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REVIEW ARTICLE

Towards chemical characterization and possible applications of juçara fruit: an approach to remove *Euterpe edulis* Martius from the extinction list

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Abstract Juçara (*Euterpe edulis* Martius) is a palm widely distributed in the Atlantic Forest. It produces a non-climacteric, black-violet small fruit similar to the Amazonian açaí (*Euterpe precatoria*). The fruit is known as *superfruit* because it presents chemical characteristics of great importance, such as anthocyanins content. Regarding bioactive compounds and antioxidant scavenging capacity, it presents high anthocyanin (634.26 to 2,929 mg of cyanidin-3-glucoside 100 g^{-1}) and total phenolic compounds (415.1 to 9,778.20 mg equivalents of gallic acid 100 g^{-1}) contents. The soluble solid content ranges from 3.0 to 4.9% and its pH is higher than other tropical fruits (4.8 to 5.6). Despite the rich bioactive compound content of juçara fruits, this plant has been traditionally used for palm heart production. The accelerated and illegal palm heart exploitation, without the use of an adequate management has led to the risk of extinction of this species. In order to prevent this species from vanishing, several studies have valued the health characteristics of juçara fruit chemical composition. An economical approach has been the production of juçara pulp described as a source of bioactive compounds, which has attracted the attention of industrial field aiming the production of functional foods, foodstuff, cosmetics and pharmaceutical products. A full botanical and chemical characterization of juçara tree and fruit is presented in this paper, as well as suggestions to increase the use of this tropical fruit and derivatives.

Keywords *Euterpe edulis* Martius · Juçara · Brazil · Health benefits · Market potential · Application

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Introduction

The Brazilian Atlantic Forest is one of the most biologically diverse and threatened regions on the planet (Maier et al. 2019). Vanishing of *E. edulis* poses a danger to the Atlantic Forest fauna. More than 48 birds and 20 mammal's species have juçara seeds and fruits as their main source of nutrients. Toucans, guans, thrushes and bellbirds are the main seed-dispersal agents, while agoutis, tapirs, peccaries, squirrels and other animals benefit from its nutritive fruits (Moon 2017). In such a scenario, juçara palm has been described as one of the most important species for the maintenance of the Atlantic Forest biome in Brazil, which covers from the state of Bahia (10°00'S) to northern Rio Grande do Sul (30°00'S), with a coastal geographic distribution, as well as the riparian forests of the states of Minas Gerais, Goiás, Mato Grosso do Sul, São Paulo and Paraná (Fig. 1) (Reis et al. 2000). Juçara palm is also found in the gallery forests of the Cerrado, forests in Paraguay and northern Argentina (Trevisan et al. 2015).

Native small producers from these regions have juçara culture as a relevant profitable activity, as each part of the plant has different applications. The risk of extinction is considered an important issue for the local population (Conab 2016). In a sustainable approach, the whole tree can be used in different ways (Fig. 2): palm leafs and body provide material for construction and handicrafts, and root and oil can be used in folk medicine for the treatment of respiratory diseases such as flu and pneumonia (Macía et al. 2011). The fruit of juçara is considered a valuable part of the tree, being commonly commercialized in pulp

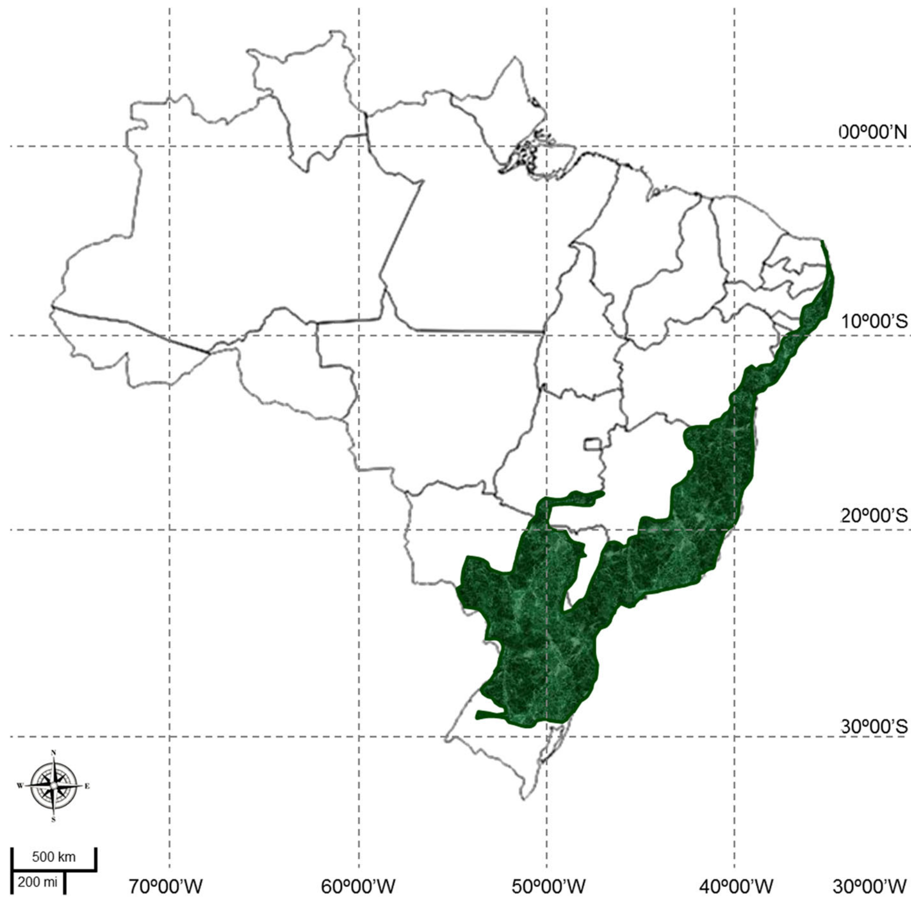

Fig. 1 Original Atlantic Forest in Brazilian territory Legend: ~ Brazil states. Datum WGS-84

