



The fruit of peach palm (*Bactris gasipaes*) and its technological potential: an overview

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Abstract

The Amazon hosts numerous fruit species, which are consumed by the local population and distributed by the local economy in the commerce markets, but most of them are unknown to the general population. Therefore, for a better understanding of the Amazon biome, the main objective of this review was to describe the physicochemical, nutritional and biological characteristics of the peach palm, highlighting its antioxidant potential. The peach palm tree is considered a polyvalent palm native to tropical Latin America, predominantly cultivated by small farmers in agroforestry systems, its fruits present high potential for functional food production because of the presence of bioactive compounds in its composition, and high nutritive value with considerable amounts of carbohydrates and lipids, as well as it provides an important source of vitamin A. Thus, an approach has been taken on the main topics for further studies that may benefit the industry and improve the local economy where these fruits are found. In view of this, the dissemination of works already performed with this fruit, strategically relevant, can stimulate new lines of research to consolidate this field for food, pharmaceutical and cosmetic industries.

Keywords: *Bactris gasipaes*; carotenoids; fatty acids; nutritional composition; palm peach.

Practical Application: The review on the properties of the peach palm fruit gathers important information to expand knowledge and future valuation of the fruit, including all genotypes (microcarp, mesocarp and macrocarp).

1 Introduction

The peach palm tree (*Bactris gasipaes*) is a tropical plant, native from Americas that presents wide genetic diversity in its wild and domesticated population (Carvalho et al., 2013a). According to studies, there are approximately 73 species spread in South Mexico, the Caribbean, Brazil and Paraguay. The cultivated peach palm is widely distributed from Honduras to the Central region of Bolivia and Eastern Pará (Brazil) (Bezerra & Silva, 2016; Graefe et al., 2013).

The peach palm tree can be cultivated with different purposes: for palm heart and fruit (popularly known as peach palm) (Bezerra & Silva, 2016; Matos et al., 2019). In the Brazilian Amazon, the peach palm tree is almost exclusively cultivated for fruit purpose, which is consumed after its cooking in water and salt (Carvalho et al., 2013a; Chisté & Fernandes, 2016).

The peach palm presents high nutritional value, rich in fat, fiber, starch and total carotenoids, among them the β -carotene that attributes to its pulp an intense yellowish color, besides its significant functional appeal (Table 1).

The presence of bioactive compounds in peach palm makes its consumption attractive due to the association with lower incidence of certain types of cancer and cardiovascular diseases. The antioxidant compounds act in the protection of molecules as lipids, DNA and proteins, against the oxidative attack (Pérez-Mateos et al., 2005).

The high content of carotenoids present in the peach palm fruits are mentioned as the main responsible for the antioxidant action (Espinosa-Pardo et al., 2014; Jatunov et al., 2010), contributing

to the ingestion of antioxidant compounds in the human diet (Carvalho et al., 2013b). As the carotenoids present a molecular structure of conjugated double bonds, they become powerful agents with antioxidant action (Jatunov et al., 2010) contributing to the strengthening of the immune system and reducing risks of diseases (Carvalho et al., 2013b; Serrano et al., 2011).

In addition to direct consumption, the fruit can be used as raw material to produce many products, especially peach palm flour, oils and fermented drink, for example. The peach palm in the form of flour is an alternative to avoid the market saturation of fresh fruits and to diversify its demand. High-starch mesocarp species are the most appropriate because when starch is heated, it tends to generate technological properties of interest for certain types of products, such as breads, cakes, soups, creams, sauces and porridge (Bezerra & Silva, 2016).

The objective of this work is to present an overview of the published literature related to pupunha, from the physical and genetic characteristics of the fruits to their commercial use, with an emphasis on physical-chemical, nutritional, biological and technological characterization as well as in the elaboration and commercialization of new products.

2 Peach palm (*Bactris gasipaes*)

In Brazil, there are different types of soil and climate resulting in great diversity of fruit species distributed around the six biomes (Amazon Forest, Caatinga, Cerrado, Atlantic Forest, Pantanal and Pampa) (Neri-Numa et al., 2018). The Amazon

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Table 1. Physical characterization, nutritional composition, and amino acids of the protein in the mesocarp of peach palm (*Bactris gasipaes*) fruits (*in natura*) with comparisons to FAO/WHO recommendations and the literature.

