

Dragon fruit (*Hylocereus undatus* Haw.) jam: Use full, development and characterization

Geleia de pitaia (*Hylocereus undatus* Haw.): Aproveitamento, desenvolvimento e caracterização

Gelatina de pitaia (*Hylocereus undatus* Haw.): Utilización, desarrollo y caracterización

Received: 05/18/2021 | Reviewed: 05/28/2021 | Accept: 05/30/2021 | Published: 06/14/2021

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Abstract

The aim of this study was developing formulations of *H. undatus* Haw. jam with pulp and peel, as well as evaluating nutritional compounds and texture properties through sensorial, instrumental, physical, biochemical and microbiological analyses of the final product. The fruit were selected, sanitized, pulped and grinded, and the formulations with different concentrations of pulp and peel (0 – 100%) were developed and evaluated. Microbiological evaluation showed that the formulations are in accordance with the current legislation. The increase in peel concentration in the jam formulations resulted in better consumer acceptance and higher concentration of phenolic compounds, antioxidants and B complex vitamins, such as B₁, B₅ and B₆. In addition, it gave the jams acceptable and pleasant sensorial characteristics and texture. Adding peel to the formulations enabled us to make total use of the fruit, with no waste, besides making the coproduct richer in compounds that are beneficial to consumers' health.

Keywords: *Hylocereus undatus* (Haw.); Jam; Antioxidants; Vitamins; Dragon Fruit peel.

Resumo

O objetivo deste estudo foi desenvolver formulações de geleia a partir de *H. undatus* Haw. com polpa e casca, além de avaliar compostos nutricionais e propriedades de textura por meio de análises sensoriais, instrumentais, físicas, bioquímicas e microbiológicas do produto final. Os frutos foram selecionados, sanitizados, despolpados e moídos, e as formulações com diferentes concentrações de polpa e casca (0 - 100%) foram desenvolvidas e avaliadas. A avaliação microbiológica mostrou que as formulações estão de acordo com a legislação vigente. O aumento da concentração da casca nas formulações de geleias resultou em melhor aceitação pelo consumidor e maior concentração de compostos fenólicos, antioxidantes e vitaminas do complexo B, como B₁, B₅ e B₆. Além disso, estas formulações apresentaram características sensoriais aceitáveis e agradáveis. Adicionar as cascas às formulações possibilitou o aproveitamento total da fruta, sem desperdício, além de enriquecer o coproduto em compostos benéficos à saúde do consumidor.

Palavras-chave: *Hylocereus undatus* (Haw.); Geleia; Antioxidantes; Vitaminas; Epiderme de pitaita.

Resumen

El objetivo de este estudio fue desarrollar formulaciones de gelatina a partir de *H. undatus* Haw. con pulpa y piel, además de evaluar compuestos nutricionales y propiedades texturales mediante análisis sensorial, instrumental, físico, bioquímico y microbiológico del producto final. Los frutos fueron seleccionados, higienizados, despulpados y molidos, y se desarrollaron y evaluaron formulaciones con diferentes concentraciones de pulpa y piel (0 - 100%). La evaluación microbiológica mostró que las formulaciones están de acuerdo con la legislación vigente. El aumento de la concentración del peeling en las formulaciones de gelatina resultó en una mejor aceptación por parte del consumidor y una mayor concentración de compuestos fenólicos, antioxidantes y vitaminas B, como B₁, B₅ y B₆. Además, estas formulaciones mostraron características sensoriales aceptables y agradables. La incorporación de las cáscaras a las formulaciones permitió aprovechar al máximo la fruta, sin desperdicio, además de enriquecer el coproduto en compuestos beneficiosos para la salud del consumidor.

Palabras clave: *Hylocereus undatus* (Haw.); Gelatina; Antioxidantes; Vitaminas; Epidermis de pitón.

1. Introduction

Currently, food waste is an environmental problem and the increasing concern with the environment has been mobilizing several market segments. Food waste can be used in many ways, such as making total use of food to reduce organic matter in the environment and enhance the quantity of nutrients and health benefits. This practice has been adopted as an easy alternative for sustainable, with greater use of natural resources, which allows reducing expenses in a more considerable way, besides enabling diversified diets (Amaral, Pereira, Ferreira & Gregório, 2012).

Dragon fruit (genus *Hylocereus*) belongs to the Cactaceae family, and it is originally from some regions of Mexico, South and Central Americas. It is widely grown in countries such as Malaysia, Vietnam, Thailand, Taiwan (Muhammad, Mohd.Zahari, Gannasin, Mohd.Adzahan & Bakar, 2014), and it has been recently introduced in Brazil. The fruit has several varieties, which can be all differed by characteristics such as color of its epicarp and/or mesocarp – the latter contains black seeds (Ariffin et al., 2009). Studies have demonstrated that dragon fruit has compounds that are beneficial to consumers, as antioxidants (Rui, Zhang, Li & Pan, 2009; Mercado-Silva, 2018; Som, Ahmat, Hamid & Azizuddin, 2019).

In countries where the fruit is widely consumed, peel waste by juice processing and natural dying industries causes accumulation of organic matter (Muhammad et al., 2014; Phongtongpasuk, Poadang & Yongvanich, 2016). In China, dragon fruit peel is consumed as salad, due to its high antioxidant activity, beyond the functional properties (Zhuang, Zhang & Sun, 2012). Furthermore, the peel represents approximately 33% of the total weight of the fruit, which is often discarded and used as animal food (Amid & Manap, 2014).