form, which consists of fragments of epicarp (peel) and mesocarp (pulp) obtained after softening and depulping through technological processes. Fibers originated from the mesocarp can be used in the manufacture of bakery products, and the hard seed, adherent to the endocarp, can be used as filter in water treatment, as fertilizer or for the production of seedlings that can be used for continuous growth and reforestation of the extinction areas (Pereira et al. 2017).

Juçara fruit can come of native forest (extractivism) or cultivated forests. No data on fruit production has been collected so far by the Brazilian Institute of Geography and Statistics; consequently, there is no information on the amount of fruit produced yearly. However, the Ministry of the Environment of Brazil ranked the main production areas in the country: Santa Catarina, São Paulo, Rio Grande do Sul, Rio de Janeiro and Espírito Santo (Conab 2016). According to Conab - National Supply Company (2016), fruit production can achieve 193 tons per year, being the state of Santa Catarina, in the south of Brazil, the largest producer, concentrating 84% of juçara production (Conab 2016). Juçara pulp commercialization has also increased considerably, driven by the açaí market that negotiates about 40 thousand tons of pulp per year. The minimum price of juçara and açaí fruit is US$ 0.78 and US $ 0.42 per kg, respectively, with the pulp price being about five times higher than the *in natura* fruit (Conab 2019). Nowadays juçara pulp is no longer just a product that aims to increase the income of small local farmers, it has become a valuable raw material. A greater profit can be obtained from the industrialization and consumption of juçara fruit rather than from wood production, which reinforces the need for increasing its utilization. The production of juçara fruit may be estimated as 2.5 bunches per tree/year which corresponds to approximately 8 kg of fruits per palm tree. In an already established seven-year-old plantation the total fruit yield was 2,500 kg per hectare per year, reaching a total income of US$ 25,886.47, being more profitable than what was obtained from wood market (US$ 3,997.78) (Maier et al. 2019).

For almost a century, juçara palm has been commercially valued only for the extraction of its palm heart, which consists in cutting the whole palm. In the 1970s, Brazil became the world's major producer, consumer and exporter of juçara palm heart. In 2001, the Brazilian market consumed 100,000 tons/year of juçara palm heart, equivalent to an area of 130,000 hectares, and juçara tree alone accounted for almost 97% of the Brazilian palm heart marketed, which almost dragged it into extinction. In 1995, Brazil continued to be the main producer and consumer of palm heart, exporting 30% of the production (Corpei 2001). However, in 2008 juçara was classified as an endangered species in accordance with Normative Instruction n. 06, from September 23, 2008, which defines the "Official List of the Brazilian Flora Threatened to Extinction" (Brazil 2008), due to deforestation and illegal extraction of palm heart. In 2016, Brazilian Law n° 6,209 (Brazil 2016) instituted the Policy of Incentive to the Cultivation of Vegetable Species, which included the obtainment of palm heart and fruits. This new policy had the purpose to stimulate a sustainable management of native species; the installation of agroindustry for processing and packaging of derived products; and the acquisition of necessary machinery and equipment. All those points together intended to reduce the consumption of palm heart obtained from predatory extraction, which represented approximately 80% of the palm heart consumed in the country. In an attempt to encourage a more sustainable management, the surveillance of juçara palm heart illegal trade has been intensified, and at the same time, the exploitation of fruits considerably increased as the pulp has become a more commercially interesting product.

Studies on the biochemical composition of juçara indicated that it can be considered a "superfruit" due to its nutritional value and content of bioactive compounds, such as anthocyanins, which can suggest its utilization in formulations of products with functional allegation (Felzenszwalb et al. 2013; Ribeiro et al. 2019a, 2019b). There is no determination for specific content of bioactive compounds to classify a superfruit, however it can be considered as a marketing term which refers to fruits that have exceptional nutritional quality and possible health benefits, such as high antioxidant (Cbi, 2016). According to the research platforms (Scopus and Sciencedirect), over the last 20 years, studies concerning juçara fruit has been mainly conducted by five areas: (i) Agricultural and Biological Sciences (55%), (ii) Environmental Science (13%), (iii) Biochemistry, Genetics and Molecular Biology (9%), (iv) Medicine (8%) and (v) Chemistry (5%). Other areas are responsible for 10% of the publications.

This review aims to present juçara's botanical aspects, traditional culture, innovative products, biochemical composition and observations about production chain and current market. The focus on its potential applications has the objective to increase its visibility contributing to the specie's preservation.

Botanical and morphological description

The family *Arecaceae* (Palmae) is represented by approximately 3500 species, with about 240 genera, and has tropical palm trees species naturally found in the Americas as representative members (Vedel-Sørensen et al. 2013).

Palm heart can be harvested from several palm species; however the main tradable sources are juçara palm (*Euterpe edulis*), peach palm (*Bactris gasipaes*) and açaí palm (*Euterpe oleracea* and *Euterpe precatoria*). While *E. edulis* is native to the Brazilian Atlantic Forest, the other species are from the Amazon (Moon 2017).