Biometric analysis of peach palm fruit										
Genotype	Seed	Peel color	Weight (g)	Size (cm)	Diameter (cm)	Reference				
Macrocarpa	Presence	Red-green	45.45 ± 8.18	3.97 ± 0.30	4.93 ± 0.43	(Pires et al., 2019)				
Microcarpa	Absence	Green	21.20 ± 3.56	1.99 ± 0.15	2.95 ± 0.20	(Costa et al., 2019)				
Mesocarpa	Presence	Yellow-green	30.05 ± 2.15	3.14 ± 0.22	3.03 ± 0.13					
Macrocarpa	Presence	Red-green	52.30 ± 1.98	4.68 ± 0.10	5.63 ± 0.32					
Macrocarpa	Presence	Yellow-red	58	-	-	(Clement et al., 1998)				
Nutritional composition macrocarpa (g 100 g ⁻¹)										
Moisture	Lipids	Proteins	Ashes	Total fiber	Starch	Reference				
44.3	23.0	6.9	1.3	9.3	59.5	(Arkcoll & Aguiar, 1984)				
46 ± 0.42	5.93 ± 0.43	1.30 ± 0.09	0.72 ± 0.31	0.76 ± 0.12	44.32 ± 0.32	(Andrade et al., 2003)				
68.5	1.9	2.4	0.5	1.6	-	(Ferreira & Pena, 2003)				
47.0 ± 3.5	7.7 ± 3.2	2.3 ± 0.4	0.6 ± 0.1	6.6 ± 1.5	-	(Yuyama et al., 2003)				
43.90-65.39	8.25-40.83	4.20-6.47	1.08-2.54	0.87-3.40	-	(Carvalho et al., 2013b)				
50.69-57.76	2.24-5.50	1.39-2.54	1.15-1.37	-	-	(Costa et al., 2019)				
47.98-63.96	2.62-6.88	2.00-3.90	0.80-2.74	-	-	(Pires et al., 2019)				
Essential minerals composition macrocarpa (100 g ⁻¹)										
Ca (mg)	K (mg)	Na (mg)	Mg (mg)	Cl (µg)	Mn (µg)	Zn (µg)	Se (µg)	Iron (µg)	Cr (µg)	Reference
21.8 ± 2.4	206.4 ± 3.3	12.6 ± 2.0	17.6 ± 1.0	30.7 ± 3.7	82.6 ± 8.7	278.3 ± 30.4	11.4 ± 0.7	739.3 ± 130.5	13.9 ± 0.9	(Yuyama et al., 2003)
800	2000	500	350	2.0-5.0 (mg)	15	70	10	50-200	8.2 ± 0.4	RDA
2%	12%	1%	5%	2%	5%	2%	9%	6%	9%	Mean contribution
Non-essential minerals composition macrocarpa (100 g ⁻¹)										
Au (ng)	Ba (µg)	Br (µg)	Ce (µg)	Se (ng)	Pa (µg)	Sb (ng)	La (ng)	Rb (µg)	Reference	
57.8 ± 2.2	103.9 ± 2.6	143.5 ± 8.7	2.1 ± 0.4	10.4 ± 2.6	60.9 ± 21.7	56.5 ± 17.4	521.8 ± 87	491.4 ± 39.1	(Yuyama et al., 2003)	
Fatty acids composition macrocarpa (g 100 g ⁻¹)										
				Clement et al. (1998)	Yuyama et al. (2003)	Osorio et al. (2012)				
Lauric 12:0				-	-	0.014-0.015				
Myristic 14:0				0.42-0.52	-	0.105-0.147				
Palmitic 16:0				26.6-47.4	24.1-42.3	34.0-39.9				
Palmitoleic 16:1				5.09-6.72	3.9-7.4	7.9-10.8				
Stearic 18:0				1.84-3.27	0.8-3.5	1.0-1.6				
Oleic 18:1				37.0-49.9	42.8-60.8	38-51.9				
Linoleic 18:2				1.19-1.73	2.5-5.4	2.4-8.6				
Linolenic 18:3				2.10-6.35	0.0-1.4	0.2-1.5				
Σ Saturated fatty acids (SFA)				28.86-51.19	24.9-46.0	36.1-41.7				
Σ Monounsaturated fatty acids (MFA)				42.09-56.62	46.7-68.2	45.9-62.7				
Σ Polyunsaturated fatty acids (PFA)				3.39-8.08	2.5-6.8	6.2-10.1				
Ratio PFA/SFA				0.12-0.16	0.05-0.27	0.06-0.25				
Amino acids composition (% g N)										
Essential										
Phenylalanine	Histidine	Isoleucine	Leucine	Lysine	Methionine	Threonine	Tryptophan	Valine	Reference	
2.4 ± 0.02	-	1.70 ± 0.05	3.14 ± 0.03	1.67 ± 0.06	0.80 ± 0.01	2.71 ± 0.08	0.45 ± 0.02	2.83 ± 0.09	(Yuyama et al., 2003)	
6.0	-	4.0	7.0	3.5	5.5	4.0	1.0	5.0	(FAO/WHO, 1973)	
Non-essential										
Aspartic acid	Glutamic acid		Alanine	Cysteine	Glycine	Prolamine	Serine	Reference		
4.43 ± 0.19	4.98 ± 0.33		-	3.51 ± 0.21	2.87 ± 0.06	2.57 ± 0.08	2.72 ± 0.31	(Yuyama et al., 2003)		