The use of different parts of plants, such as roots, seeds and leaves, in addition to food residues from industrial processes, is currently a viable alternative for the production of coproducts and extraction of compounds of food interest and with functional properties for human health. Among these compounds, carbohydrates, antioxidants, fibers, vitamins and minerals are associated with promoting health and increasing the nutritional value of foods. Thus, total waste recovery leads to an increase in nutritional values, which makes the fruit a richer nutritional option.

Among the coproducts, jam is a popular food in many countries, and makes it possible to consume a particular fruit

even outside the season. According to Touati, Tarazona-Díaz, Aguayo & Louaileche (2014), jams are a type of food with intermediate moisture content, and it is prepared by cooking fruit with the addition of sucrose, pectin, acid and other ingredients which will characterize the product. It finds its origin in the practice of food preservation for consumption throughout the year. Jams must have adequate consistency, and when they are stored at high temperatures or not stored properly, there is significant loss in terms of nutritional values and sensorial properties (Touati et al., 2014; Rababah et al., 2015; Panchal, Gaikwad, Dhemre & UD, 2018).

Another important factor for jam formulation is pectin – pectic substances – which is responsible for gelation due to hydrophobic interactions and hydrogen bonds in acid conditions ($\text{pH} < 3,5$), and low water activity (Javanmard, Chin, Mirhosseni, & Endan, 2013). As a feature of a well commercially accepted product, jams must have a content of 60 °Brix (Holzwarth, Korhummel, Siekmann, Carle & Kammerer, 2013). In front of these factors, the aim of this study is developing of dragon fruit jam using whole fruit (pulp and peel), as well as evaluating sensorial, physical, chemical, biochemical and microbiological characteristics of the final product.

2. Methodology

2.1 Samples

Dragon fruit (*Hylocereus undatus* Haw.) were picked during the 2016 harvest, in Marialva, state of Paraná, Brazil (coordinates: 23°46'35.51"S, 51°79'71.10"W). The fruit were selected, washed and sanitized in 1% sodium hypochlorite. Pulping was done with sterile material, and the pulp and peel were macerated and set aside for further analysis and for preparing the jam formulations.

2.2 Jam preparation

The jam formulations were prepared by following the composition stated by Touati et al. (2014), which contains fruit pulp, sucrose, pectin and citric acid. Pectin and citric acid were added as much as needed (*quantum satis*), following the rules by RDC (Technical Regulation of Good Practices for Food Services) N°8, from March 6th, 2013. Quantification of pectin present in the pulp and peel was assessed in accordance with Pearson (1976), in order to evaluate the need of addition to the formulations.

Pulp and sugar proportion was calculated according to Mazur et al. (2013), and it was 2:1 (2 parts of the fruit:1 part of sugar – w/w). The jam formulations were determined by a mixture planning with restrictions, in which pulp and peel contents varied. The minimum and maximum amounts of both ingredients were determined by previous tests. For ternary mixture, the third component used was sugar. Data were analyzed by using the Statistica software, and the following formulations were devised: 100 % pulp: 0 % peel (w/w) (F1); 75 % pulp: 25 % peel (w/w) (F2); 50 % pulp:50 % peel (w/w) (F3); 25 % pulp:75 % peel (w/w) (F4); and 0 % pulp:100 % peel (w/w) (F5).

For jam production, the ingredients were placed into a stainless steel container and exposed to cooking until the concentration of soluble solids reached 60 to 68 °Brix. Citric acid was added until pH 3.5. After that procedure, the jam, still at a temperature higher than 85°C, was placed into glass jars previously sterilized, closed with metal buffers, and inverted for 5 minutes. After cooling, the jars were labeled and stored at room temperature. Pectin values found in both pulp and peel, obtained on a dry weight basis, were lower than 0.10 and 14.33 g of calcium pectate 100 g⁻¹, respectively. Peel pectin content is 143 % greater compared to the pulp. Therefore, we did not consider the addition of commercial pectin to the jam formulations.

2.3 Microbiological Evaluation

The analysis was carried out in accordance with requirements of the current legislation, RDC N°12, from 2001 ANVISA (National Health Surveillance Agency), Brazil, (BRASIL, 2001) for preserves. Yeast and mold analysis was done in conformity with the methodology by Downes and Ito (2001), by spread plate in Dichloran 18 Glycerol agar (DG-18), for counting after 5 days of incubation at 25 °C. Results are expressed as colony-forming units (CFU) g⁻¹ of the sample and the acceptable tolerance limit for yeast and mold is 1,0x10⁴, according to RDC N°12.

2.4 Sensorial analysis

Sensorial analysis was carried out by applying the 9-point hedonic scale test (9 = like extremely; 1 = dislike extremely), with 120 non-trained judges (77 women and 43 men). The parameters evaluated were global appearance, taste, texture and purchase intention (Touati et al, 2014). The latter underwent scale evaluation, from 1 to 5 (5 = I would certainly purchase; 1 = I would certainly not purchase). All samples (25 g) were placed into transparent plastic cups codified with three random numbers, at room temperature. The study was approved by the Ethics Committee for Research on Human Beings, under registration number CAAE: 43121714.1.0000.0104.

2.5 Physicochemical analyses

2.5.1 Color measurements

Dragon fruit jam measurement was determined by the digital colorimeter CR-10 model, manufactured by KONICA MINOLTA. Variables were collected as proposed by the International Commission on Illumination (ICI), using the L*, a* and b* variables, in accordance with Santos et al. (2016).