E. edulis is a palm tree with approximately 15 m of height, and 15 cm of stipe diameter. The apex has a group of pinnate leaves, with about 2.0 to 2.5 m length that stand out easily from the plant (Soares et al. 2014) (Fig. 2a). At the base of the stipe, there is a visible cone of roots colored from brown to red.

An important feature of juçara is that it is a single stem palm, therefore it does not produce tillers. This characteristic results in the death of the plant during the extraction of the palm heart. Another important characteristic is that *E. edulis* takes 8 to 12 years to produce high-quality palm heart, whereas *B. gasipaes* palm can be harvested just 18 months after planted. Over the time, adult trees produce less seeds resulting on a reduction on dispersal and germination, leading to population decline and possible extinction (Moon 2017). Moreover, its germination is slow and uneven, as occurs with the majority of palm species, being influenced by intrinsic factors and related to the environment (Tiberio et al. 2012). For this reason, the use of fruits from juçara palm tree has emerged as a form of sustainable exploitation.

Juçara fruit is non-climacteric, small and rounded, with a color that varies from green to black-violet during the ripening process. The average fruit weight is approximately 1.7 g with a diameter of 1.5 cm. It has a very thin fibrous-fleshy mesocarp, with hard endosperm that constitutes 87.5% of the diameter of the fruit and up to 90% of its weight (Fig. 2b–e) (Bicudo et al. 2014). Each palm produces on average three inflorescences that generate bunches with 3 to 5 kg of fruits, and each kg of fruit contains approximately 750 units. Harvest period goes from April to November, with differences among Brazilian states (Conab 2016).

Chemical composition

Physico-chemical and nutritional characteristics

In Brazil, palm heart is defined as the edible part of palm from the Palmae family, found mainly in tropical and subtropical climates. It is the white, soft and fibrous tissue found in the palm's stem. Palm heart from juçara tree (*Euterpe edulis*) is considered the favorite for both international and Brazilian consumption (Corpei 2001; Fantini and Guries 2007). However, currently extraction in an extractive manner is not allowed due to the risk of extinction. The chemical composition may vary according to season and soil. According to Table 1 (Online Resource) juçara fruit presents richer composition when compared to palm heart, mainly regarding phenolic compounds and vitamin C. In this case, the fruit can be considered a better source of bioactive compounds with antioxidant activity. Nowadays, besides the sustainable concern that is more widespread, people are more interested in a healthy diet, which can lead to an increase in the consumption of foods with a natural colors and functional appeal (Ali and Rahut 2019; de Mejia et al. 2020). In this way, juçara fruit has more technological and nutritional advantages than palm heart, consequently increasing its commercial value.

According to other chemical characteristics, the pH of juçara fruit and pulp ranges from 4.8 to 5.6 (da Silva et al. 2014; Inada et al. 2015; Moreira et al. 2017) and the content of soluble solids from 3.0 to 4.9% (Inada et al. 2015; Moreira et al. 2017). Other berries, such as blueberry and strawberry, generally contain about 15% soluble solids (Nile and Park 2014).

Juçara is considered a source of energy due to its higher lipid content in comparison with other fruits varying from 18.45 to 50.18% (w/w) in dry weight basis (dwb) (da Silva et al. 2014; Inada et al. 2015; Moreira et al. 2017). In other tropical fruits, such as araça, uvaia (da Silva et al. 2014), jaboticaba (Inada et al. 2015) and mango (Moreira et al. 2017), the total lipid content is much lower, varying from 0.19 to 2.2% (w/w), while in apple, papaya, banana, guava, kiwi, blackberry, red raspberry, strawberry, blueberry and cherry the lipid content varies from (0.1 to 0.42% w/w) (de Souza et al. 2014). Açaí pulp is the most similar to juçara pulp in relation to total lipid content (33.49–48.0% w/w) (Ferreira et al. 2016; Gordon et al. 2012). A study by Borges et al. (2011) identified 16 fatty acids in juçara fruit, with a predominance of monounsaturated fatty acids (45.53–56.82%), being oleic acid (44.63–55.61%) the major component. In that study, polyunsaturated fatty acids represented 18.79% to 26.03% of the total lipid content, and the main constituents were linoleic (18.19–25.36%) and linolenic (0.60–1.46%) acids (Borges et al. 2011; Schulz et al. 2015). The predominance of unsaturated fatty acids, such as monounsaturated fatty acids, is associated with the reduction of cardiovascular disease (Cheng et al. 2016; Ooi et al. 2015).

Saturated fatty acids represented 24.32% to 28.89% of total lipid content, mainly palmitic acid (20.25– 25.00%) (Borges et al. 2011). Other tropical fruits such as avocado, pineapple, banana, papaya, passion, watermelon and melon present lower concentrations of oleic and linoleic acids (0.02–36.7% and 0.25– 19.6% respectively) (Morais et al. 2017).

