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Review

A review of the fruit nutritional and biological activities of three Amazonian species: bacuri (*Platonia insignis*), murici (*Byrsonima* spp.), and taperebá (*Spondias mombin*)

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Summary

Introduction – **The Amazonian region contains several native fruit species of potential interest, including bacuri (*Platonia insignis*), murici (*Byrsonima crassifolia* and *B. verbascifolia*), and taperebá (*Spondias mombin*).** *Methodology* – **This is an updated review of the reported nutritional composition and biological activities of bacuri, murici, and taperebá fruits and their co-products.** *Results and discussion* – **Amazonian fruits and their co-products are a potential source of various bioactive compounds, such as phenolic compounds and carotenoids. They are also a good source of nutrients such as calcium, magnesium, vitamin C, vitamin A, and dietary fiber. These phytochemical compounds possess properties and activities that could be used to delay or prevent many diseases.** *Conclusion* – **This review highlights the potential of these species as functional foods and for therapeutic purposes, particularly for the domestic market.**

Keywords
Brazil, Amazon, food composition, biological properties, phytochemical compound, phenolics, underutilized species

Résumé

Revue des propriétés nutritionnelles et biologiques des fruits de trois espèces amazoniennes: bacuri (*Platonia insignis*), murici (*Byrsonima* spp.) et taperebá (*Spondias mombin*).

Introduction – **La région amazonienne recèle plusieurs espèces de fruits indigènes d'intérêt potentiel, en particulier bacuri (*Platonia insignis*), murici (*Byrsonima crassifolia* et *B. verbascifolia*) et taperebá (*Spondias mombin*).** *Méthodologie* – **Il s'agit d'une mise à jour des connaissances rapportées sur la composition nutritionnelle les activités biologiques des fruits de bacuri, murici, taperebá et leurs coproduits.** *Résultats et discussion* – **Les fruits amazoniens et leurs coproduits sont une source potentielle de divers composés bioactifs tels que composés phénoliques et caroténoïdes. Ils représentent également une bonne source de nutriments tels que calcium, magnésium, vitamine C, vitamine A et fibres alimentaires. Ces composés phyto-chimiques possèdent des propriétés et des activités qui pourraient être utilisées pour retarder ou prévenir de nombreuses maladies.** *Conclusion* – **Cet examen souligne le potentiel de ces espèces comme aliments fonctionnels et à des fins thérapeutiques, en particulier pour le marché domestique.**

Mots-clés
Brésil, Amazonie, composition alimentaire, propriétés biologiques, composé phyto-chimique, composé phénolique, espèce sous-utilisée

Significance of this study

What is already known on this subject?

- Bacuri, murici, and taperebá are naturally occurring nutritional fruits with important bioactive compounds. They are a part of the Brazilian population's fruit intake, especially in their production regions.

What are the new findings?

- This review highlights the potential of these species as functional foods and for therapeutic purposes, particularly for the domestic market.

What is the expected impact on horticulture?

- Identifying the bio-functional qualities of these fruits is important to the Brazilian fruit production economy, since it provides valuable information for the domestic market.

Introduction

Brazil is the third-largest producer of edible fruits, surpassed only by China and India. Fruit production is mainly concentrated in the south, southeast, and northeast of the country (Canuto *et al.*, 2010; Vieira *et al.*, 2011). Fruit production in the Amazon represents only 0.2% of the total production, and produces mainly exotic fruits that are consumed either fresh or processed (Canuto *et al.*, 2010). The Amazon region has a rich biodiversity of fruit species, with approximately 220 species of edible fruit, representing 44% of the native fruit biodiversity in Brazil (Neves *et al.*, 2012).

Tropical areas typically possess diverse fruit species with many uses, including fresh consumption, animal feed-

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ing, agribusiness, and crop diversification (Bataglion *et al.*, 2015). The Amazonian region contains a large number of native and exotic fruit species of potential interest because of growing recognition of their nutritional and therapeutic value (Malta *et al.*, 2013; Rufino *et al.*, 2010).

The consumption of tropical fruit is increasing in the local Brazilian and international market, which represents an opportunity for local growers to gain access to markets where consumers place emphasis on exotic food characteristics, and nutrients with the potential to prevent diseases or support health (Rufino *et al.*, 2010). The diversity of species in Amazonia is influenced by the surrounding flora, by migration, and by the evolution of new species (Shanley *et al.*, 2010).

