used for medicinal purposes. The flowers can be ingested or used to make tea, the seeds have a laxative effect, the fruit has an effect on gastrites, the stalk and flowers are also used for kidney problems (Donadio et al., 1998). The vegetative parts of the cactus have application in the pharmaceutical industries (Stintzing et al., 2005).

Extracts from some cacti have been associated as central nervous system stimulants and regulators of blood pressure, sleep, hunger and thirst (Franco et al., 2003).

Pitaya seeds contain oil that is a mild laxative (Crane and Balerdi, 2005) capable of reducing total cholesterol and low-density cholesterol (LDL) in humans (Phebe et al., 2009). This oil has a high level of functional lipids and can be used as a new source of essential oil (Lim et al., 2010), which is comparatively superior to linseed (*Linum usitatissimum* L.) and canola oil (*Brassica napus L. var. Oleifera*) (Ariffin et al., 2009), in addition to already being heavily used as a natural colorant in the food industry (Jamilah et al., 2011; Esquivel and Ayara-Quesada, 2012). These characteristics can bring about a significant market demand for fruits considered exotic.

In a recent survey, Luo et al. (2014) identified 24 components in the carbon dioxide extract obtained by gas chromatography-mass spectrometry of the *H. polyrhizus* peel, of which 90.66% were identified; 29.77% were triterpenoids and 16.46% steroids. In the *H. polyrhizus* extract, 92.82% of the chemical compounds were identified, of which 23.39% were triterpenoids and 19.32% steroids. According to the authors, the chemical compounds found in these plants possess anti-cancer and anti-HIV activities (Patocka, 2013).

Perez et al. (2005) studied the wound healing properties of aqueous extracts from the leaves, shell, fruit pulp and flowers of *H. undatus*, and observed positive healing process effects in mice from all parts of the fruit. In diabetic animals, healing usually occurs late, and topical applications of *H. undatus* produced a significant increase in hydroxyproline, tensile strength, total protein, DNA collagen content and improved epithelialization, thus facilitating healing. In this study, however, the authors failed to observe hypoglycemic activity of *H. undatus*.

In research carried out by Wu et al. (2006), the authors evaluated the antiproliferative activity of red pitaya in melanoma cells, determining if the fruit could be considered a promising anticancer agent. The results obtained showed antiproliferative activity on B16F10 melanoma cells, revealing that the chemical compounds of pitaya peel are presented as a more potent inhibitor of cancer cell growth of B16F10 melanoma than the chemical components present in the pulp.

Anand et al. (2010) conducted a study that evaluated the *in vivo* vascular properties from the aqueous extract of *H. undatus* in diabetic rats induced by streptozotocin (STZ), and concluded that administration of pitaya extract increased protection of the aorta in these cases.

IN- VITRO AND *VIVO* STUDIES OF ANTIOXIDANT PROPERTIES OF PITAYA

Diverse research has been conducted in order to investigate the presence of compounds with antioxidant activity in pitaya fruit, but available information is scarce (Mahattanatawee et al., 2006). Studies indicate that pitaya is rich in antioxidants and betacyanin (Wybraniec and Mizrahi, 2002) and that species of the Cactaceae family are a source of betaninas, filocactinas, hilocereninas, betacyanins with 5-O-glycosides and 6-O-glycosides (Herbach et al., 2006).

Wu et al. (2006) observed in their studies that the total phenolic content of pitaya pulp and peel are similar, and the contents of flavonoids indicate that the fruit pulp and peel are rich in polyphenols and are valuable sources of antioxidants. However, in a study conducted by Gregoris et al. (2013), the authors found in four different *in vitro* methods and pitaya is an exotic fruit poor in compounds with antioxidant properties.

Kim et al. (2011) investigated the antioxidant activity of total polyphenols and flavonoids against various free radicals of pulps and peels of white pitaya and red pitaya of Korean origin. The authors found that the content of flavonoids and polyphenols in the methanolic extract of both red and white pitaya bark were approximately three to five times higher than the content of these antioxidants in the pulp of red and white pitaya, respectively. The investigators were able to identify the presence of phenolic compounds, the derivatives of hydroxycinnamic acid, glycosides, betacyanin flavonoids and their derivatives, in addition to some unknown compounds.