The fatty acids content in juçara pulp is essential for the digestion, absorption and transport of lipid soluble vitamins and phytochemicals, such as carotenoids (Pinard et al. 2014). Carotenoid content in juçara pulp and fruit was also determined. Values ranged from 414 μg 100 g^{-1} to

Table 1 Bioactive compound content and antioxidant scavenging capacity of juçara fruit and non-traditional Brazilian tropical fruits also considered *superfruits*

Fruits	Total anthocyanins[a]	Total phenolics[b]	Antioxidant capacity[c]	Reference
Juçara	634.26–2,929	415.1–9,778.20	2,400.14–6,450	Argentato et al. (2017)
				Cunha Júnior et al. (2016);
				Pereira et al. (2019); Peron et al. (2017); Moreira et al. (2017); Shanmugavelan et al. (2013)
Açaí	372.8–1,100	1,452–3,437	1,196–2,693.1	Alcázar-Alay et al. (2017);
				Ferreira et al. (2016); Garzón et al. (2017);
Acerola	18.9–215	914.2–1,738.9	1,605–9,660	Maciel et al. (2010); Mariano-Nasser et al. (2017); Rufino et al. (2010); Vasavilbazo-Saucedo et al. (2018)
Jabuticaba	58.1–315	460.9–2,420	1,200–6,000	Inada et al. (2015); Lima et al. (2011); Wu et al. (2012); Wu et al. (2013)
Jambolão	79–210.9	354.9–1,639.7	2,383–5,500	Brandão et al. (2011); Faria et al. (2011); Singh et al. (2016)

[a]mg cyanidin-3-glucoside equivalents 100 g^{-1} in dry weight basis; [b] mg gallic acid equivalents 100 g^{-1} in dry weight basis; [c] TEAC – Trolox Equivalent Antioxidant Capacity and ORAC – Oxygen Radical Absorbance Capacity (μmol of Trolox equivalents 100 g^{-1} in dry weight basis)

737.5 μg 100 g^{-1} of fresh matter (da Silva et al. 2014; Inada et al. 2015), which were greater than in other tropical fruits like açaí (Ribeiro et al. 2010), grumixama, araçá (da Silva et al. 2014), jaboticaba, blackberry, papaya, watermelon and guava (Inada et al. 2015). Carotenoids, which are isoprenoid secondary metabolites, present in the juçara pulp and fruit, can avoid vitamin A (retinol $C_{20}H_{30}O$) deficiency in mammals, due to their action as precursors of this compound (Álvarez et al. 2015). The major component was *all-trans*-lutein (2.9 mg 100 g^{-1}) and *all-trans*-β-carotene, *all-trans*-α-carotene and 9-*cis*-β-carotene (0.38 mg 100 g^{-1} to 2.7 mg 100 g^{-1}), both precursors of vitamin A (da Silva et al. 2014).

Carbohydrates are the most abundant macronutrients in plants, due to their cell wall composition. Fresh fruits vary greatly in their carbohydrate content. Juçara has low carbohydrate content (de Melo et al. 2016) representing a total dry matter content in the range of 28.3–42.5% (w/w) (da Silva et al. 2014; Guergoletto et al. 2016; Inada et al. 2015; Moreira et al. 2017). Those values were lower than in other fruits like grape, banana, melon, pineapple, papaya, jabuticaba, mango, araça, grumixama and uvaia (up to 90% w/w of total dry matter) (Hui 2006; Vicente et al. 2009; da Silva et al. 2014). Regarding the sugar profile, it is possible to find in juçara fruit mainly sucrose, fructose and glucose (Guergoletto et al. 2016). A study (Inada et al. 2015) showed values of fructose (0.5%) and glucose (0.3%) in juçara, approximately 10 times lower than in jabuticaba (*M. jaboticaba*, cv. Sabará) which can be an obstacle for its use on juice industry. This sugar content is also lower than in other fruits, such as grape, watermelon, Koren cherry, mango, peach and kiwi (4.00–12.64%) (Shanmugavelan et al. 2013).

Juçara fruit is considered rich in minerals. According to previous studies, the mineral content varies from 3.47 to 8.8% (w/w) (da Silva et al. 2014; Moreira et al. 2017). The mineral profile showed the presence of 17 chemical elements (phosphorus, sulfur, potassium, calcium, magnesium sodium, cobalt, aluminum iron, manganese, zinc, copper, nickel, selenium, cadmium, boron and molybdenum) (Inada et al. 2015; Schulz et al. 2015).

According to published data, a 200 g portion of juçara pulp has higher mineral levels than the Recommended Daily Intake (RDI), and it is significant for adults and children aged 7 to 10 years, mainly for magnesium, copper, zinc, iron and manganese, besides increasing the zinc intake of vegetarians, since the lack of meat in their diet leads to low levels of this mineral in the human body (da Silva et al. 2013).

Juçara fruit can also contribute to the daily intake of vitamins A, C and E (da Silva et al. 2014; Inada et al. 2015). A portion of 100 g of juçara contains 186 mg of ascorbic acid, two times higher than what is found in açaí fruits (84 mg 100 g^{-1}) (Rufino et al. 2010), and almost six times higher than in banana, mango and papaya (14–33 mg 100 g^{-1}) (Siriamornpun and Kaewseejan 2017). The consumption of juçara fruits also contributes to the dietary intake of vitamin E, as 200 g of fruits represent 4.5% of the RDI for adults.

Dietary fiber is one of the main components of plant foods and its importance in nutrition and health is widely recognized. Juçara fruit is a good source of dietary fiber (de Melo et al. 2016), a content of 27.1 to 28.3% (w/w) on dry weight was previously reported (da Silva et al. 2014; Inada et al. 2015). According to data (Inada et al. 2015), a 100 g portion of juçara pulp could provide approximately 17% of the recommended daily intake for fiber. Similar value of dietary fiber was reported for açaí fruits (*E. oleracea*), 20 to 30.9% (w/w) in dry weight (Sangronis and Sanabria 2011). Many studies have addressed the role of dietary fiber in preventing cardiovascular diseases, cancer, obesity, diabetes and intestinal disorders (Buttriss and Stokes 2008).