Considering the speed of introduction of new species of fruits and other plants, identification of these species and characterization of their functional properties poses a challenge (Neves *et al.*, 2012). Therefore, this review sought to provide an overview of nutritional and biological activities of three Amazonian species: bacuri (*Platonia insignis*), murici (*Byrsonima* spp.), and taperebá (*Spondias mombin*).

Methodology

Between April and July 2016, a literature search was conducted through the search engines Scopus, Science Direct, and Google Scholar to gather publicly available information on the nutrient composition of three selected Amazonian fruits: bacuri (*Platonia insignis*), murici (*Byrsonima* spp.), and taperebá (*Spondias mombin*). Search terms included the scientific name and English common name of each fruit species, in conjunction with terms such as nutrient composition, chemical composition, minerals, vitamins, phytochemicals, seeds, and leaves. Reference lists of scientific articles were cross-checked and only relevant papers were included. The data search was limited to reports of fruits sourced from Amazonian sites, and included articles and books published between 1999 and 2016. The values in tables were calculated as the average of data from different authors who used similar analytical methods. Data from food composition tables were also included.

Botanical description

Bacuri, murici, and taperebá (Figure 1) are species of fruit trees found primarily in the northern and northeastern regions of Brazil. Their botanical characteristics are diverse (Table 1). The bacuri tree is a fruit tree in the *Clusiasea* family, *Clusioideae* subfamily, and is classified as *Platonia insignis* (Aguiar *et al.*, 2008; Souza *et al.*, 2013). The tree is predominantly found in the open vegetation in areas of transition, and is commonly found in the northern and northeastern regions of Brazil. It is a medium to large tree, reaching a height of 30 to 35 m and a diameter of 1.5 to 2.0 m in more developed specimens (Homma and de Carvalho, 2010; Silva and de Carvalho, 2011). The tree can produce up to 2,000 fruits per year (Shanley *et al.*, 2010; Boulanger and Crouzet, 1999). The bacuri tree can be used as a source of wood and resin, in addition to the extraction of oil and bran as a by-product (Shanley *et al.*, 2010; Nascimento *et al.*, 2007). Bacuri fruit has a thick rind and traditionally two seeds, and is about 10% pulp by weight (Shanley *et al.*, 2010). The fruit is ovoid to globose with a diameter of 7 to 15 cm and an average weight of 200 to 1,000 g. Externally, bacuri fruit has a pale yellow to brownish yellow color. The edible part inside is soft, fibrous, and mucilaginous, and the juice pulp has a strongly attractive and exotic flavor. Bacuri fruit has the most economically valuable pulp among the native Amazonian fruit trees (Boulanger and Crouzet, 1999; Ferreira and Melo, 2007).

The murici tree belongs to the genus *Byrsonima*, which has been most extensively studied within the *Malpighiaceae* family, and contains about 130 species. *Byrsonima crassifolia* and *B. verbascifolia* belong to *B.* subgen. *Byrsonima* (cited as *B.* subgen. *Brachyzeugma* Nied.) (Barbosa *et al.*, 2014; Hamacek *et al.*, 2014; Guilhon-Simplicio and Pereira, 2011). It is found predominantly in the northern, northeastern, and central regions of Brazil, including the Amazonian region (Guilhon-Simplicio and Pereira, 2011; Alves and Franco, 2003; Sales *et al.*, 2013). The tree can reach between 0.8 and 10.0 m in height, and the wood is used in the construction of housing and fine masonry (Guilhon-Simplicio and Pereira, 2011; Alberto *et al.*, 2011). The murici fruit is small and round in shape, between 1.7 and 2.0 cm in diameter, with an average weight of between 4.45 and 5.45 g. The fruit is predominantly yellow, and the pulp is fleshy, soft, and juicy. A strong and unusual cheese flavor contributes to its unique and exotic flavor (Neves *et al.*, 2012; Hamacek *et al.*, 2014; Alves and Franco, 2003; Sales *et al.*, 2013; Alberto *et al.*, 2011; Morzelle *et al.*, 2015)

