Ciências Agrárias
SEMINA



DOI: 10.5433/1679-0359.2021v42n3Supl1p2023

# Nutritional quality and technological potential of pitaya species

# Qualidade nutricional e potencial tecnológico de espécies de pitaya

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## Highlights

*Hylocereus undatus* had the highest sugar content and low acidity.
*Hylocereus costaricensis* had the highest phenolic content and antioxidant capacity.
*Hylocereus megalanthus* was the only species that showed sucrose in its composition.

## Abstract

*Hylocereus costaricensis, H. undatus,* and *H. megalanthus* are pitaya species produced and marketed in Brazil. The cultivation of this fruit has increased in recent years owing to its attractive appearance and sweet taste, and it may be either consumed fresh or processed for beverages and desserts. Studies on the biochemical traits and antioxidant capacity of these species can contribute to the development of new pitaya cultivars for fresh consumption and/or industrial processing. Sugars and organic acids were extracted from fruit, separated, and quantified using a chromatographic system. Total phenolic content and antioxidant capacity were quantified by spectrophotometric analysis using the Folin-Ciocalteu assay and 2,2-diphenyl-1-picrylhydrazyl radical scavenging, respectively. The data were subjected to analysis of variance and the Tukey's test. *H. undatus* presented 9.83% of the total sugars, distributed as 4.75% glucose and 5.08% fructose. Total sugar concentration for H. megalanthus was 5.93%, with 0.99%, 3.25%, and 1.69% of glucose, fructose, and sucrose, respectively, and was the only species containing sucrose. The concentrations of organic acids for *H. costaricensis, H. undatus,* and *H. megalanthus* were 0.83%, 0.71%, and 0.62% for malic acid and 0.37%, 0.36%, and 0.40% for citric acid, respectively. Ascorbic acid (vitamin C)

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Received: May 19, 2020 - Approved: Feb. 25, 2021

was not detected in the pulp samples. *H. costaricensis* had the highest content of total phenolic content and antioxidant capacity, 33.75 mg gallic acid equivalents 100 g$^{-1}$ and 175.51 µmol Trolox equivalent antioxidant activity 100 g$^{-1}$, respectively. Thus, the consumption of *H. megalanthus* fruits is recommended for people who require carbohydrate-restricted diets, although sensorially it seems to have the sweetest pulp, probably owing to the presence of sucrose. *H. undatus* pulp is interesting for the desserts and beverages industry owing to its high sugar content and low acidity, whereas fruits of *H. costaricensis* have the highest antioxidant capacity and can be used for natural food coloring.
**Key words:** *Hylocereus undatus. Hylocereus costaricensis. Hylocereus megalanthus.* Nutritional quality. Dragon fruit.

## Resumo

As espécies *Hylocereus costaricensis, Hylocereus undatus* e *Hylocereus megalanthus* estão entre as espécies de pitayas mais produzidas e comercializadas no Brasil. O cultivo dessa fruta tem aumentado nos últimos anos devido à sua aparência atraente e sabor adocicado, podendo ser consumida *in natura* ou processada para bebidas e sobremesas. Estudos sobre as características bioquímicas e capacidade antioxidante da polpa dessas espécies podem contribuir para o desenvolvimento de novas cultivares de pitaya visando o consumo fresco e/ou processamento industrial. Os açúcares e ácidos orgânicos foram extraídos e, posteriormente, separados e quantificados em sistema cromatográfico. A quantificação do conteúdo fenólico total e da capacidade antioxidante foi realizada por análise espectrofotométrica utilizando o método de Folin-Ciocalteu e o ensaio de sequestro de radicais DPPH, respectivamente. Os dados foram submetidos ao teste F utilizando ANOVA, teste de Tukey e análise dos componentes principais. H. undatus apresentou 9,83% de açúcares totais, distribuídos na forma de 4,75% de glicose e 5,08% de frutose. A concentração total de açúcar para H. megalanthus foi de 5,93%, com 0,99, 3,25 e 1,69% para glicose, frutose e sacarose, respectivamente, sendo a única a ter sacarose. As concentrações de ácidos orgânicos para as espécies H. costaricensis, H. undatus e H. megalanthus foram: 0,83, 0,71 e 0,62% para ácido málico e 0,37, 0,36 e 0,40% para ácido cítrico, respectivamente. O ácido ascórbico (vitamina C) não foi detectado nas polpas. H. costaricensis teve o maior teor de conteúdo fenólico total e capacidade antioxidante, 33,75 mg GAE 100 g-1 e 175,51 µmol TEAC 100 g-1, respectivamente. Assim, recomenda-se o consumo de frutos da espécie H. megalanthus para as pessoas que necessitam de dietas com restrição de carboidratos, embora sensorialmente pareça ser a polpa mais doce entre elas, provavelmente devido à presença de sacarose. A polpa de H. undatus é interessante para a indústria de sobremesas e bebidas devido ao alto teor de açúcares e baixa acidez, enquanto frutos de H. costaricensis possuem alta capacidade antioxidante e podem ser utilizados como corante alimentício natural.
**Palavras-chave:** *Hylocereus undatus. Hylocereus costaricensis. Hylocereus megalanthus.* Qualidade nutricional. Fruta dragão.