*Mean values of three repetitions ± standard deviation; At least one letter on the line does not represent a significant 95% difference. Results expressed in dry basis. RDA based on the recommended daily allowances for adult men in the 25-50 age range (NAS/NRC, 1989). - Values not cited by the authors.

biome is predominantly covered by a rain forest, characterized by a hot and humid climate and heavy rains, which are often incident throughout the year (Chisté & Fernandes, 2016). Due to this particular environment, the Amazon hosts several fruit species that are widely consumed by the local population, found

in markets and local fairs (Matos et al., 2019) that are still little explored and represent economic potential to contribute to the food, pharmaceutical and agro industrial fields.

Among the species, the peach palm (pupunha: Brazil; chontaduro, cachipay: Colombia; pejiabay: Costa Rica; chontaruro:

Equador; pijuayo: Perú; gachipaes: Venezuela) is a palm tree belonging to the *Arecaceae* family, native representative from Americas, fully domesticated in the Amazon region, with a great variety of races and ecotypes (Bezerra & Silva, 2016; Bolanho et al., 2014).

The peach palm (Figure 1) is a caespitose palm (multicaule) that can reach up to 20 m in height. The stem diameter ranges from 15 to 30 cm and the internodes length from 2 to 30 cm. The internodes are armed with numerous rigid spines from black to dark brown. However, the species commonly used for palm heart production include those that do not cultivate spikes in the peduncle, which facilitates their handling, cultivation and process (Bezerra & Silva, 2016).

The species commonly used for palm heart production include those which are cultivated without spines on the peduncle and it facilitates the handling, processing and higher yield of the fruits (Morera, 1988; Moro, 1993). The peduncle supports a crown of 15 to 25 pinnate leaves, with the leaflets inserted at different angles. The unopened tender leaves, located in the center of the crown,

form the palm heart, an important economic product. The palm heart is removed from the top of the stem corresponding to the central part, with pleasant taste, smooth and low calorie (Bezerra & Silva, 2016). The monoic inflorescence appears in the armpits of the senescent leaves. After pollination, the bunches may contain between 50 and 1000 single seed fruits, and weigh from 1 to 25 kg. Several factors, such as nutrition or poor pollination, drought, competition, insect attacks and diseases can cause decrease in fruit production and contribute to the low average weight of the bunch. The individual fruits weigh between 10 and 250 g (3 to 4 cm in diameter) (Arkcoll & Aguiar, 1984; Clement & Mora-Urpí, 1988), with epicarp and mesocarp ranging from yellow to orange (Chisté & Fernandes, 2016).

The multiple origin of peach palm and the segregation of its hybrids increased the high genetic diversity (Figure 2) (Clement, 1986; Clement & Mora-Urpí, 1988), therefore, there is visible variability in the fruit shape, color, fibrosis, oil content, starch content, among others. Thus, there are no definite varieties of peach palm, distinguished by “primitive races” or ecotype,



Figure 1. Thorny peach palm tree and smooth peach palm tree (Graefe et al., 2013).