The taperebá tree belongs to the *Anacardiaceae* family, which contains about 60 to 75 genera and 600 species, of which the genus *Spondias* comprises about 14 species globally. Trees belonging to this family are commonly found in America, Asia, and Africa, typically in tropical areas. In Brazil, it is found mainly in the northern and northeastern regions (Tiburski *et al.*, 2011; Ugadu *et al.*, 2014; Duvall, 2006; Silva *et al.*, 2014). *Spondias mombin* is known as taperebá or cajá in Brazil. The fructiferous tree can reach from 15 to 30 m in height, and the seeds are spread through animal dispersal. The market sales of this fruit are increasing owing to its accessibility and availability throughout the year. Besides the fruits, the bark and leaves of this tree are often used in traditional medicine (Ugadu *et al.*, 2014; Duvall, 2006; Silva *et al.*, 2014). The fruits are round, elliptical, or ovoid-shaped drupes, and are 2 to 5 cm in length and 1.75 to 3.55 cm in diameter. The average weight of the fruit is 15.3 g, and the majority of its mass is made up of seeds, producing a low yield in fruit pulp (Neves *et al.*, 2012; Silva and Carvalho, 2011; Tiburski *et al.*, 2011; Duvall, 2006; Silva *et al.*, 2014; Maldonado-Astudillo *et al.*, 2014; Mattietto *et al.*, 2010; Bora *et al.*, 1991). The fruit is rich in carotenoids and vitamin A, and the color of the peel and pulp is predominantly yellow. It has a fibrous and smooth texture and tastes sour-sweet and refreshing (Neves *et al.*, 2012; Tiburski *et al.*, 2011; Silva *et al.*, 2014; Maldonado-Astudillo *et al.*, 2014; Bora *et al.*, 1991).

Nutritional composition

Amazonian fruits are widely recognized as a good source of nutrients, and Table 2 shows the predominant chemical and nutritional components of bacuri, murici, and taperebá fruits.

Bacuri are characterized by a high soluble sugar content, primarily containing glucose and fructose (Yamaguchi *et al.*, 2014; Rogez *et al.*, 2004). This fruit contains a notably high concentration of amino acids (Nazaré, 2000). It contains sodium, potassium, phosphorus, magnesium, iron, calcium, copper, and zinc in higher amounts than other Amazonian fruits, such as *araça boi* (*Eugenia stipitata*) and *cupuaçu* (*Theobroma grandiflorum*) (Homma and de Carvalho, 2010; Yamaguchi *et al.*, 2014; Rogez *et al.*, 2004). Sousa *et al.* (2011) found that Brazilian fruits, including bacuri, cupuaçu (*Theobroma grandiflorum*), and guava, have high contents of lipids.