2.5.2 Proteins

Determination of crude protein was done according to the method by Kjeldahl (AOAC, 1998) and in triplicate. The sample was digested for 4 to 6 h with a catalytic mixture and concentrated H₂SO₄, neutralized with a 40% NaOH solution, and subsequent formation of borate complex, a product that results from the reaction between the nitrogen available in the sample with 4% boric acid. Ammonia titration with a 0,1 mol L⁻¹ solution of HCl was done until the turning point, and the mean values were calculated. The results were expressed through total nitrogen percentage of the sample (% Nitrogen).

2.5.3 Texture properties

Texture properties of the dragon fruit jam formulations were evaluated with a TATX-Stable Microsystem texturometer. The parameters evaluated with regard to the texture profile were firmness, adhesiveness, elasticity, cohesiveness, gumminess, chewiness and resilience. The results were expressed as g.

Measures were analyzed by using a P36R probe (36mm diameter aluminum cylinder probe) at room temperature (25 ± 3 °C). The instrument was operated at pre-test speed = 1 mm s⁻¹, test speed = 1 mm s⁻¹, post-test speed = 20 mm s⁻¹, distance = 15 mm, and trigger = 5 mm, automated force detection with a 5 kg load cell (force trigger = 5 g force⁻¹). The analysis was carried out with 10 repetitions.

2.6 Antioxidant properties

2.6.1 Extraction

Extracts for the unprocessed fruit and jam formulations were obtained in accordance with Gümüşay, Borazan, Ercal &

Demirkol (2015), with some changes. 1 g of the sample was added to 10 mL of methanol 75 %/water 25 % (v/v) under agitation for 15 min in a magnetic agitator. The samples were centrifuged at 1500 g for 10 min, and the supernatant was recovered and stored in amber flasks to be protected from light until the analyses.

2.6.2 DPPH Method

Antioxidant activity by the DPPH radical method (2,2-Diphenyl-1-picrylhydrazyl) was done in compliance with Ma et al., (2011). 25 μL of the sample and 2 mL of the $6,25 \times 10^{-5}$ mol L^{-1} DPPH solution were added to tubes protected from light, where they were kept at rest for 30 min. Scanning was done in a spectrophotometer at 517 nm and a calibration curve was prepared with trolox (acid (\pm)-6-hydroxi-2,5,7,8- tetramethylchromane -2-carboxylic) ($y = -0,0003x + 0,7061$, $R^2 = 0,9960$). The results were expressed as $\mu\text{mol trolox g}^{-1}$ of the sample.

2.6.3 ABTS Method

Antioxidant activity by the ABTS method (2,2'-azino-bis(-acid 3- ethylbenzothiazoline -6-sulphonic)) was carried out in accordance with Rufino et al. (2007). 30 μL of each sample extract and 3 mL of the ABTS^+ radical solution (5 mL of a 7 mmol L^{-1} ABTS solution and 88 μL of 140 mmol L^{-1} potassium persulfate, reaction for 16 hours protected from light) were transferred to tubes away from light, where they were kept for 6 min. Scanning was done in a spectrophotometer at 734 nm and a calibration curve was prepared with Trolox ($y = -0.0003x + 0.6950$, $R^2 = 0.9931$). The results were expressed as $\mu\text{mol trolox g}^{-1}$ of the sample.

2.6.4 Phenolic compounds

Determination of phenolic compounds was done in accordance with the method by Singleton & Rossi (1965), with changes. 125 μL of the sample, 125 μL of the Folin-Ciocalteu reagent / distilled water 1:1 (v/v) and 2250 μL of a 3.79 mol L^{-1} sodium carbonate solution was placed into tubes protected from light, where they remained for 30 min. Scanning was done in a spectrophotometer at 725 nm. The calibration curve was determined from a gallic acid solution ($y = 0.0009x + 0.0122$, $R^2 = 0.9914$) and the results were expressed as mg of gallic acid equivalent per sample mass (GAE g^{-1}).

2.7 Determination of vitamins B₁, B₅ and B₆

2.7.1 Extraction

The QuEChERS methodology was applied as described by Lehotay, Mañtovská & Yun (2005). The pulp, peel and formulation samples (15 g) that showed better acceptance in the sensorial analysis (F2, F3 and F4) were homogenized and extracted with 15 mL of acetonitrile (CAN) with 1% of acetic acid (v:v). 6 g of anhydrous magnesium sulfate and 1.5 g of sodium acetate was added, which underwent vortex agitation for 1 min. The volume was centrifuged during 10 min at 6000 rpm and 4 °C. Afterwards, 1 mL of the supernatant (CAN) was transferred to a microcentrifuge tube containing 50 mg of (Primary secondary amine) PSA and 150 mg of anhydrous magnesium sulfate. The tube was agitated during 20 s and, later, centrifuged for 10 min at 6,450 g and 4 °C. The aliquot was filtered by a nylon syringe filter with 0.20 μm porosity and transferred to a flask for analysis.

2.7.2 Chromatographic conditions

The analyses were carried out in a high-performance ACQUITY UPLC System, manufactured by Waters (Massachusetts, USA), coupled to an ACQUITY TQD triple quadrupole mass spectrometer, by Waters (Massachusetts, USA),

with electrospray ionization in positive mode. We used an EC NUCLEODUR 100-5 C18ec chromatographic column (250 mm long, 4.6 mm in diameter, 5.0 μm particle size) at 24 °C. The mobile phase consisted in methanol and acidified water 0.05 % trifluoroacetic acid (TFA) in a 70:30 (v:v) proportion, both of LC-MS grade purity. The run was isocratic with a 0.35 mL min⁻¹ flow.