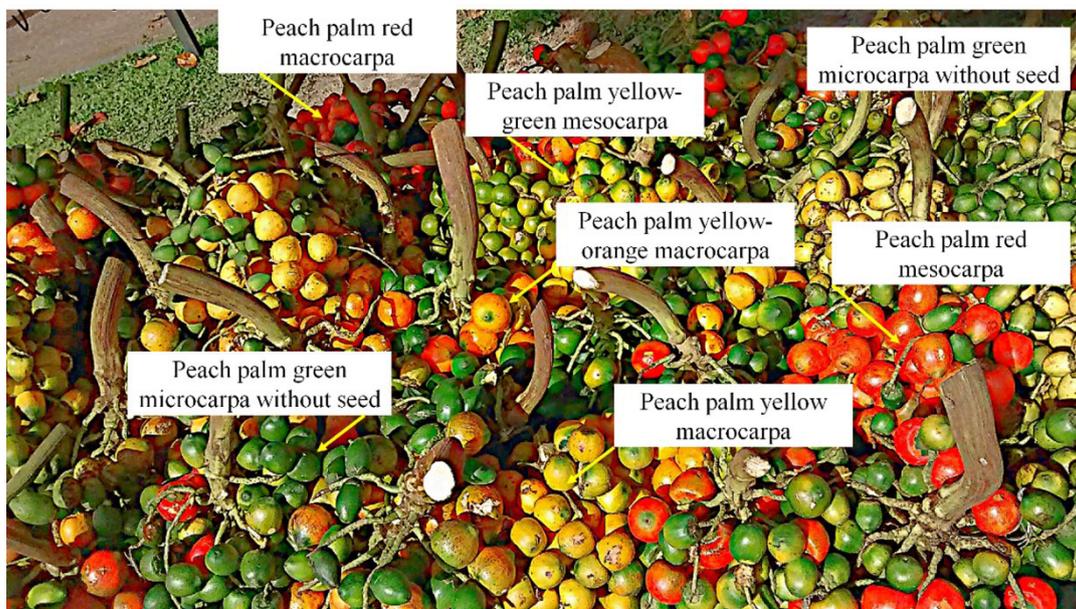


Figure 2. Bunches of peach palm marketed in the metropolitan area of Belém (Pará).

which are sets of populations of distinct origin, selected and cultivated by a distinct ethnic (Clement & Mora-Urpí, 1988). In some studies, there are at least three distinct peach palm races, with different colors, flavors, and nutritional constituents (Clement et al., 2004; Costa et al., 2019). The main criterion for classification of fruits is through the thickness of the pulp, separating the peach palm groups in microcarpa, mesocarpa, and macrocarpa. The microcarpa race has small fruits, relatively little pulp compared to seed volume and the pulp is generally fibrous and oily. The mesocarpa and macrocarpa progressively have larger fruits, with a higher pulp percentage in relation to microcarpa, higher starch content and lower lipids (Costa et al., 2019; Mora-Urpí et al., 1997). Studies that correlate physical characterization and chemical composition data show that generally smaller fruits tend to be more fibrous and oily, while larger fruits tend to be rich in starch, with these two major components (starch and lipid) in an inversely proportional ratio (Bezerra & Silva, 2016; Costa et al., 2019; Leterme et al., 2005). The observed variation demonstrates the importance of determining the chemical composition within each race and/or population of interest to the consumers or the agroindustry, aiming the quality of the fruits.

3 Physicochemical composition

The peach palm fruit presents high levels of dietary fiber, lipids, carotenoids (β -carotene, γ -carotene, lycopene), minerals, essential amino acids (Table 1) and low levels of sodium and sugars (Rosso & Mercadante, 2007; Espinosa-Pardo et al., 2014; Rojas-Garbanzo et al., 2011). In the Amapá state, through the government program of sustainable development, the peach palm was included in the school menus due to its nutritional composition. The fruits were used in the preparation of porridges or mixed with savory dishes, presented good preference (Brasil, 2015).

In a study by Yuyama et al. (2003), investigating the chemical composition of the mesocarp of three peach palm trees located in Central Amazonia, it was concluded that, in terms of the recommended daily consumption for an adult male in the 25-50 years age group (National Academy of Sciences/National Research Council, 1989), the average contribution of peach palm fruits for mineral elements was low (Table 1). The biological importance of non-essential minerals present in peach palm is unknown, however, traces can be found in animal and plant tissues (Jane et al., 1992).

Due to its nutritional content, the peach palm is considered a fruit of excellent energy value. The absence of gluten and starch richness make this raw material interesting for the development of new products in patients with celiac disease (Bezerra & Silva, 2016). Nevertheless, it must be assumed that the fruit cannot be consumed fresh due to the presence of anti-nutritional factors (calcium oxalate salts, lectins, some polyphenols, saponins and inhibitors of amylase and trypsin) (Bezerra & Silva, 2016; Rojas-Garbanzo et al., 2011). The ingestion of small doses is sufficient to cause intense burning sensation in the mouth and throat, swelling of the airways and suffocation, and if ingested in large doses, it may be fatal. Recovery from poisoning by large doses of calcium oxalate is possible, however the liver and kidneys are permanently affected.