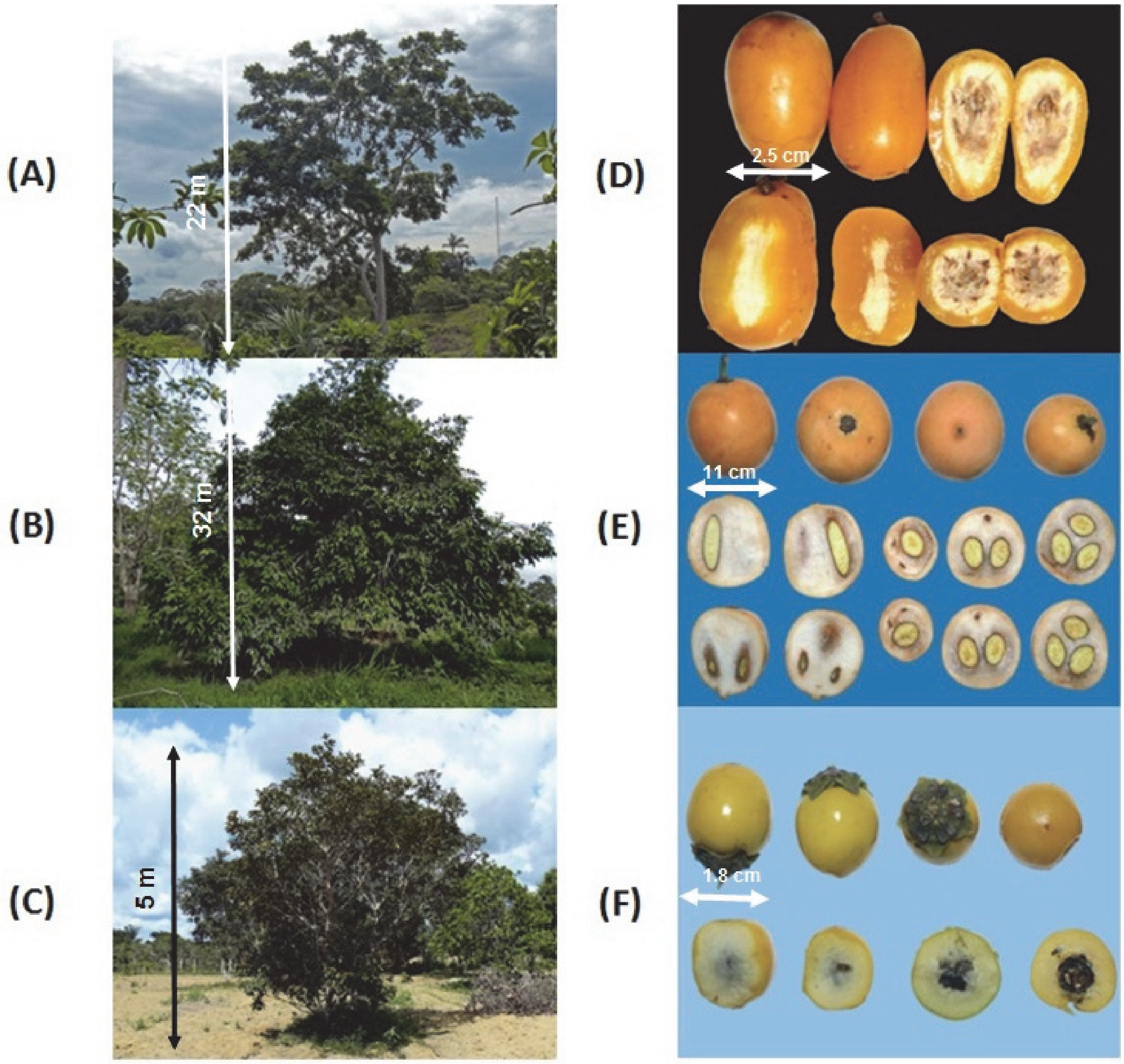

Figure 1. Trees and fruits (internal and external views) of (A, D): taperebá (*Spondias mombin*); (B, E): bacuri (*Platonia insignis*); and (C, F): murici (*Byrsonima crassifolia* and *B. verbascifolia*). Adapted from Rabelo (2012).

Table 1. Phenotypic description of three Amazonian fruits.

Plant structure traits	Bacuri *Platonia insignis*	Murici *Byrsonima* spp.	Taperebá *Spondias mombin*
Tree height (m)	30.0-35.0	0.8-10.0	15.0-30.0
Fruit diameter (cm)	7.00-15.00	1.70-2.00	1.75-3.55
Weight (g)	200-1,000	4.45-5.45	≈ 15.30
Fruit color	White yellow	Yellow	Yellow
Shape	Ovoid to globose	Small round	Round, elliptical or ovoid
References	Homma and de Carvalho, 2010; Silva and Carvalho, 2011; Boulanger and Crouzet, 1999; Ferreira and Melo, 2007	Neves *et al.*, 2012; Hamacek *et al.*, 2014; Guilhon-Simplicio and Pereira, 2011; Alves and Franco, 2003; Sales *et al.*, 2013; Alberto *et al.*, 2011; Morzelle *et al.*, 2015	Neves *et al.*, 2012; Silva and Carvalho, 2011; Tiburski *et al.*, 2011; Ugadu *et al.*, 2014; Duvall, 2006; Silva *et al.*, 2014; Maldonado-Astudillo *et al.*, 2014; Mattietto *et al.*, 2010; Bora *et al.*, 1991

Table 2. Chemical and nutritional composition of three Amazonian fruits.