Ionization and conditions were optimized for each vitamin studied by infusion at a flow of 5 $\mu\text{L min}^{-1}$ in an adequate concentration prepared in methanol:water (50:50, v:v), containing 0.1% of formic acid (v:v). Two fragmentation transitions were detected. MRM transitions, cone voltage, collision energy and dwell time were set for each substance (Table 1).

Table 1. Parameters of the mass spectrometer of the UPLC-MS/MS system for the vitamins studied.

Vitamin	ion precursor (<i>m/z</i>)	R _T (min.)	ions product (<i>m/z</i>)	V _{cone} (V)	EC (eV)	dwell time (s)
B ₁	265	5.10 – 5.30	122; 144	20	15	0.1
B ₅	220	7.00 - 7.30	72; 90	25	25	0.1
B ₆	170	6.10 - 6.30	134; 152	30	25	0.1

R_T (min): Retention time in minutes; V_{cone}: Cone voltage in Volt; EC: Collision energy in electron-volt.
Source: Authors.

The calibration curves were separated by standard addition in the following concentrations: 5, 10, 15, 20 and 25 $\mu\text{g mL}^{-1}$ for each vitamin. The standards used were B₁ (Thiamine hydrochloride, $\geq 99\%$ (HPLC), Sigma-Aldrich), B₅ (D-Pantothenic acid hemicalcium salt, $\geq 99\%$ (HPLC), Sigma-Aldrich) and B₆ (Pyridoxine hydrochloride, $\geq 98\%$ (HPLC), Sigma-Aldrich).

2.8 Statistical analysis

The data were submitted to analysis of variance through ANOVA. For means comparison, we used the Tukey's test ($p < 0.05$), through the statistical program Assistat 7.7 beta (Campina Grande, Paraíba, Brazil). The graphs were created with the aid of the Software SigmaPlot version 11.0.

3. Results and Discussion

3.1. Microbiological analysis

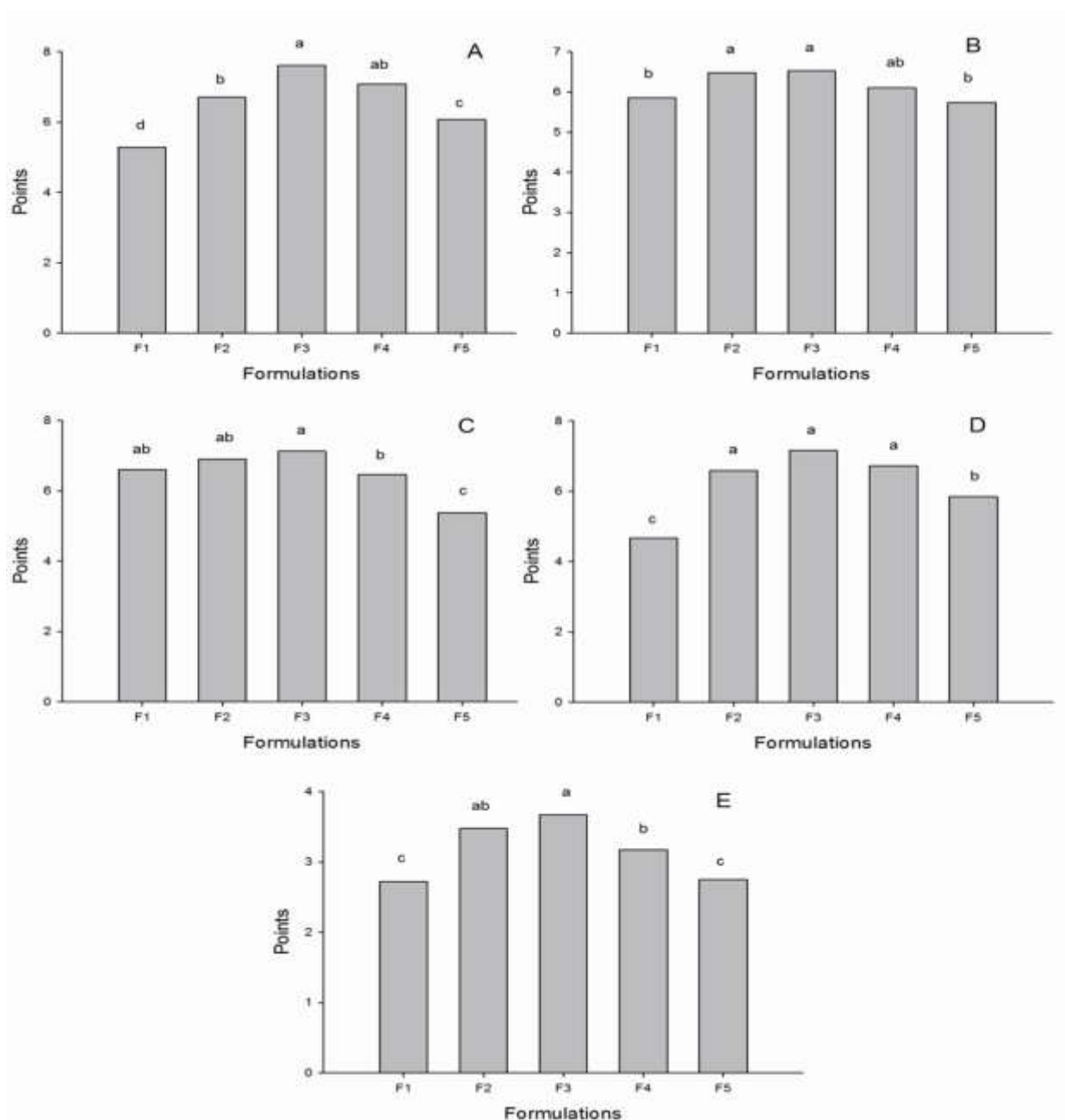
The microbiological analysis was carried out in accordance with what is determined by the current legislation (RDC N°12, from January 2nd, 2001, ANVISA (National Health Surveillance Agency), Brazil). The samples were evaluated with respect to yeast and mold, and all formulations complied with the requirements established, below the tolerance limit of 10⁴ yeast and mold per each gram of a sample.