Traditionally, the peach palm fruit is consumed in a unique way in the majority of countries where it is cultivated. After separated from the bunch, the fruits are boiled in salt water at times ranging from 30 to 60 minutes, depending on the variety of the fruit, they are peeled and split lengthwise, then the seeds are extracted and ready for consumption (Chisté & Fernandes, 2016; Mandel, 1996).

Carrera (1999) studied the chemical and physical properties of isolated starches from six Phenotypes of peach palm, and the starch found represented most of the nutritional composition, suggesting that the fruit is an excellent source of starch in the Amazon region. Jane et al. (1992) studied the isolated starch of peach palm from different parts of Costa Rica and its gelling and thermal properties, the authors found that the concentration of amylose varied from 8 to 19% and the phosphorus content from 0.049 to 0.054%. Amylopectin branch chain lengths determined by the fraction peak showed degrees of polymerization of 18 and 30 for short and long chain, respectively. The authors attributed variations in physical properties mainly to differences in amylose content and amylopectin structure (Jane et al., 1992).

The peach palm nutritional composition varies depending on the ecotype and geographic region due to the conditions of cultivation, climate and soil of the region, that present great influence on the growth and development of the fruits (Blanco et al., 1990).

Rojas-Garbanzo et al. (2016) in their studies found a significant difference ($p < 0.05$) in the moisture content of three lots of peach palm harvested in Pérez Zeledón (Costa Rica); however, no variability was found between the Tucurrique (Costa Rica) lots. Among the components analyzed, only the starch content did not present significant differences ($p > 0.05$) between lots from the same area and between regions. This result is extremely important, since the types of products that can be developed from the peach palm fruits are subject to the content of starch (puree, biscuits, bread, cake), therefore, the standardization of the physicochemical characteristics of raw material allows the standardization of the final product quality.

Yuyama et al. (2003) reported peach palm fruits as source of eight essential and non-essential amino acids (Table 1), such as tryptophan and methionine. Although its amino acid content is lower than the minimum daily intake recommended by the Food and Drugs Agency (2018), it is important to consider the peach palm as a source of daily protein requirements for adults and children. It was reported that the protein content of peach palm fruits is not affected by cooking (30 min in boiling water), with a final protein content of 5.0 ± 1.1 g 100 g⁻¹ (wet basis) in cooked peach palm pulp (Rojas-Garbanzo et al., 2012).

Cysteine was the non-essential amino acid found with the highest amount among flours, being relatively higher in peach palm fruit flours that were not cooked (2.32 to 2.64%), for samples without shell and with shell, respectively, and 2.48% for the flours that have undergone the cooking).

From a nutritional point of view, the protein of the peach palm fruit is of low biological value, a common occurrence in products of plant origin, with methionine and lysine being the most limiting amino acids.

The most important mineral elements found in the peach palm are potassium, selenium and chromium (Yuyama et al., 2003). Fiber is another component present in peach palm, with a concentration varying from 2 to 10 g 100 g⁻¹ of fruit. Due to the functional properties of the fibers, the interest for the production of products with higher percentage of nondigestible fractions increases, because they are not initially digested by organisms, they are fermented by microorganisms in the intestines, producing compounds (butyrate, ethyl and propionate) that can exert a positive action on the individual's health (Bezerra & Silva, 2016).

Quesada et al. (2011) reported a low glycemic index of 35 mg dL⁻¹ in pejobay compared to white bread. Foods with low glycemic index are considered to be beneficial for patients with diabetes and coronary heart disease because the released sugars are absorbed more slowly (Graefe et al., 2013).

Studies involving the proximate composition show carbohydrate values ranging from 50 to 80%, represented mainly in the form of starch (Bezerra & Silva, 2016; Fernández-Piedra et al., 1995; Quesada et al., 2011).

In addition to direct consumption, peach palm can be used as a raw material for the production of various products, especially in the form of flour (Pires et al., 2019; Valencia et al., 2015), oil (Melhorança & Pereira, 2012), pasta (Oliveira et al., 2006; Sakurai et al., 2019), edible film (Costa et al., 2019), fermented beverage (Andrade et al., 2003), bacterial substrate for amylase production (Oliveira et al., 2007) and functional food products (Rojas-Garbanzo et al., 2012).