Analyzed elements	Bacuri *Platonia insignis*	Murici *Byrsonima* spp.	Taperebá *Spondias mombin*
Moisture (g 100 g^{-1})	84.99 ± 0.75	76.18 ± 4.14	86.87 ± 1.34
Protein (g 100 g^{-1})	1.53 ± 1.07	1.33 ± 0.57	0.71 ± 0.40
Ash (g 100 g^{-1})	0.62 ± 0.19	0.81 ± 0.22	0.58 ± 0.17
Carbohydrate (g 100 g^{-1})	14.09 ± 4.30	12.98 ± 7.26	13.90 ± 0.00
Lipids (g 100 g^{-1})	2.03 ± 1.31	4.27 ± 2.75	0.44 ± 0.25
Fiber (g 100 g^{-1})	7.18 ± 1.87	9.43 ± 4.31	1.38 ± 0.42
Sodium (mg 100 g^{-1})	26.37 ± 0.00	45.43 ± 0.00	4.28 ± 1.80
Potassium (mg 100 g^{-1})	149.81 ± 0.00	346.73 ± 0.00	214.14 ± 104.85
Calcium (mg 100 g^{-1})	17.09 ± 0.00	83.38 ± 7.60	20.88 ± 8.97
Magnesium (mg 100 g^{-1})	22.16 ± 0.00	43.70 ± 0.00	13.55 ± 2.19
Iron (mg 100 g^{-1})	n.a.	1.00 ± 0.41	0.76 ± 0.44
Manganese (mg 100 g^{-1})	0.45 ± 0.00	0.08 ± 0.00	0,02 ± 0.00
Phosphorus (mg 100 g^{-1})	10.76 ± 0.00	7.69 ± 0.00	26.40 ± 6.42
Zinc (mg 100 g^{-1})	1.04 ± 0.00	0.37 ± 0.39	0.17 ± 0.00
Copper (mg 100 g^{-1})	0.38 ± 0.00	0.09 ± 0.00	0.07 ± 0.07
Selenium (mg 100 g^{-1})	n.a.	2.36 ± 0.00	n.a.
Cobalt (mg 100 g^{-1})	n.a.	27.24 ± 0.00	n.a.
Nickel (mg 100 g^{-1})	n.a.	26.41 ± 0.00	n.a.
Soluble solids (°Brix)	14.27 ± 1.56	8.89 ± 2.59	12.24 ± 2.45
pH	3.26 ± 0.19	3.93 ± 0.58	2.91 ± 0.43
Total sugars (g 100 g^{-1})	11.13 ± 0.92	n.a.	5.07 ± 0.75
Total solids (%)	15.71 ± 3.56	n.a.	n.a.
Titratable acidity (%)	1.87 ± 0.72	0.47 ± 0.30	1.68 ± 0.20
Reducing sugars (g 100 g^{-1})	6.03 ± 2.89	2.97 ± 0.00	4.80 ± 0.78
References	Canuto *et al*., 2010; Aguiar *et al*., 2008; Rogez *et al*., 2004; De Nazaré, 2000; De Carvalho *et al*., 2003; Clerici and Carvalho-Silva, 2011; da Silva *et al*., 2010	Hamacek *et al*., 2014; Morzelle *et al*., 2015; Silva *et al*., 2008; De Souza *et al*., 2012; Almeida *et al*., 2011; Dias *et al*., 2012; Guimarães and Silva, 2008; Moo-Huchin *et al*., 2014; Neves *et al*., 2015	Tiburski *et al*., 2011; Maldonado-Astudillo *et al*., 2014; Mattietto *et al*., 2010; Bora *et al*., 1991; Leterme *et al*., 2006

n.a.: not applicable.

Murici pulp contains a high amount of dietary fiber (Hamacek *et al*., 2014; Silva *et al*., 2008; Souza *et al*., 2012) and a significant amount of lipids (Morzelle *et al*., 2015), and is very rich in minerals, such as calcium, phosphorous, and iron (Zuniga *et al*., 2006). Hamacek *et al*. (2014) observed that murici fruit can provide the daily recommended dose of vitamins because it contains a high amount of vitamin C, and is a good source of vitamins A and E. Murici contains amounts of vitamin A similar to those in nectarine, and higher than those in strawberry, and contains more vitamin E than kiwi fruit and peach.

Taperebá contains significant dietary fiber (1.18%), comprising both soluble and insoluble fibers, although soluble fiber (0.75%) is found in a greater proportion (Mattietto *et al*., 2010). It has high levels of potassium along with jackfruit, soursop, jenipapo (*Genipa americana*) and mangaba (*Hancornia speciosa*), contains significant amount of magnesium and copper compared to other fruits, and is a source of vitamins C and A. It can be considered a source of pro-vitamin A; a portion of 100 g provides about 37% of the RDI for adults (Tiburski *et al*., 2011; Ugadu *et al*., 2014).

Phytochemical constituents

Many bioactive compounds have been identified in bacuri, murici, and taperebá. These fruits are considered as significant sources of these phytochemical constituents (Table 3).

Bacuri contains phytochemical constituents with antioxidant properties, such as polyphenols. The seeds of this plant have been studied to identify potential bioactive compounds (Yamaguchi *et al*., 2014; Bruno *et al*., 2013). Bacuri fruit is rich in fatty substances, diterpenes, xanthones, and triglycerides (Yamaguchi *et al*., 2014; Bruno *et al*., 2013). According to Bruno *et al*. (2013), bacuri seeds contain fatty acids, including palmitic, linoleic, stearic, and oleic acids, and are therefore attractive to the natural oil industry. Garcinielliptone is a natural benzenphenone that has been isolated from bacuri seeds. This substance is not commonly found in fruits, and bacuri is the first member of the genus *Platonia* known to contain this type of compound. Costa Junior *et al.* noted that garcinielliptone has significant antioxidant activity (Bruno *et al*., 2013; Costa Junior *et al*., 2011).