3.1 Sensorial analysis

The sensorial analysis was evaluated through the following parameters: overall appearance, aroma, taste, texture and purchase intention (Figure 1). Statistically, all formulations presented significant difference with regard to the parameters evaluated. F3 formulation had the highest mean values in all parameters assessed, followed by F2 and F4 formulations. F1 and F5 reached the lowest mean values. Most of the judges demonstrated to be satisfied with the formulations containing pulp and

peel. F3 formulation (50 % pulp: 50 % peel) stood out.

Figure 1. Sensorial evaluation of the *H. undatus* (Haw.) jam formulations. A. Appearance; B. Aroma; C. Taste; D. Texture and E. Purchase intention to the results of formulations F1, F2, F3, F4 and F5.



*Lowercase letters between columns show the significant difference ($p > 0.05$) among the formulations.
Source: Authors.

Dragon fruit peel stands out for several features, such as significant amounts of betanine, hydroxytyrosine, betacyanine, pectin, triterpenoids and steroids, which are considered anti-inflammatory and anti-tumoral, besides antioxidant properties (Phongtongpasuk et al., 2016). In addition, pectin found in the peel can be added to food and drinks with low viscosity, and it is also a functional and healthy ingredient (Muhammad et al., 2014).

In fact, research shows the importance of fruit peels that carry additive properties. For instance, we have *Myrciaria jaboticaba* peel, which is a source of antioxidants (Plaza et al., 2016); pomegranate peel, which contains pectin and is a source

of fibers (Abid et al., 2017); passion fruit peel flour, which is a source of pectin and fiber due to its gelling power (Coelho et al., 2017). These examples show that fruit peels are recommended for consumption, as well as used as coproducts, for they are sources of beneficial compounds. Furthermore, they are viable for food industries, since they avoid wasting that leads to organic matter accumulation.

3.3 Physicochemical determination

In regards to the color of the formulations (Table 2), lower values were identified for L* and b* parameters with peel addition. As for a*, the mean values were higher for superior peel concentrations. These mean values reflect upon consumers' preference due to more attractive colors, which is a result of peel addition, as demonstrated by the sensorial analysis. Peel addition ranging from 25 % to 75 % directly contributed to enhancing general acceptance of the jam, and there was no significant difference for L*, a* and b* parameters.

Table 2. Physical parameters evaluated in the fruit (peel and pulp) and in the different *H. undatus* jam formulations.

Parameters	Samples							
	Peel	Pulp	F1	F2	F3	F4	F5	
Color	L*	32.45 ± 2.72 ^b	45.20 ± 1.92 ^a	34.17 ± 0.32 ^b	26.10 ± 0.67 ^c	23.25 ± 1.58 ^c	25.05 ± 0.57 ^c	23.90 ± 1.53 ^c
	a*	37.77 ± 2.79 ^a	0.47 ± 0.26 ^{cd}	-1.75 ± 0.64 ^d	4.02 ± 2.09 ^{bc}	2.97 ± 2.70 ^{bc}	4.20 ± 1.78 ^{bc}	6.30 ± 1.09 ^b
	b*	-1.87 ± 1.00 ^d	4.62 ± 0.55 ^c	10.70 ± 0.41 ^a	7.27 ± 0.54 ^b	5.57 ± 2.04 ^{bc}	5.60 ± 0.50 ^{bc}	5.97 ± 1.00 ^{bc}
	Protein (%)	1.68 ± 0.19 ^a	2.30 ± 0.15 ^a	2.23 ± 0.36 ^a	1.83 ± 0.58 ^a	1.53 ± 0.32 ^a	1.93 ± 0.51 ^a	1.41 ± 0.09 ^a

*Lowercase letters between lines represent significant difference (p>0.05), by Tukey's test. F1: 100 % pulp: 0 % peel (w/w); F2: 75 % pulp: 25 % peel (w/w); F3: 50 % pulp:50 % peel (w/w); F4: 25 % pulp:75 % peel (w/w); and F5: 0 % pulp:100 % peel (w/w).
 Source: Authors.

Betalaine and its derivatives are bioactive compounds responsible for the intense red color of dragon fruit peel and pulp. Besides, they offer health benefits since they are sources of antioxidants, and because they are important in the food industry (Xu, Zhang & Wang, 2016; Esquivel, Stintzing & Carle, 2007).

Percentage of the protein evaluated (Table 2) did not present significant values between the fruit itself (peel and pulp) and the jam formulations. Even though the protein is unstable to thermic processing, such as pasteurization applied during jam preparation, it remained stable after the preparation of the coproduct. Zhuang et al., (2012) determined 6.75 % of protein in *Hylocereus undatus* peel, native to China. Conversely, for our study, we identified lower values (1.68 %).