Information on peach palm fruit starch in the literature is still scarce. However, in the study reported by Valencia et al. (2015), the starch content found in peach palm (84.5%) was compared with the content of cassava starch and starch isolated from a non-conventional source such as the "Cavendish" banana variety. Regarding the structure of the peach palm starch, they are presented in different forms, such as spherical and oval, with predominance of truncated form on one side, as this form is observed in tapioca starch granules and modified tapioca starch (Liu, 2005; Makmoon et al., 2013; Valencia et al., 2015).

The high amylose content found in peach palm starch (19.3%) indicates that this type of starch can be used as raw material for the preparation of films and coatings to be used in food products (Valencia et al., 2015).

A previous study reported that the peach palm oil contains omega-3 (linolenic acid), omega-6 (linoleic), and omega-9 (oleic acid) fatty acids, commonly associated with decreasing in Low Density Lipoprotein (LDL) levels and risk of cardiovascular diseases (Bezerra & Silva, 2016). However, the fruits present high variability between the bunches and the harvest season (Arkcoll & Aguiar, 1984; Graefe et al., 2013). Carvalho et al. (2013b) reported that Wistar rats supplemented with red peach palm before and after lactation showed increasing in High Density Lipoprotein (HDL)-cholesterol, as well as reduction of body weight, total cholesterol and triglycerides. In this sense, peach palm pulp oil can be considered a good option for human consumption (Clement et al., 1998; Osorio et al., 2012).

Regarding to the saturated fatty acids (Table 1), palmitic acid was the one with the highest concentrations in the peach palm pulp, but in the seed, the predominant fatty acids are the lauric and myristic ones. According to Carvalho et al. (2013a), the moisture content, lipids and carotenoids are the components that best represent the genetic diversity of the peach palm. The B02-P30 matrix had the highest lipid content, with values between 8.25 and 40.83%. Ferreira and Pena (2003), in a study on the hygroscopic behavior of the peach palm flour, observed a lipid content ranging from 6.1% to 9.8%. However, Oliveira et al. (2006) and Carvalho et al. (2009) reported values of 11.56% and 10.3% lipids, respectively, in peach palm flour studies.

Due to the high concentration of oleic fatty acid the peach palm oil has a high nutritional value, liquid at room temperature and less suspect to oxidation compared to oils with a higher proportion of linoleic acid (Santos et al., 2017).

Another property that can be observed for peach palm is the antimicrobial activity of the oil extracted from the bark of two species (Table 2). Significant levels of carotenoids are found in peach palm (Bereau et al., 2003). Vitamin A deficiency is a serious public health problem and mainly affects children, causing clinical manifestations known as night blindness (Bereau et al., 2003). Peach palm is considered a good strategy to prevent or remedy vitamin A deficiencies. Since, once added in the diet, it increases the hepatic content (Bezerra & Silva, 2016; Yuyama et al., 1991; Yuyama & Cozzolino, 1996).

In order to deepen researches on genetic improvement of peach palm tree species, cultivated in the Northern Brazil, the peach palm pulp total carotenoid content ranged from 0.8 to 12.4 mg 100 g⁻¹, among 21 genotypes developed by the Brazilian Agricultural Research Corporation, and demonstrated wide variation among fruits of the same species, grown in the same region (Carvalho et al., 2013b).

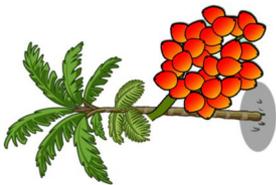
Furtado et al. (2004) studied the concentration of carotene, trans- β -carotene, cis- β -carotene, and carotenoids in vegetables and fruits commercialized in Costa Rica, reporting values for peach palm of 4.2, 59.1, 93.2, 20.5 and 63.7 $\mu\text{g g}^{-1}$ for α -carotene, trans- β -carotene, cis- β -carotene, trans-lycopene and cis-lycopene, respectively.

Blanco & Muñoz (1992) found similar carotenoid contents in fresh and cooked peach palm, and determined that the retention of nutrients after cooking is greater than 85%. Rosso & Mercadante (2007) quantified carotenoids in six Amazonian fruit species and found that peach palm is a good source of provitamin A, with a total carotenoid content of 19.80 mg 100 g⁻¹. Rojas-Garbanzo et al. (2011) identified nine carotenoids in fresh peach palm from Costa Rica, the most predominant as the β -carotene.

Costa et al. (2019) found values of total carotenoids of 57.0, 95.6 and 79.8 $\mu\text{g g}^{-1}$, for micro, meso and macrocarpa peach palm ecotypes, respectively.