Bioactive compounds: polyphenols

Polyphenols are a highly heterogeneous group with approximately 10,000 compounds (Ooi et al. 2015), which, according to their chemical characteristics, are responsible for physiological roles in plants and consumers (Boncler et al. 2017). Based on their structure they can be classified mainly as: flavonoids, phenolic acids, lignans and stilbenes (Zhou et al. 2016) and an important group of flavonoids are anthocyanins. In juçara, the two main anthocyanins are cyanidin-3-*O*-rutinoside and cyanidin-3-*O*-glucoside (Guergoletto et al. 2016; Inada et al. 2015), being the anthocyanins cyanidin-3,5-diglucoside, cyanidin-3-sambubioside, cyanidin-3-rhamnoside, pelargonidin-3-glucoside, pelargonidin-3-rutinoside, peonidin-3-glucoside, peonidin-3-rutinoside, and malvidin-3-glucoside also identified (Argentato et al. 2017; Bicudo et al. 2014; Brito et al. 2007; Garcia-Mendoza et al. 2017; Guergoletto et al. 2016; Inada et al. 2015).

Although sensory characteristics of juçara fruit (*E. edulis*) are similar to those of açaí fruits (*E. oleracea* and *E. precatoria*), the nutritional properties seem to be more relevant, which is interesting for the development of potentially functional products (Siqueira et al. 2018). Juçara fruits have two to three times more anthocyanins than açaí (*E. oleracea* and *E. precatoria*) fruits (Siqueira et al. 2018; Teixeira et al. 2015), ranging from 634.26 to 2,929 mg cyanidin-3-glucoside equivalents 100 g^{-1} fruits (Table 1). Those molecules have multiple hydroxyl groups in their structure, which are associated with a high antioxidant capacity, resulting on a protective effect against oxidative damage (Brewer 2011).

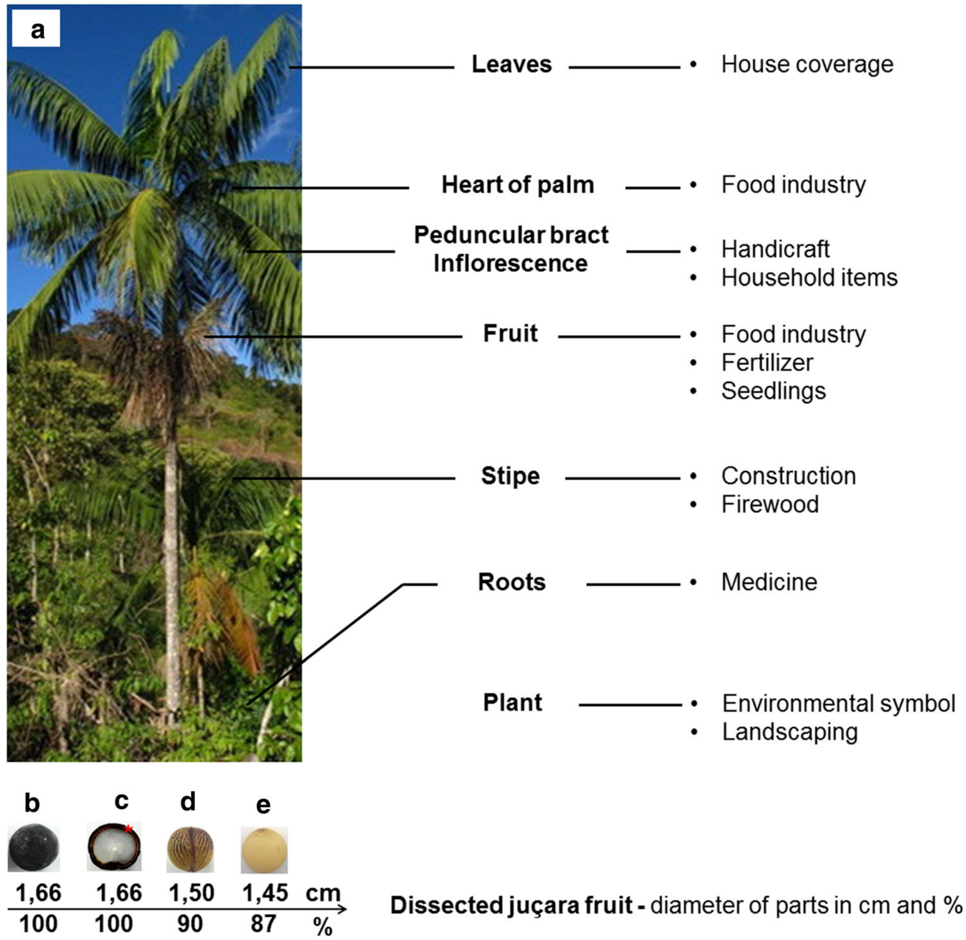

Fig. 2 Juçara palm tree and main applications (**a**), fruit in nature (**b**), fruit in cross section, evidencing the dark pulp* and white seed (**c**), fiber seed (**d**), fiber-free seed—endosperm (**e**)

The maximum value, also stands out when compared with other 3 non-traditional Brazilian tropical fruits with recognized importance but also little used, like acerola (*Malpighia emarginata*), jabuticaba (*Myrciaria cauliflora*) and jambolão (*Syzygium cumini*), presenting a higher content of anthocyanins and total phenolic compounds (Table 1). These results demonstrate the healthy and technological potential of the juçara fruit to be commercialized as product with health appeal.