Pitaya, an exotic non-climacteric fruit from South America, belongs to the family Cactaceae and is commercially available as red-skinned and red pulp (*Hylocereus costaricensis*), red-skinned and white pulp (*Hylocereus undatus*), and yellow-skinned and white pulp (*Hylocereus megalanthus*) fruits (Lima, Faleiro, Junqueira, Cohen, & Guimaraes, 2013; Lima, Faleiro, & Junqueira, 2014a).

Pitaya of *Hylocereus* grows relatively fast, reaching harvest maturation between 30 and 40 days post anthesis (Nunes et al., 2014; Pollnow, 2018), whereas *H. megalanthus* requires approximately 6 months to reach harvest maturity (Donadio, 2009). The *H. undatus* species is the 116th most commercialized product of the Companhia de Entrepostos e Armazéns Gerais de São Paulo [CEAGESP] (2019), which sold 604.16 tons of pitayas in 2017. The cities to which the CEAGESP sent the most fruit were Narandiba-SP (9.3%), Artur Nogueira-SP (7.3%), Farroupilha RS (7.2%), and Itupeva-SP (6.7%) (CEAGESP, 2019).

Even though it is widely used as fresh pulp, it has been utilized in processed form as juices, ice cream, yogurts, and mousses (Donadio, 2009; Santana, Bachiega, Morzelle, Abreu, & Souza, 2012). The fruit is also a source of bioactive compounds with antioxidant activity, such as captin which is considered a powerful cardiac tonic, in addition to other substances such as phenolic compounds, most of which have nutraceutical properties, resulting in beneficial effects on the control of gastritis and infections of the kidneys (Donadio, 2009; Lima et al., 2013; Cordeiro, Silva, Mizobutsi, Mizobutsi, & Mota, 2015).

The popularization of pitaya consumption is driven by its exotic external appearance and pulp with sweet taste and low acidity, which are the main criteria for good acceptance by consumers (Junqueira et al., 2010; Nunes et al., 2014; Fernandes, Vieites, Lima, Braga, & Amaral, 2017). Pitaya cultivation is still not widespread in Brazil; thus, establishing an opportune scenario for expanding its production chain and developing products from its pulp (Pollnow, 2018).

Pitaya has been highlighted as an economically important fruit in recent times, and the development of hybrids with superior traits for agronomic and biochemical attributes is highly desirable for the Brazilian fruit market (Junqueira et al., 2010; Lima, Faleiro, Junqueira, & Bellon 2014b; Nunes et al., 2014). Therefore, the biochemical characterization of different pitaya species is important in relation to sensorial and agronomic aspects, especially when associated with the high nutraceutical quality because of the presence of antioxidant compounds that promote benefits to human health (Lima et al., 2013; Lima et al., 2014b).

This study characterized pitaya species (*H. costaricensis, H. undatus,* and *H. megalanthus*) for sugars, organic acids, and total phenolic compounds content and antioxidant capacity, aiming to contribute to genetic breeding programs for these species, in addition to providing useful information for the food industry and beverages.