In a study performed by Matos et al. (2019), it was verified a high peach palm peel potential for carotenoid prospecting as a strategy for valorization of the product with no current commercial value. The content of carotenoids in the peel was ten times higher

Table 2. Peach palm fruits biological activity.

Peach palm (<i>Bactris gasipaes</i>)	Peel color	Source	Effect	Reference
	Red-green		Antioxidant activity Glycemic index In lactation metabolic index in rats Absence of gluten and richness of starch	Increased carotenoid availability after cooking Lower glycemic index levels in wistar rats Body weight reduction, total cholesterol Development of products for patients with celiac disease
	Green			
	Yellow-green			
	Yellow-red			
	Yellow			
	Orange		Antimicrobial activity Antioxidant activity Total soluble and insoluble fibers	Inhibitory effect against <i>S. aureus</i> , not effective against <i>P. aeruginosa</i> Higher antioxidant activity in peel than pulp Development of bakery products for people with celiac disease
	Red			

(33.69 mg 100 g⁻¹) than in the pulp (3.18 mg 100 g⁻¹). Besides the pro-vitamin A activity of some carotenoids, the consumption of foods rich in this compound is associated with increased immune response and reduced risk of degenerative diseases such as cancer, macular degeneration, cataracts and cardiovascular diseases (Table 2). Carotenoids can also undergo changes due to degradation during the process of prolonged cooking of the food and its storage through the action of enzymes, light and oxygen. Thus, vegetable and fruit dehydration can reduce the biological activity of carotenoids (Sentanin & Amaya, 2007).

In the study performed by Rojas-Garbanzo et al. (2012), the authors reported that the content of total carotenoids was influenced by the cooking and drying of peach palm, where the samples presented an increase of 17% in carotenoids in the fresh peach palm. The cooking process softens both cell walls and macromolecules, such as fatty acids and proteins that encapsulate carotenoids, making them more available.

The peach palm gas chromatography analysis revealed the existence of several δ -5-sterols, cholesterol, campesterol, stigmasterol, β -sitosterol and δ -5-avenasterol). A High Performance Liquid Chromatography (HPLC) study of tocopherols and tocotrienols showed that α -tocopherol predominates in the bands standards (Lubrano & Robin, 1997). Bereau et al. (2003) reported low levels of vitamin E in peach palm samples; however, the results of antioxidant activity were more similar to the olive oil than palm oil. Tocopherols have a chemical structure similar to cholesterol, with a bactericidal, fungicidal and anti-inflammatory action. Studies have shown that these compounds play an important role in reducing blood cholesterol by blocking its absorption (Tango et al., 2004; Ye et al., 2010).

4 Marketing and consumption

Products made from the peach palm or peach palm tree as palm heart (Table 3), are considered great economic potentials for the national and international markets (Godoy et al., 2007; Graefe et al., 2013).

Some evidence suggests that red and lower lipid content peach palm are preferred for the production of canned fruits and jellies (Graefe et al., 2013). Since damaged or deformed fruits can be used in the elaboration of flour (Godoy et al., 2007).

Table 3. Main products made from peach palm found in the literature.

Peach palm variety	Product	Reference
Micro, meso and macrocarpa	Edible films	(Costa et al., 2019)
Mesocarpa	Fermented drink	(Mora-Urpí et al., 1997)
	Pickled	(Pelais et al., 2017)
Microcarpa	Oil	(Arkolli & Aguiar, 1984; Ordoñez-Santos et al., 2019)
Micro, meso and macrocarpa	Peach palm flour and starch	(Pires et al., 2019)
-	Cake mix	(Martínez-Girón et al., 2017)
-	Snacks	(Carvalho et al., 2009)
Microcarpa	Pasta	(Oliveira et al., 2006; Sakurai et al., 2019)

In Cali (Colombia), peach palm has reached a visible presence in large supermarkets and malls, where fruits are sold fresh and more limited quantities of processed fruits are available on the shelves. The processed fruits are vacuum packed or canned in brine or processed into marmalade. In the city of Popayán (Colombia), the peach palm chips are sold in small packages. Despite just entering in major markets, it is believed that the chips have great potential (Graefe et al., 2013).

In Brazil, more specifically in the Amazon, the peach palm fruits are marketed in nuns or supermarkets, and fruits with oily characteristics are the most sought by the population (Bezerra & Silva, 2016). In order to know if the fruit has this characteristic, consumers traditionally grind a piece of raw peach palm between the fingers and rub it to identify the oily aspect (Godoy et al., 2007).