In a study conducted by Anand et al. (2010), the authors endeavored to evaluate the *in vivo* antioxidant properties of the aqueous extract of the *H. undatus* fruit in diabetic rats induced by streptozotocin (STZ), and concluded that administration of the this extract increased oxidative defense in such cases.

TOXICITY OF PITAYA

Toxicological studies are particularly relevant to help prove the safety of foods and ingredients, since they contribute to the identification of potential adverse effects; definition of exposure conditions required to produce these effects; evaluation of dose-response relationship for adverse effects, including the definition of doses that do not produce such effects and interpretation of experimental data for risk assessment, like information on the mode of action and its relevance to humans, as well as data on metabolism and toxicity, extending the results from animals to humans (ANVISA, 2013).

According to Hor et al. (2012), there is little information on toxicity studies related to the safe exposure of pitaya fruit. In this context, the potential toxicity of the methanolic extract from this fruit was assessed by acute and subchronic administration in rats. In the study on acute toxicity, single doses of fruit extract (1250, 2500 and 5000 mg/kg) were administered for rats by oral gavage, and animals were then monitored for 14 days. In the study of subchronic toxicity, pitaya extract was also administered orally to rats at doses of 1250, 2500 and 5000 mg/kg/day for 28 days. The authors neither observed mortality, nor signs of acute or subchronic toxicity, nor significant difference in body weight, organ weight or hematologic parameters in subchronic study. No abnormalities of internal organs were observed between the treatment and control groups, and the lethal oral extract of pitaya was determined to be higher than 5000 mg/kg, and doses with no observable adverse effects of the extract for male and female rats was considered to be 5000 mg/kg per day for 28 days.

In studies carried out by Luo et al. (2014), the authors used the MTT assay (3-(4,5-dimethylthiazol-2-yl)-2,5 diphenyltetrazolium bromide) to determine the cytotoxic activity of the supercritical carbon dioxide extract obtained by gas chromatography mass spectrometry of the *H. polyrhizus* and *H. undatus* bark in tumor cell line human prostate cancer cell line (PC3), human breast cancer cell line (Bcap-37) and human gastric cancer cell line (MGC-803). The authors used Adriamycin (ADM) as positive control and after 72 h of contact with the pitaya extracts of cells, dose-dependent inhibition of cell proliferation was observed.

FINAL CONSIDERATIONS

Pitaya farming is very important worldwide, and the fruit and its parts need to be further studied from a nutritional and bromatological quality standpoint, to be best utilized by the pharmaceutical and food industry. By offering quick economic return, since production starts in the first year after planting and, also due to its adaptive metabolic conditions where water is a limiting factor, cultivation can be indicated for areas that are not feasible for growing other fruits, which need better climate, as well as an available water supply and irrigation.

All parts of the plant can be eaten, including the cladodes, flowers and fruits, which have large amounts of functional compounds and proven medicinal properties, including hypertension control which has generated the pharmaceutical industry's interest in separating these compounds.

With respect to its antioxidant activity, research indicates a higher concentration of bioactive compounds with antioxidant properties in pitaya bark, making it more interesting from the pharmacological and nutritional standpoint. Regarding *in vivo* studies, no acute and subchronic toxicity studies in rats were observed, and results of cytotoxicity tests indicate the dose-dependent inhibition of cell proliferation through MTT test.

However, toxicological studies on pitaya are scarce,

and further research is paramount until consistent and reliable data to explore its unrestricted use by the food, pharmaceutical and cosmetic industries are available.

According to the research conducted in this study which is related to pitaya, it was observed that the functional properties of fruit help reduce the risk of chronic diseases. And that due to its hardiness, the pitaya is a potentially viable alternative also for the use of stony soils, sandy and rocky massifs which make its promising crop from agronomic and economic point of view. However, the pitaya has desirable features which allow it to be classified as a tropical fruit, still little is known, but with high potential for domestic and foreign markets. Derived food products of pitaya rarely appear on the market and research needs to be done to improve their trading opportunities.

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