TABLE 3. Antioxidant activity and bioactive compounds of three Amazonian fruits.

Analyzed activities or compounds	Bacuri *Platonia insignis*	Murici *Byrsonima* spp.	Taperebá *Spondias mombin*
Antioxidant activity (μmol Trolox g^{-1})	0.60 ± 0.00	11.19 ± 5.24	8.20 ± 0.57
Total polyphenols (g GAE kg^{-1})	0.40 ± 0.00	2.39 ± 0.58	0.63 ± 0.13
Ascorbic acid (mg g^{-1})	0.02 ± 0.01	0.62 ± 0.66	0.58 ± 0.82
Total anthocyanins (mg g^{-1})	0.003 ± 0.000	0.010 ± 0.003	0.570 ± 0.000
Flavonoids (mg g^{-1})	0.17 ± 0.00	0.14 ± 0.00	0.08 ± 0.01
Total carotenoids (mg g^{-1})	n.a.	0.06 ± 0.08	0.04 ± 0.03
References	Canuto *et al.*, 2010; Rufino *et al.*, 2010, 2011; Clerici and Carvalho-Silva, 2011	Rufino *et al.*, 2010; Sales *et al.*, 2013; Almeida *et al.*, 2011; Dias *et al.*, 2012; Moo-Huchin *et al.*, 2014; Morais *et al.*, 2013; Gordon *et al.*, 2011; Ribeiro *et al.*, 2013	Rufino *et al.*, 2010; Sales *et al.*, 2013; Tiburski *et al.*, 2011; Mattietto *et al.*, 2010; Murillo *et al.*, 2010; Olayiwola *et al.*, 2013; Contreras-Calderón *et al.*, 2011; Zielinski *et al.*, 2014

n.a.: not applicable.

Murici fruit contains highly active natural antioxidants (Morzelle *et al.*, 2015; Almeida *et al.*, 2011; Morais *et al.*, 2013). Approximately 19 polyphenolic compounds have been identified in murici, including gallotannins, quinic acid, gallates, proantrocyanides, quercetin derivates, and galloyl derivates, which are rarely found in fruits (Gordon *et al.*, 2011; Maldini *et al.*, 2011; Mariutti *et al.*, 2014). The fruit is considered to be a good source of carotenoids, and it contains more β-carotene than lycopene (Souza *et al.*, 2012). It also contains considerable amounts of lutein and zeaxanthin, but lesser than those found in green leafy vegetables such as kale (Mariutti *et al.*, 2013; Murillo *et al.*, 2010).

Taperebá fruits contain more phenolic compounds including tannins, and more antioxidant compounds such as vitamin C and carotenoids, than many other fruits that are consumed in Brazil (Tiburski *et al.*, 2011; Mattietto *et al.*, 2010; Murillo *et al.*, 2010; Olayiwola *et al.*, 2013). Taperebá contains more lutein than zeaxanthins, and also contain other types of carotenoids including zeinoxanthin, β-criptoxanthin, α-carotene, and β-carotene (Tiburski *et al.*, 2011; Murillo *et al.*, 2010). High amounts of gallic acid and quercetin have been found in taperebá pulp (Bataglion *et al.*, 2015). Silva *et al.* (2012) concluded that taperebá pulp can effectively inhibit oxidation, which is attributed to its yellow flavonoids, carotenoids and chlorophyll.

Biological activity

The biodiverse Amazonian region in Brazil is the source of many plant species that are important in natural folk medicine, and have been widely disseminated worldwide. The rich flora of the Amazonian biome has been extensively studied in order to evaluate the efficacy and therapeutic effects of its plants or isolated compounds. The established biological activity of the bacuri, murici, and taperebá plants is presented in Table 4.