When it comes to texture parameters (Table 3), the increase in peel addition to the jam formulations contributed to enhancing firmness, chewiness and gumminess (an increase of 433.65 %, 175.76 % and 287.83 % comparing F1 to F5, respectively), whereas adhesiveness and resilience decreased (32,073.75 % and 96.49 % less comparing F1 to F5, respectively). A decrease in resilience and adhesiveness because of greater firmness was expected, for the ability to spring back into shape is hindered when it comes to firmer gels. As for cohesiveness and elasticity parameters, they showed significant differences among the formulations. However, those differences had nothing to do with peel addition. The increase

in firmness, chewiness and gumminess may be related to an increase in pectin and dietetic fibers found in the peel (Zhuang et al., 2012; Muhammad et al., 2014). As stated by Mercado-Silva (2018), viscous consistency of the peel is due to the concentration of pectin, which consists mainly of galacturonic acid (39.11 %), lower concentrations of mannose, rhamnose, galactose, glucose and lower quantities of xylose and arabinose. Formulations F2, F3 and F4, regarding the texture evaluated in the sensorial analysis, did not present any statistical difference, thus evidencing ideal parameters for product acceptance.

Table 3. Texture parameters in the different *H. undatus* (Haw.) jam formulations.

Parameters	Formulations				
	F1	F2	F3	F4	F5
Firmness (g)	60.97 ±0.84 e	84.10 ±3.34 d	126.39 ±2.63 ^c	194.86 ±7.50 ^b	325.37 ±17.09 ^a
Adhesiveness (g)	-4.19 ±1.56 e	-50.01 ±8.10 d	-329.84 ±28.00 c	-771.42 ±17.75 b	-1348.08 ±32.01 a
Elasticity (g)	1.02 ±0.04 ^a	0.98 ±0.03 ^b	0.98 ±0.01 ^b	0.98 ±0.01 ^b	0.97 ±0.03 ^b
Cohesiveness (g)	0.94 ±0.01 ^a	0.88 ±0.03 ^b	0.88 ±0.03 ^b	0.92 ±0.05 ^{ab}	0.65 ±0.06 ^c
Gumminess (g)	57.16 ±0.61 e	73.85 ±1.12 d	111.15 ±4.84 ^c	179.25 ±13.11 b	221.68 ±19.92 ^a
Chewiness (g)	57.81 ±1.96 e	72.80 ±1.37 d	109.34 ±5.47 ^c	180.89 ±7.24 ^a	159.42 ±20.47 ^b
Resilience (g)	0.57 ±0.02 ^a	0.25 ±0.03 ^b	0.03 ±0.00 ^c	0.01 ±0.00 ^c	0.02 ±0.00 ^c

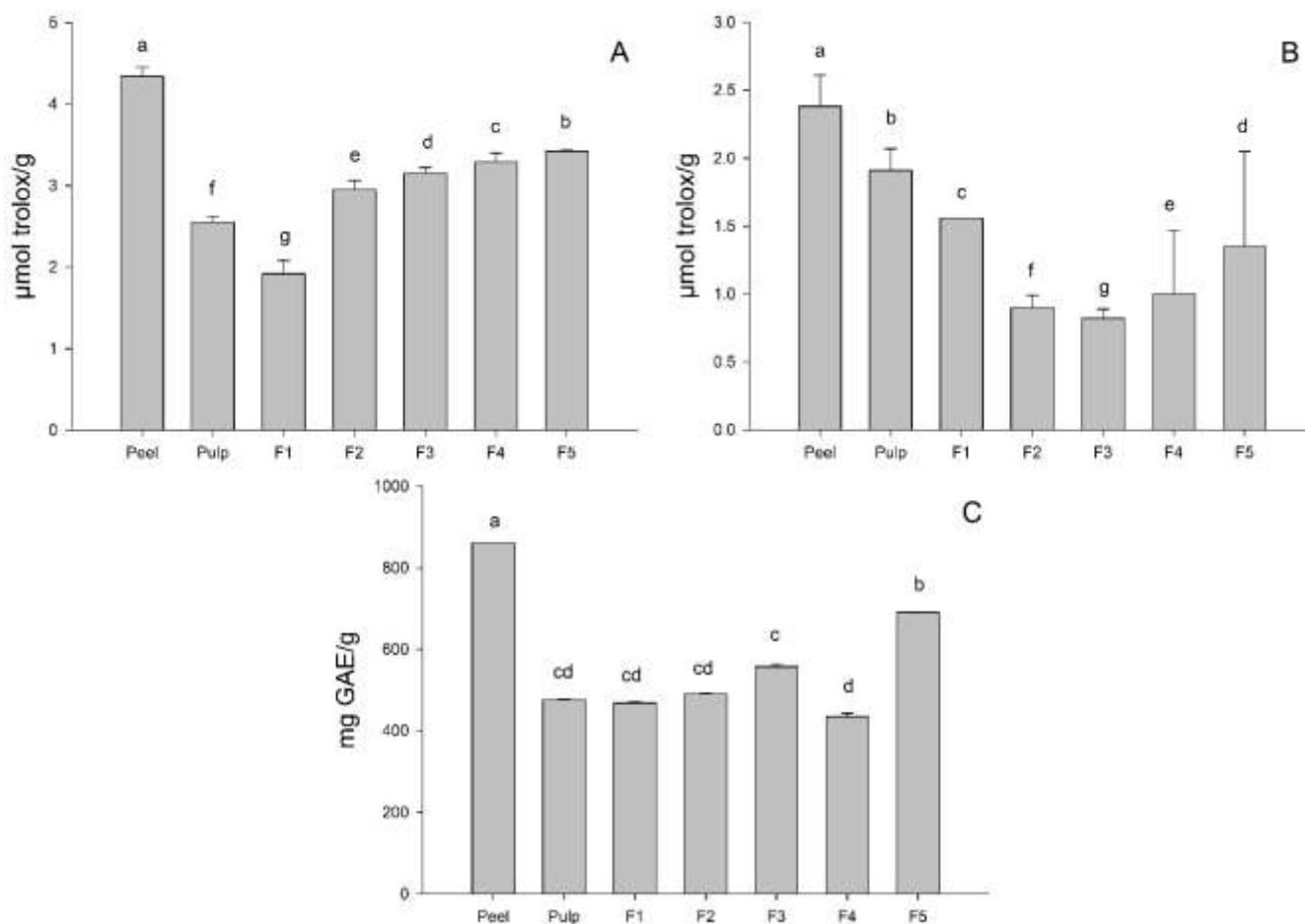
*Different capital letters between lines represent significant difference ($p > 0.05$), by Tukey's test. F1: 100 % pulp: 0 % peel (w/w); F2: 75 % pulp: 25 % peel (w/w); F3: 50 % pulp:50 % peel (w/w); F4: 25 % pulp:75 % peel (w/w); and F5: 0 % pulp:100 % peel (w/w). Source: Authors.