A completely randomized experimental design was used with ten completely ripe fruits harvested from each pitaya species (*H. costaricensis, H. undatus,* and *S. megalanthus*) that were selected from the germplasm bank of the State University of Londrina (23°20′23′′S, 51°12′32′′W, altitude 585 m), Londrina, Paraná, Brazil (Figure 1), in March 2019. The plants were grown on Dystropheric Red Latosol and were fertilized with bovine manure (15 kg per plant) at approximately one year old, following practices recommended for pitaya cultivation, including water supplementation by irrigation, weeding for weed control, and chemical control of pests and diseases.

The pulp was manually separated from the peel, and the samples were homogenized separately in a mixer for 2 min. A bulk sample was obtained from a mixture of the pulps of each species, where the seeds were crushed together with the pulp. The sample was homogenized and stored under refrigeration (5–8 °C) in the dark for 2 d.

For the extraction of sugars and organic acids, the pulp suspensions (0.50 g in 25 mL distilled water) were subjected to ultrasound (Elmasonic 60H) at 80 Hz for 20 min at 35 °C. Then, the suspensions were filtered using a Sep-Pak cartridge (Waters) and 0.22 µm cellulose acetate membrane (Sartorius).

The sugars were separated and quantified using a high-performance liquid chromatography (HPLC) system (Shimadzu LC 20 A, Kyoto, Japan) using a high-pressure pump (LC-20AT), automatic injector (SIL-20AC HT), 20 µL injection loop, refractive index detector (RID-10A), with a flow rate of 1.0 mL $min^{-1}$, column oven (CTO-20A) at 85 °C, control module (CRM-20A), and Aminex HPX-87P ion exchange column (7.8 × 300 mm ion exchange $Pb^{+2}$, Biorad, CA, USA). Data acquisition and integration of chromatographic peaks were performed using LC Solutions software (Shimadzu Co., Kyoto, Japan). The results are expressed as % or g acid 100 $g^{-1}$ pulp.

Separation and quantitation of organic acids was performed on a Shimadzu HPLC system (Kyoto, Japan) using a Shiseido CapCell Pak 5µ C18 MG 250 × 4.6 mm chromatographic column and the following conditions: mobile phase 25 mM sodium phosphate buffer solution, pH adjusted to 2.4, 1.0 mL $min^{-1}$ flow rate, column oven at 30 °C, and injection volume of 20 µL. Detection was performed simultaneously on the refractive index (RID-10A) and photodiode array (SPD-M20A) detectors, programmed at a fixed wavelength of 215 nm and in the scan mode from 200 to 400 nm. The results are expressed as % or g acid 100 $g^{-1}$ pulp.

The total phenolic compound content was quantified in the extract obtained from pulp (1.0 g) in ethanol 70% (v/v) using the Folin Ciocalteau reagent and gallic acid as the standard. The analysis was performed using a spectrophotometer (Biomate 3, Thermo) at a wavelength of 725 nm and the results are expressed in mg gallic acid equivalents (GAE) per 100 g of sample.

The antioxidant capacity evaluation using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay was conducted with 50.0 µL ethanolic extract mixed with 1.0 mL of buffer 100 mM acetate buffer (pH 5.5), ethanol (1.0 mL), and 0.5 mL of 250.0 µM DPPH ethanolic solution. The tubes were kept at room temperature (~25 ºC) for 15 min in the dark, and the absorbance of the remaining DPPH radicals was measured using a spectrophotometer (Biomate 3, Thermo) at a wavelength of 517 nm. 6-Hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox) was used as the standard for quantification, and results were expressed in µmol Trolox equivalent antioxidant capacity (TEAC) per 100 g sample.

After verifying the normality and homoscedasticity of the errors using the Shapiro-Wilk and Bartlett tests, the data were subjected to the F-test ($P < 0.05$) using ANOVA, and the means were compared using Tukey's test ($P < 0.05$). In addition, the principal component analysis was performed. All statistical analyses were performed using R statistical computing.