In a study performed for the preparation of canned peach palm, the sensorial analysis presented excellent results demonstrating that there were no significant differences between the flavor of the canned fruit and the cooked one (Pelais et al., 2017).

Tracy (1987) determined that 10% peach flour could serve as a substitute for wheat flour in the baking industry, producing an excellent baking quality.

The peach palm was also studied for possible use in mass production from a mixture of 15% peach palm flour and 85% wheat flour. In the cooking tests of spaghetti and spiked pasta, the addition of peach palm flour to the dough did not significantly change its quality and texture (Oliveira et al., 2006).

However, in a later study, the addition of cassava starch, peach palm flour and gilded linseed allowed the production of well-structured dry pasta. In addition, the mass had a good rate of acceptance and intention of purchase by the tasters (Sakurai et al., 2019).

Rosa et al. (2016) developed a pre-mix for cake with peach palm (*Bactris gasipaes* Kunth) flour, free of gluten. It is important that the market offers bakery products containing the same sensory and nutritional quality as products that present gluten to people with celiac disease (Tracy, 1987).

Martínez-Girón et al. (2017) developed cakes with different proportions of peach palm flour, and the authors found in their studies that the peel flour can be considered as a natural food coloring alternative for cooked products, in order to replace artificial food coloring, besides increasing the biological properties of cakes.

The indigenous peoples of the Amazon use peach palm fruits to produce *caçuma* or *cachiri*, a fermented alcoholic beverage similar to beer (Andrade et al., 2003; Graefe et al., 2013).

The peach palm in the form of flour is an alternative to avoid saturation of the fresh fruit market and to diversify its demand (Bezerra & Silva, 2016). Peach palm flour was used in the production of extruded maize products and may be considered an interesting ingredient to improve the carotenoid content, since the extrusion process did not decrease the carotenoid content in the product (Basto et al., 2016).

Rojas-Garbanzo et al. (2011) studying the identification and quantification of carotenoids in peach palm flour concluded that more research is needed to control the effects that processing and storage have on carotenoids and their bioavailability.

In a later study, Rojas-Garbanzo et al. (2012) found that peach palm flour can also be used as an ingredient rich in bioactive compounds for the formulation of functional foods.

The peach palm flour was also used for the elaboration of ice cream cone and they presented high content of carotenoids in comparison to the traditional cones. In addition, the peach palm flour showed similar texture to the cones made with wheat flour (Sakurai et al., 2019). It is noteworthy that the peach palm ice cream cone does not contain gluten, providing consumption by new markets, such as the celiac disease one (Santos et al., 2017). Therefore, the possibility of developing gluten-free products such as peach palm flour may increase the supply of food products to individuals with celiac disease and contribute to a more diversified diet for this population group.

For the first time, the potential use of the peach palm peel, which is considered agro industrial residue in Brazil, was investigated for the quantification and identification of carotenoids and it can be concluded that the peach palm peel has a high potential to be used as a source of carotenoids by food, cosmetic and pharmaceutical industries as bioactive colorants and/or ingredients (Matos et al., 2019).

A dehydrated product with film characteristics based on peach palm and *tucupi* was studied by Costa et al. (2019) and they obtained a product with superior technological quality, considered as a good source of energy value and carotene. And depending on the characteristic of the variety used, the product can be applied as a separator of components, as in pizzas, which the dough has low moisture and the filling has high moisture, to replace the algae in sushi, as protection of foods with high activity of water or to prevent the exudation of fresh or frozen products.

5 Conclusion

The peach palm fruit, fresh, cooked or dried, may be considered as a source of bioactive compounds with significant antioxidant capacity, and its carotenoid content is higher than that found for other tropical fruits such as banana, mango, melon and papaya. Despite its low protein content, peach palm contains all essential amino acids, with methionine and lysine present at levels below those recommended. Peach palm provides few essential minerals, with an emphasis on potassium, selenium and chromium, which are present in amounts corresponding to 12, 9 and 9% of the recommended daily rates, respectively. Flour is the main form of processing and conservation of peach palm fruit and can be used as an ingredient for the formulation of functional foods, considered an excellent source of carbohydrates (59%) and energy (417 kcal 100 g⁻¹). The addition of the peach palm peel increases the content of carotenoids, fatty acids and dietary fibers. This review suggests that the processing and marketing of peach palm have a significant potential to increase food security and fruit yields. To perform these potential gains, participatory research is needed that directly engages stakeholders

and addresses multiple challenges in the different stages of industrialization and marketing.

Conflict of interest

The authors declare no financial interests or personal relationships to influence the present study.

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