3.4 Antioxidant Properties

Antioxidant activity showed higher mean values regarding the fruit peel in both methods evaluated, DPPH (Figure 2.A) and ABTS (Figure 2.B), as follows: 4.32 and 2.38 $\mu\text{mol Trolox g}^{-1}$, respectively, when compared with the pulp and other samples. For the DPPH analysis, formulations F2, F3, F4 and F5 reached higher mean values (2.95 to 3.42 $\mu\text{mol trolox g}^{-1}$), pulp and F1 (2.55 and 1.92 $\mu\text{mol trolox g}^{-1}$, respectively), which differs from the results of the ABTS method, in which all formulations had lower mean values regarding the unprocessed fruit (peel and pulp). In both methods, all samples showed significant difference within the methods evaluated.

The jam formulations reached lower values when it comes to the unprocessed fruit. That applies, for example, to the activity presented by the peel, which had a decrease in antioxidant content ranging from 21.00 to 24.70 % (DPPH) and 43.28 to 57.07 % (ABTS), due to heating. With regard to phenolic compounds (Figure 2.C), peel samples and formulation F5 achieved higher values of 860.74 and 690.37 mg AGE g^{-1} , respectively, compared to the other samples, whose values ranged from 557.04 to 434.82 mg AGE g^{-1} . The samples showed significant difference at a 5 % probability, except for the pulp and formulations F1 and F2.

Figure 2. Antioxidant activities of *H. undatus* (Haw.) jam formulations. A. DPPH method; B. ABTS method; and C. Phenolic compounds of the peel, pulp and formulations F1, F2, F3, F4 and F5.



* Lowercase letters between the columns represent significant difference ($p < 0.05$) among the formulations.
Source: Authors.

In the literature antioxidant activity values of 28.30 and 175.00 $\mu\text{M trolox g}^{-1}$ for pulp and peel were found, respectively (Dembitsku et al., 2011) and 1.57 $\mu\text{mol trolox g}^{-1}$ (Chen et al., 2014) for the ABTS method. As for the DPPH method, values such as 10.39 $\mu\text{mol VC g}^{-1}$ were found for the fruit pulp (Li et al., 2017). Those values are lower than the ones shown by our study.

With regard to phenolic content, only the jam a 100 % made of peel was close to the content found in unprocessed peel, a phenomenon on account of pulp and peel dilution with sugar during jam preparation (Naeem et al., 2017). Previous studies present lower values of phenolic compounds compared to the ones found in this study: 77.50 and 39.70 $\text{mg AGE } 100 \text{ g}^{-1}$ for dragon fruit peel (Zhuang et al., 2012; Dembitsky et al., 2011), and 42.40 $\text{mg AGE } 100 \text{ g}^{-1}$ for pulp (Dembitsky et al., 2011).

Several factors, which comprise features of the chemical compounds, availability of the food matrix, as well as interactions with the other components of the food either processed or not, affect bioavailability and stability of the compounds of phenolic character (Kamiloglu, Pasli, Ozcelik, Camp, & Capanoglu, 2015). Nonetheless, fresh-cut dragon fruit fruit, evaluated in terms of antioxidant activity, did not have influence over minimal processing (Li et al., 2017). Conversely, this study demonstrated a slight change in the unprocessed fruit compared to the thermally processed one. It should be stressed that