*H. undatus* had a total sugar content of 9.83% comprising 4.75% glucose and 5.08% fructose, whereas *H. costaricensis* had 8.72% of total sugars, comprising 5.95 %

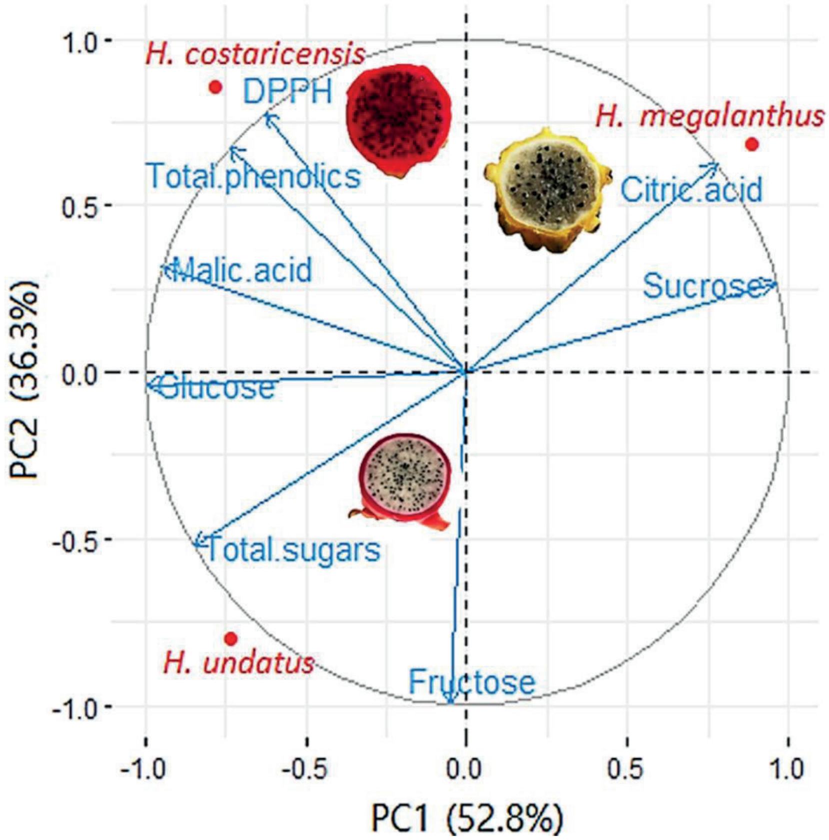


**Figure 1.** Principal component analysis (PCA) of the biochemical traits and antioxidant capacity of pitaya species

glucose and 2.77% fructose (Table 1). For *H. megalanthus,* the total sugars content (5.93%) was distributed as 0.99%, 3.25%, and 1.69% of glucose, fructose, and sucrose, respectively. Sugars constitute approximately 80% of the soluble solids with glucose, fructose, and sucrose being predominant (Berk, 2016). According to Junqueira et al. (2010), fruits with high sugar levels are preferred for *in natura* consumption and have a high trading value. Pulp of *H. megalanthus* had a low total sugar content, although it was the only species that contained sucrose. Furthermore, the presence of sucrose was verified by Wall and Khan (2008) in *Hylocereus* spp. fruits, representing approximately 2% of the total sugars.