Furthermore, juçara fruit and pulp are excellent sources of polyphenols, with total content varying from 415.1 to 9,778.20 mg equivalents of gallic acid 100 g^{-1} in dry weight basis (Table 1), being more concentrated than in açaí (98.9 to 3,437 mg 100 g^{-1}) (Garzón et al. 2017; Gordon et al. 2012), red raspberry, blueberry, cherry (305.38 to 850 mg 100 g^{-1}) (de Souza et al. 2014), jabuticaba (815 mg 100 g^{-1}) (Inada et al. 2015) and banana, mango, papaya (19 to 327 mg 100 g^{-1}) (Siriamornpun and Kaewseejan 2017).

In relation to the phenolic profile, 32 compounds have already been identified in juçara (Online Resource Table 2), 17 phenolic acids (protocatechuic, *p*-coumaric, vanillic, gallic, caffeic, ferulic, syringic, sinapic, ellagic, chlorogenic, benzoic, *p*-hydroxybenzoic, 3,4-dihydroxybenzoic, 3,4-dihydroxyphenylacetic, *p*-hydroxyphenylacetic, *trans*-cinnamic and *m*-coumaric acids), 13 flavonoids (apigenin, kaempferol, aromadendrin, catechin, epicatechin, quercetin, taxifolin, myricetin, isoquercetin, rutin, hispidulin, luteolin deoxyhexosyl-hexoside and dihydrokaempferol-hexoside), 1 stilbene (resveratrol) and 1 phenol aldehyde (vanillin) (Argentato et al. 2017; Bicudo et al. 2014; Borges et al. 2011; Guergoletto et al. 2016; Inada et al. 2015; Schulz et al. 2015, 2017; Siqueira et al. 2018).

Usually the antioxidant capacity of juçara is superior to other fruits such as açaí (0.03 to 64.5 µmol Trolox g^{-1} measured by TEAC—Trolox Equivalent Antioxidant Capacity with $ABTS^{\bullet+}$ radicals (ABTS—2,2-azinobis-(3-ehtylbenzothiazoline6-sulphonic acid) (Gordon et al. 2012; Rufino et al. 2010), jabuticaba (435 µmol Trolox g^{-1} measured by TEAC with $ABTS^{\bullet+}$ radicals (Re et al. 1999) (Inada et al. 2015), mango (75.5 uM Trolox g^{-1} measured by TEAC with $ABTS^{\bullet+}$ radicals) (Moreira et al. 2017), banana and papaya (1.47 to 5.37 DPPH radical scavenging IC_{50} (mg mL^{-1}) measured by DPPH—2,2-diphenyl-1-