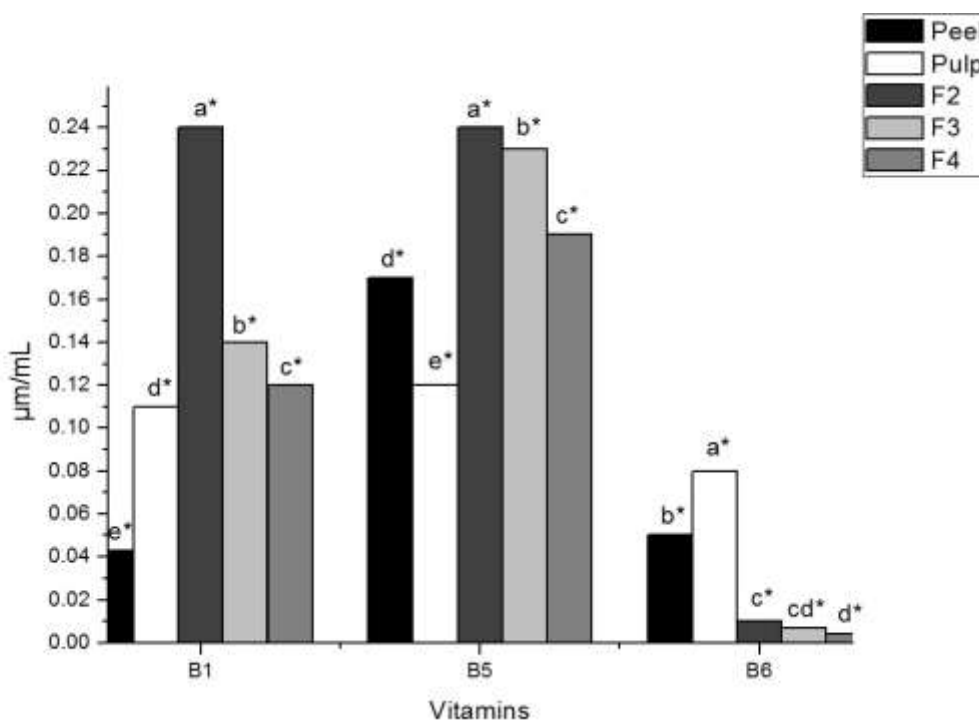
both the pulp and the peel of *Hylocereus* sp. are considered rich in phenolic compounds and antioxidants (Dembitsky et al., 2011).

3.5 Determination of vitamins B₁, B₅ and B₆

In order to evaluate complex B vitamins (B₁, B₅ and B₆), the formulations which showed greater acceptance in the sensorial analysis (F2, F3 and F4) was considered, fresh peel and pulp. The results are shown by Figure 3.

According to Figure 3, the fruit pulp showed higher mean values in comparison with the peel, except for vitamin B₅. The jam formulations (F2, F3 and F4) achieved higher contents of vitamins B₁ and B₅ in comparison with the unprocessed fruit; on the other hand, they had lower contents of vitamin B₆. Fruit are high in vitamins, such as fat-soluble (A, D, K and E) and hydro-soluble ones (C and B complex), besides minerals (Rababah et al., 2015). Fruit of the species *Hylocereus* sp., such as red dragon fruit (*Hylocereus polyrhizus*) have in their composition some vitamins as B₁, B₂, B₃ and C (Yenrina, Azima & Khumairoh, 2016).

Figure 3. Quantification of vitamins B₁, B₅ and B₆ in *H. undatus* (Haw.) peel and pulp, and in the jam formulations (F2, F3 and F4).



*Capital letters between columns for the same vitamin stand for significant difference ($p > 0.05$) among the samples evaluated.
 Source: Authors.

As pointed out by Mercado-Silva (2018), *H. undatus* fruit has in its composition 0.2 mg of niacin (vitamin B₂) and 25 mg of ascorbic acid for every 100 g of fresh pulp. As for Thiamine (B₁) and Riboflavin (B₂), they were not detected in this species. That differs from our study, for it presented B₁ content in the samples analyzed. A study evaluating the composition of dragon fruit (*H. undatus*) jam with the fruit extract during storage for 3 months evidenced a decrease in ascorbic acid in the aforementioned period at room temperature (30 °C) and refrigerated (5 °C). The mean values were 2.45 to 2.96 mg 100 g⁻¹ of jam, and 2.47 to 2.96 mg 100 g⁻¹ of jam, respectively (Panchal et al., 2018).

Vitamins, among other compounds of bioactive character, can be affected or lost during processing, cooking and

storage (Rababah et al., 2015). However, these results suggest stability and, consequently, the concentration of vitamins B₁ and B₅ when they are exposed to thermal treatment, such as cooking. Vitamins B₁, B₂, B₃ and C also were analyzed, but, were not determined due to absence or degradation during the processes we carried out.

4. Conclusion

The addition of peel to dragon fruit jam showed feasibility of a coproduct that was entirely developed with total waste recovery, with emphasis being placed on the F3 formulation, which had good acceptance, besides bioactive compounds. Apart from reducing the amount of waste from personal consumption and industries, it enhances the beneficial properties of dragon fruit peel, leading to a better taste according to consumers, who strongly approved peel addition. Furthermore, it results in a considerable source of antioxidant compounds, vitamins such as B₁, B₅ and B₆, besides sensorial features that were considered pleasant by consumers, within food safety and quality standards. It is important to mention that future studies should be carried out to evaluate the shelflife of this product, as well as the stability of bioactive compounds and sensory attributes during storage.

Acknowledgments

The authors would like to thank the Brazilian Federal Agency and the Coordination for the Improvement of Higher Education Personnel (Coordenação e Aperfeiçoamento de Pessoal de Nível Superior, Brasil [CAPES]) for their support, as well as the Research Support Center Complex (Complexo de Centrais de Apoio à Pesquisa [Comcap]) - Ministério da Ciência e Tecnologia (Finep).

Conflict of interest

The authors have not declared any conflict of interests.

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