Bacuri contains several biologically active compounds, notably garcinielliptone FC (GFC), a natural prenylated benzophenone, which has several beneficial health effects. Garcinielliptone FC compounds are found mainly in bacuri seeds, and are capable of preventing lipoperoxidation, probably through hydroxyl radical scavenging activity (Costa Júnior *et al.*, 2011). Garcinielliptone FC possesses cytotoxic and leishmanicidal activity (Costa Júnior *et al.*, 2013b), and decreases the frequency of pilocarpine-induced seizures, which may influence epileptogenesis and promote anticonvulsant action in a pilocarpine model (Silva *et al.*, 2014). Garcinielliptone FC is also a potential antiparasitic agent (Silva *et al.*, 2015). The ethyl acetate and dichloromethane fractions of bacuri seeds contain compounds with biological activity. Costa Júnior *et al.* (2011b) concluded that the dichloromethane fraction is strongly neuroprotective. The protective effect of the ethyl acetate and dichloromethane fractions against H_2O_2-induced cytotoxicity in *S. cerevisiae* was measured (Costa Júnior *et al.*, 2013a), and compounds in the ethyl acetate fraction were found to possess antioxidant activity (Costa *et al.*, 2011a).

Murici showed higher antioxidant activity (11.19 ± 5.24 μmol Trolox g^{-1}) compared to bacuri (0.60 ± 0.00 μmol Trolox g^{-1}) and taperebá (8.20 ± 0.57 μmol Trolox g^{-1}) (Table 3). This antioxidant activity has been measured in the fruit, leaves, bark, and stems (Malta *et al.*, 2013; Silva *et al.*, 2007; Rufino *et al.*, 2009). Extracts of murici root and stems contain ethyl acetate, which is known to exhibit bactericidal effects. Bacteria (Martínez-Vázquez *et al.*, 1999), and murici fruit extract exhibits antibacterial activity (Pío-León *et al.*, 2013). Lipophilic extracts from murici bark are regarded as a potential source of anti-inflammatory compounds (Maldini *et al.*, 2009). Murici flavonoid extracts possess potential antidepressant effects (Herrera-Ruiz *et al.*, 2011), while other extracted compounds including tannins, saponins, coumarins, and terpenes have shown activity against rotavirus (Cecílio *et al.*, 2012). Malta *et al.* (2012) found that murici extract provided higher protection against hydrogen peroxide and cyclophosphamide, compared to gabiroba (*Campomanesia cambessedeana*) extract. The extract also did not possess any mutagenic or genotoxic effects.

Taperebá leaves contain many phenolic compounds, including saponins, tannins, flavonoids, alkaloids, and glycosides, which display antimicrobial activity against various organisms (Aromolaran and Badejo, 2014). The bark is a source of alkaloids, saponins, tannins, eugenols, and phenolic compounds, which possess potential anti-tumor activity (Ataman *et al.*, 2010). Phenolic compounds from leaf extracts exhibit anticonvulsant properties, and sedative and antidopaminergic effects (Ayoka *et al.*, 2006). Rutin and quercetin from taperebá extracts are considered to possess antiviral properties acting against dengue virus (Silva *et al.*, 2011). Tannic acid derived from taperebá is found to be active against *Leishmania leishmania* and *Leishmania donovani* (Accioly *et al.*, 2012).

Table 4. Biological activity of three Amazonian fruits.

Species	Parts of plant	Biological activities	References
Bacuri *Platonia insignis*	Seed	Antioxidant and anticonvulsant effects	Costa *et al.*, 2011a
	Seed	Antioxidant effects and antioxidant effect preventing lipoperoxidation	Costa Junior *et al.*, 2011
	Seed	Antioxidant activity	Costa Júnior *et al.*, 2013a
	Seed	Cytotoxic and leishmanicidal properties	Costa Júnior *et al.*, 2013b
	Fruit	Free radical scavenging behavior	Rufino *et al.*, 2010
	Seed	Anticonvulsant activity	Da Silva *et al.*, 2014; Da Costa *et al.*, 2011
	Seed	Antiparasitic agent	Silva *et al.*, 2015
	Seed	Cicatrizing activity	Mendes *et al.*, 2015
Murici *Byrsonima crassifolia*	Root/stem/fruit	Antimicrobial activity	Martínez-Vázquez *et al.*, 1999; Pío-León *et al.*, 2013
	Leaf/bark/fruit	Antioxidant activity	Almeida *et al.*, 2011; Silva *et al.*, 2007
	Bark	Anti-inflammatory activity	Maldini *et al.*, 2009
	Leaf/bark	Spasmogenic activity	Bkjar and Malone, 1993
	Leaf	Photochemoprotective effect	Souza *et al.*, 2012
	Leaf	Antiulcerogenic activity	Pompeu *et al.*, 2012
	Fruit	Free radical scavenging behavior	Rufino *et al.*, 2009
	Aerial part	Antidepressant effect	Herrera-Ruiz *et al.*, 2011
Murici *Byrsonima verbascifolia*	Fruit	Antigenotoxic and antimutagenic properties	Malta *et al.*, 2012
	Fruit	Antioxidant and antiproliferative activities	Malta *et al.*, 2013
	Leaf	Antiviral activity against rotavirus	Cecílio *et al.*, 2012
Taperebá *Spondias mombin*	Leaf	Sedative, antiepileptic and antipsychotic effects	Ayoka *et al.*, 2006
	Leaf	Gastroprotective effects and antioxidative potentials	Sabiu *et al.*, 2015
	Fruit/leaf	Antioxidant and antimicrobial properties	Aromolaran and Badejo, 2014
	Leaf	Antifertility property	Asuquo *et al.*, 2013
	Bark	Anticancer activity	Ataman *et al.*, 2010
	Leaf	Antiviral activities against dengue virus	Silva *et al.*, 2011
	Leaf	Leishmanicidal activity	Accioly *et al.*, 2012
	Fruit	Free radical scavenging behavior	Rufino *et al.*, 2010