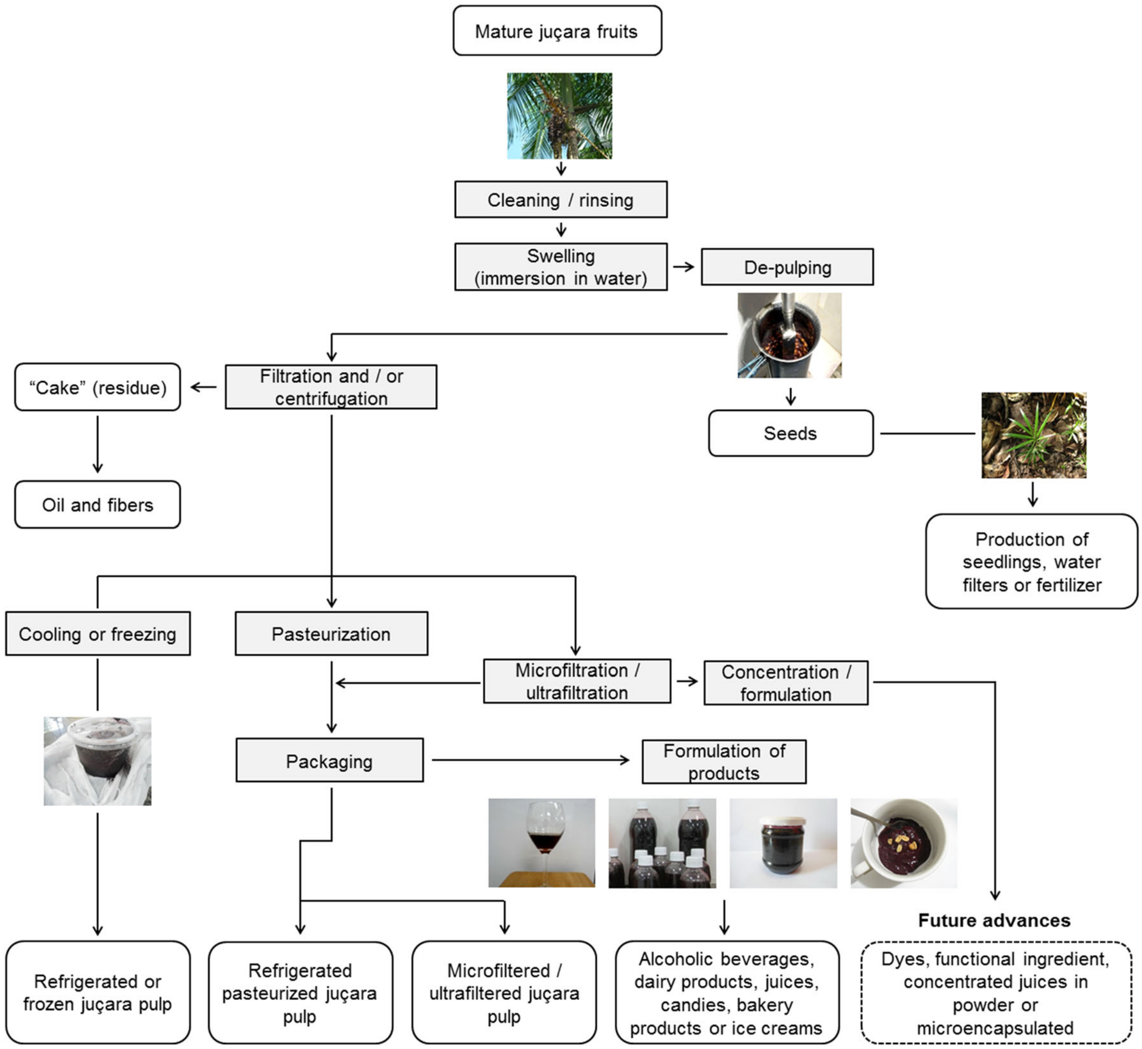

Fig. 3 Flow diagram of different methods of juçara fruit processing

picrylhydrazyl radical scavenging IC_{50} (mg mL^{-1}) (Siriamornpun and Kaewseejan 2017).

The main healthy effect of juçara fruit is related to antioxidant scavenging capacity, which also proved to be effective on *in vivo* studies. The consumption and utilization of juçara, under specific conditions and doses were able to: (1) decrease the lipid peroxidation of healthy humans (Schulz et al. 2015); (2) restore the fecal content of *Bifidobacterium* spp, improving intestinal barrier integrity in the offspring of rats exposed to juçara polyphenols in the intrauterine and lactation periods (Morais et al. 2015); (3) preserve lean mass and decrease blood glucose and triacylglycerol in newborn rats (Argentato et al. 2017); (4) have a protective effect being considered anticancer, antimutagenic, antimicrobial, anti-inflammatory, antineurodegenerative (Nile and Park 2014); (5) and protect against the UVB-induced oxidative damage (Nile and Park 2014). Other health benefits of bioactive compounds from juçara fruit are given in Table 2 (Online Resource).

Applications of juçara palm fruits

All components of juçara palm can be used in different fields as shown in Fig. 2. However, the fruit and the palm heart are the most used for industrial purposes. In order to add value to juçara fruit, new uses are proposed such as food ingredient and supplement, as shown in the diagram of applications for the use of juçara palm fruits (Fig. 3) (Moreira et al. 2017; Pereira et al. 2017).

Furthermore, anthocyanins, extracted from juçara fruit, are an alternative in the food industry, as potential substitutes for synthetic food colorants (de Mejia et al. 2020; Lima et al. 2019) which are nowadays of public concern because of the adverse effect of synthetic dyes on human health, particularly affecting neurological functions and behavioral patterns (Sigurdson et al. 2017). Natural dyes produced with juçara anthocyanins can also be used by the cosmetic industry, manufacturing lipsticks, creams and lotions (Nile and Park 2014; Kostick et al. 2007), an already commercialized example is a makeup (patent US 2007/0166253 A1), produced with juçara pigment, which can improve colour and treat skin.

The oil extracted from the juçara fruits is rich in polyunsaturated fatty acids, being linoleic, palmitic and oleic acids the main components. It can be used in the cosmetic (Felzenszwalb et al. 2013) and pharmaceutical industries, in the manufacture of creams and capsules.

When developing new products, the food, pharmaceutical and cosmetic industries require toxicological tests. A toxicological evaluation was carried out of juçara pulp *in nature* and demonstrated that tests are needed for the application of correct doses to avoid adverse effects on human health. In this study, positive response on Ames test was observed, when the highest concentration of juçara pulp was used (5 mg/mL) (Felzenszwalb et al. 2013). No studies on the toxicity of juçara pulp or skin powder were identify in the literature, which remains as an open field.

Whichever form of use, due to its physicochemical and nutritional composition (Schulz et al. 2016), juçara fruit and pulp are perishable at room temperature, requiring conservation technologies after harvest. Pasteurization methods followed by freezing are the most widely used, however other technologies such as high pressure treatment (Moreira et al. 2017) and spray drying have also been studied to preserve the bioactive compounds and nutritional value increasing the product's shelf life, improving storage and transportation stability and reducing costs of cold chain procedures (Guergoletto et al. 2017; Paim et al. 2016). Those methods combined have also been used to provide alternative products to the market, such as pasteurized and high pressure fruit juices, probiotic fermented and spray dried juices (Guergoletto et al. 2017; Lima et al. 2019; Moreira et al. 2017; Paim et al. 2016), the latter being an alternative to lactose intolerant or allergic people with dairy restrictions.

Market potential

Although pulp commercialization is more profitable than fruit, it implies greater financial investment for the implementation of a production facility (Conab 2019), and the cost will vary with the processing technology.