**Table 1**
**Biochemical traits and antioxidant capacity of Hylocereus (pitaya) species**

| Specie | Sugars (g 100 g$^{-1}$) | | | |
|---|---|---|---|---|
| | Glucose | Fructose | Sucrose | Total |
| *H. costaricensis* | 5.95±0.17 a | 2.77±0.14 c | n.d. | 8.72±0.31 b |
| *H. undatus* | 4.75±0.11 b | 5.08±0.11 a | n.d. | 9.83±0.13 a |
| *H. megalanthus* | 0.99±0.09 c | 3.25±0.08 b | 1.69±0.09 | 5.93±0.13 c |
| Species | Organic acids (g 100 g$^{-1}$) | | | |
| | Malic | Citric | Ascorbic | Total |
| *H. costaricensis* | 0.83±0.01 a | 0.37±0.01 b | n.d. | 1.20±0.12 a |
| *H. undatus* | 0.71±0.09 b | 0.36±0.08 c | n.d. | 1.07±0.13 a |
| *H. megalanthus* | 0.62±0.08 c | 0.40±0.04 a | n.d. | 1.02±0.09 b |
| Species | Total phenolic content (mg gallic acid equivalent 100 g$^{-1}$) | | | |
| *H. costaricensis* | 33.75±2.7 A | | | |
| *H. undatus* | 23.32±4.9 B | | | |
| *H. megalanthus* | 22.90±2.3 B | | | |
| Species | Antioxidant capacity (µmol trolox equivalent 100 g$^{-1}$) | | | |
| *H. costaricensis* | 175.51±14.5 A | | | |
| *H. undatus* | 52.40±10.1 B | | | |
| *H. megalanthus* | 68.18±9.5 B | | | |

Means followed by the same letters in columns do not differ by the Tukey's test (P < 0.05); *n.d. = not detected.

The concentrations of malic acid in *H. undatus, H. costaricensis,* and *H. megalanthus* were 0.83%, 0.71%, and 0.62%, respectively, whereas those for citric acid were 0.37%, 0.36%, and 0.40%, respectively. Ascorbic acid (vitamin C) was not detected in the pulp of the pitaya species analyzed. Rocha, Godoy, & Cunha (2020) found a concentration of 1.81 mg 100 g$^{-1}$ in red pulp pitaya (*H. costaricensis*), which confirms the low concentration of this acid in the pulp of this species. Fernandes et al. (2017) also found low ascorbic acid levels in *H. undatus,* 3.64 mg ascorbic acid per 100 g of pulp, and Lima et al. (2014b) found high concentrations of malic acid. According to Nerd, Gutman, & Mizrahi (1999), an acidity level of less than 1% increases fruit sweetness perception by consumers.

Among the species analyzed, *H. costaricensis* showed higher levels of total phenolic compounds and antioxidant capacity, 33.75 mg GAE 100 g$^{-1}$ and 175.51 µmol TEAC 100 g$^{-1}$, respectively, than the other species (Table 1). Wu et al. (2006) evaluated *H. polyrhizus* fruits and reported 42.4 ± 0.04 mg GAE 100 g-1 and 175 ± 15.7 µmol TEAC 100 g$^{-1}$, for total phenolic compounds and antioxidant capacity, respectively, similar to the values determined in the present study, whereas Fernandes et al. (2017) reported 8.59 mg GAE 100 g$^{-1}$ for *H. undatus.* The total phenolic content and antioxidant capacity of the analyzed pitayas were higher than those of other fresh fruits, such as acerola, guava, cashew, and strawberry (Freire, Abreu, Rocha, Corrêa, & Marques, 2013).

The presence of anthocyanins may explain the high levels of total phenolics and antioxidant capacity of *H. costaricensis,* which is an important criterion for the selection of commercial pitaya species because of its benefits to human health (Calvete et al., 2008; Nunes et al., 2014). Fruits with intense red coloration of the pulp, such as strawberries and raspberries, also have high concentrations of antioxidant capacity and phenolic compounds compared to those of white pulp fruits (Calvete et al., 2008).

According to the principal component analysis (Figure 1), *H. costaricensis* is associated with high levels of malic acid, total phenolics, and antioxidant capacity, whereas the highest concentrations of glucose and fructose are notable in *H. undatus.* In contrast, the presence of sucrose and a high content of citric acid are traits associated with *H. megalanthus,* which may justify consumers' perception of these fruit having the sweetest pulp (Nunes et al., 2014).

The low total sugar levels for *H. megalanthus* allow its fruits to be recommended for people who require a low-carbohydrate diet, although sensorially it seems to be the sweetest pulp among the investigated species, probably owing to the presence of sucrose. *H. undatus* pulps are especially interesting for the desserts and beverages industry because of their high sugar content and low acidity, whereas fruits of the *H. costaricensis* species can be exploited as functional food owing to the high level of total phenolics and antioxidant capacity, in addition to use as natural food coloring.

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