Food applications

Bacuri is traditionally sold in bags at markets, fairs, and coffee shops, and in the form of frozen pulp as well (Silva and Carvalho, 2011; Ferreira and Melo, 2007; Clerici and Carvalho-Silva, 2011; da Silva *et al.*, 2010). The bark is used in regional recipes (Homma and de Carvalho, 2010) and the fruit has become an exotic component of dishes in modern cuisine (Shanley *et al.*, 2010; Ferreira and Melo, 2007). Regionally, it is widely used in the juice and nectar industry, and in ice cream and frozen products. In dairy products, it is included in yogurt, creams, and desserts. It is consumed in jelly and fruit desserts in many regions of Brazil (Shanley *et al.*, 2010; Homma and de Carvalho, 2010; Silva and Carvalho, 2011; Ferreira and Melo, 2007; De Nazaré, 2000; da Silva *et al.*, 2010). In confectionery, it is used as a filler in chocolates and cakes, and as liquor in alcoholic products (Shanley *et al.*, 2010; Silva and Carvalho, 2011; Ferreira and Melo, 2007).

The cheese-like flavor of murici has aroused the interest of fine dining chefs, who have made use of the fruit in meat and fish sauces (Silva and Carvalho, 2011; Rezende and Fraga, 2003). In the Amazon and northeast, the pulp is commonly mixed with water and manioc flour, and served either sweetened with sugar or brown sugar or unsweetened (Silva and Carvalho, 2011). Murici can be used in the production of juices and nectars, as a filler in chocolate, and in wines and liquors, and is consumed in the form of ice cream, jelly, and desserts (Silva and Carvalho, 2011; Alves and Franco, 2003; Zuniga *et al.*, 2006; Neves *et al.*, 2011).

Taperebá is sold unprocessed or in pulped form (Silva *et al.*, 2014), but is mainly frozen, as it can be transported throughout the country (Tiburski *et al.*, 2011; Bicas *et al.*, 2011). The fruit has a good yield, and its aroma and strong exotic flavor has led to its wide use in the juice and nectar industry, and in savory dishes in regional restaurants (Silva and Carvalho, 2011; Mattietto *et al.*, 2010; Bora *et al.*, 1991; Soares *et al.*, 2006). The ice cream industry also uses taperebá fruit. Regionally, the pulp is consumed in jelly and yogurt (Silva and Carvalho, 2011; Tiburski *et al.*, 2011; Ugadu *et al.*, 2014; Bora *et al.*, 1991; Soares *et al.*, 2006) and in the form of liquors, wines, and alcoholic beverages (Bora *et al.*, 1991).

Conclusion and future prospects

Bacuri, murici, and taperebá are naturally occurring nutritional fruits with important bioactive compounds, and are a part of the Brazilian population's fruit intake, especially in the regions where they are produced. Identifying the bio-functional qualities of these fruits is important to the Brazilian fruit production economy, since it provides valuable information for the domestic market. Bacuri, murici, and taperebá fruits and their co-products are important sources of bioactive compounds and nutrients, which can be used in food and therapeutic applications.

It is also important to investigate the synergy of mixtures of fruits and their nutritional, functional, and sensory potentials. Novel research could improve our knowledge of the synergistic effects of these fruits. Such investigations could lead to the discovery of the most beneficial effects of these underutilized fruits.

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