Maier et al. (2019) found that the cost of implementing a project to produce juçara fruit and cutting your trunk for wood production can reach US$ 2,716.62 per hectare, having as products, the juçara fruit for commercial sale and the timber for community use. According to the authors, throughout 30 years invested on scientific projects, the estimated total amount of labor costs would be US$10,296.54 (69.1%) and inputs cost would be US$ 4,611.74 (30.9%), being the total income from the juçara fruit US$ 25,886.47. Projects like this can help the permanence of small producers in the field, reducing migration to the city.

Although Santa Catarina, a south state, was a reference in the production of juçara, until the year 2003/2004, the South and Southeast Brazilian market was supplied by Amazonian açaí (Schulz et al. 2016). However, in 2004, with the implantation of the first processing unit of juçara fruit in southern Brazil, in the city of Garuva, Santa Catarina (Bourscheid et al. 2011), the pulp production increased in the south. In 2007, a small processing unit of juçara fruit started in the city of Rio Pomba, Minas Gerais, which increased consumption and promoted scientific research on juçara.

The available data on the production of juçara pulp showed an increase. On 2010 the amount was of 5 tons, then 97.76 tons in 2011 (Trevisan et al. 2015), till 193 tons in (Conab 2016). Açaí pulp was mainly commercialized to USA, Japan and South Korea. Juçara also has potential to be part of this trading market. The value of açaí and juçara pulp exported reached US$ 17 million in 2012, corresponding to approximately 6 thousand tons of pulp (Conab 2016).

Entities such as "Network Juçara Project", "Lovely Project—Sustainable Atlantic Forest" and "Juçara Project—Environment and Community Development", encourage the consumption of juçara pulp by consumers, resulting in an increase for juçara pulp production mainly in Northeast, Southeast and South of Brazil. Rio de Janeiro and São Paulo consume around 650 tons/month of açaí pulp and more than 1000 tons/month of a mixed with guarana and granola. Other states achieve a consumption of approximately 40 thousand tons juçara pulp/year (Conab 2016). A part of this market is supplied with juçara pulp, processed by Companhia Juçaí—Ciano Sustainable Food Industry L.T.D, located in the state of Rio de Janeiro, Brazil. The company represents a successful case of juçara pulp valorization. Standing also for a preservation porpoise of a conservative utilization of Atlantic Forest juçara.

The company started operating in the Brazilian market in 2015, when 18.6 thousand liters of Juçaí were sold. In 2018 the factory started to produce 5 tons already filled and frozen in the packaging, which resulted in monthly revenue of about US$ 19,580.60. Currently, the product is sold at more than 160 points in the city of Rio de Janeiro, for approximately US$ 2.00 each, and exportation to Chile has already initiate (Brito 2018).

Although the market is growing, the commercialization of juçara pulp is still small compared to açaí pulp. This is caused by a low production due to planting difficulties requiring extractive production, concentrated production in a specific period of the year and non-standardization of pulp production. In this context, studies that focus on the use and production of juçara pulp will encourage the region development, as its commercialization on industrial scale will generate employment and income for the local population, besides contributing to the appreciation of the value of this species, favoring its preservation.

Conclusion and future prospects

Encouraging juçara fruit management rather than palm heart commercialization is a project with strong social approach, besides great environmental and economically promising footprint.

Data on juçara composition demonstrates that it assumes great importance in human nutrition due to its rich chemical content, which includes fatty acids, proteins, minerals, vitamins and dietary fibers. In addition, this fruit presents a great variety of phenolic compounds with bioactive potential, such as anthocyanins, with proved health benefits. This suggests that the use of juçara in the development of food products or even in cosmetics may represent a viable alternative for the use and valorization of these fruits. In addition, the high content of minerals and antioxidants found in juçara and the combination of other key success factors for a food product, such as the origin of the plant (Atlantic Forest Biome), high biological activity (it is rich in bioactive molecules) and the environmental benefit (reduction of the slaughter of the palms of juçara in function of the valorization of their fruits) represents an excellent opportunity for the use of juçara fruit pulp, with great potential of impact throughout the entire production chain of food, pharmaceutical and cosmetic industry.

Despite the small number of industries that process this raw material, a small market is starting to appear, and there is an increasing interest for healthier products and sustainable production. It is of common sense that the variety of ecosystems should be preserved as well as the species individually. Traditional technological procedures are used in order to increase the variety of products that can be obtained from juçara fruit, such as heat treatment (i.e. pasteurization), dehydration and technological alternatives with less deleterious effect that intend to preserve the bioactive composition such as drying methods (i.e. spray drying). All those methods have as main purpose to increase the conservation and stability of juçara fruit or pulp, and increase juçara commercialization. Those technological approaches may need a substantial financial investment and face difficulties to be implemented in a large production scale. However, there is a need to value the juçara fruit culture in order to stimulate the commercialization of derivates from the fruit.

Juçara fruit has a short harvesting period, it is considered a highly perishable product, and its functional properties need to be preserved until consumption. Whereas that most workers responsible for the fruit harvesting and first processing are in the middle of the atlantic forest biome in Brazil, it is necessary to invest on standard methods making it easier to perform a more sustainable culture and promote a better juçara fruit conservation, reducing the palm tree extraction. In addition, marketing approaches that brings attention to the consumption of juçara, would increase consumers interest on juçara palm fruits.

The combined efforts of producers, research institutions and innovative industries will provide technological alternatives for the use of the fruits of juçara, making it possible to remove this tree from the list of endangered species.

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