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Celebrating the International Year of Fruits and Vegetables

Biological activity and chemical composition of native fruits

a review

Actividad biológica y composición química de las frutas nativas

revisión

Atividade biológica e composição química de frutas nativas

uma revisão

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Abstract

Brazilian native fruit trees have great potential for their use in the food and pharmaceutical industries. Among these, the Myrtaceae family stand out for the diversity of known native fruits, as the case of “araçazeiro” or cattley guava [*Psidium cattleianum*], “pitangueira”, Suriname cherry or Brazilian cherry [*Eugenia uniflora*], “guabijuzeiro” [*Myrcianthes pungens*], “guabirobeira” [*Campomanesia xanthocarpa*] and “uvalheira” [*Eugenia pyriformis*]. These fruits contain substances of nutritional and potentially functional importance, including dietary fiber, vitamins (especially A and C) and minerals (potassium, iron, manganese, magnesium, calcium, phosphorus), as well as antioxidant compounds, such as phenolics and carotenoids. The consumption of fruits rich in bioactive compounds and high antioxidant activity has the potential to prevent chronic non-communicable diseases such as cancer, diabetes mellitus, dyslipidemias, cardiovascular diseases, and chronic respiratory diseases. For example, Suriname cherry and cattley guava fruit extracts showed anti-hyperglycemic, anti-dyslipidemic and antioxidant effects in animal models with insulin resistance, cattley guava also showed anticarcinogenic, antimicrobial, anti-inflammatory and anti-aging activities. “Uvaia” has a promising effect as an antimicrobial agent. In this review, summarized information on the main native fruits of the Myrtaceae is presented, highlighting their composition and biological activities in order to direct new research.

Keywords: cattley guava, Suriname cherry, guabiju, guabiroba, uvaia, diabetes mellitus, health

Resumen

Los árboles frutales nativos de Brasil poseen un gran potencial para su uso en la industria alimentaria y la farmacéutica. La familia *Myrtaceae* se destaca por la diversidad de frutos autóctonos conocidos, como el arazá [*Psidium cattleianum*], la pitanga [*Eugenia uniflora*], el guabiyú [*Myrcianthes pungens*], la guabiroba [*Campomanesia xanthocarpa*] y la uvaia [*Eugenia pyriformis*]. Estas frutas contienen sustancias de importancia nutricional y potencialmente funcional, por ejemplo, fibra dietética, vitaminas (especialmente A y C) y minerales (potasio, hierro, manganeso, magnesio, calcio, fósforo, etcétera), así como compuestos antioxidantes, como fenoles y carotenoides. El consumo de frutas ricas en compuestos bioactivos y de alta actividad antioxidante tiene potencial para prevenir enfermedades crónicas no transmisibles, como cáncer, diabetes mellitus, dislipidemias, enfermedades cardiovasculares y enfermedades respiratorias crónicas. Por ejemplo, los extractos de fruta de pitanga y arazá mostraron efectos antihiperglucémicos, antidislipidémicos y antioxidantes en modelos animales con resistencia a la insulina. A su vez, arazá también mostró actividades anticancerígenas, antimicrobianas, antiinflamatorias y antienvejecimiento. La uvaia ha mostrado un efecto prometedor como agente antimicrobiano. Esta revisión tiene como objetivo recopilar información sobre los principales frutos nativos de la familia *Myrtaceae*, destacando su composición y las actividades biológicas para orientar nuevas investigaciones.

Palabras clave: arazá, pitanga, guabiyú, guabiroba, uvaia, diabetes mellitus, salud

Resumo

As árvores frutíferas nativas brasileiras têm grande potencial para uso na indústria alimentícia e farmacêutica. Dentre estes, a família Myrtaceae se destaca pela diversidade de frutas nativas conhecidas, como o araçazeiro [*Psidium cattleianum*], a pitangueira [*Eugenia uniflora*], o guabijuzeiro [*Myrcianthes pungens*], a guabirobeira (*Campomanesia xanthocarpa*] e a uvalheira [*Eugenia pyriformis*]. Essas frutas contêm substâncias de importância nutricional e potencialmente funcional, incluindo fibras alimentares, vitaminas (principalmente A e C) e minerais (potássio, ferro, manganês, magnésio, cálcio, fósforo, etc.), além de compostos antioxidantes, como fenólicos e carotenoides. O consumo de frutas ricas em compostos bioativos e de alta atividade antioxidante tem potencial para prevenir doenças crônicas não transmissíveis, como câncer, diabetes mellitus, dislipidemias, doenças cardiovasculares e doenças respiratórias crônicas. Por exemplo, os extratos de pitanga e araçá apresentaram efeitos anti-hiperglicêmicos, antidislipidêmicos e antioxidantes em modelos animais com resistência à insulina, e ainda, araçá também apresentou atividades anticarcinogênica, antimicrobiana, antiinflamatória e antienvelhecimento. Uvaia tem um efeito promissor como agente antimicrobiano. Com base no exposto, esta revisão tem como objetivo reunir informações das principais frutas nativas da família Myrtaceae, destacando sua composição e atividades biológicas para direcionar novas pesquisas.

Palavras-chave: araçá, pitanga, guabiju, guabiroba, uvaia, diabetes mellitus, saúde

1. Introduction

Despite the abundance of fruits in the world, there are a large number of native species in Brazil that are underexplored(1). In particular, in south Brazil there are several native fruits with great potential for their use in the food and pharmaceutical industry(2)(3). Among these, the Myrtaceae family stands out, with several commercial fruit trees(2), as the cattley guava [*Psidium cattleianum* Sabine], Suriname cherry [*Eugenia uniflora* L.], guabirobeira [*Campomanesia xanthocarpa* Berg], guabijuzeiro [*Myrcianthes pungens* Berg] and uvalheira [*Eugenia pyriformis* Cambess](4).

These species have high economic potential because, in general, their fruits are berry type possessing desirable pulp yield and organoleptic characteristics, and nutritional and phytochemical aspects desirable for both fresh commercialization or the manufacture of innovative food products(5).

These fruits also contain substances of nutritional and potentially functional importance. They present dietary fiber, antioxidant compounds, including phenolics and carotenoids, vitamins (especially A and C), and minerals (potassium, iron, manganese, magnesium, calcium, phosphorus)(2)(3), offering an interesting option for special consumer markets interested in the presence of compounds potentially capable of preventing diseases(6)(7).

The consumption of fruits and vegetables rich in bioactive compounds such as phenolics, carotenoids, terpenes and anthocyanins has the potential to prevent chronic non-communicable diseases, such as cancer, diabetes mellitus, dyslipidemia and cardiovascular and chronic respiratory diseases(8).

In this review, summarized information on the main native fruits of the Myrtaceae is presented, highlighting their composition and biological activities in order to direct new research.

Figure 1. Examples of native fruits from the Myrtaceae family

2. Physical-chemical and bioactive composition, and biological activity

2.1 Cattley guava [*Psidium cattleianum* Sabine]

Psidium cattleianum is known by different names in Portuguese, such as *araçá*, *araçá-rosa*, *araçá-de-comer*, *araçá-da-praia* or *araçá-coroa*, in English as cattley guava, strawberry guava or cherry guava, and in Spanish as *arazá*(9). In Brazil, it is mostly known as *araçá* and its fruit is widely consumed fresh or processed into jams, jellies, ice creams and juices(10).

The cattley guava skin can be yellow or red, and the yellowish white pulp is juicy, sweet, a little bit acid and spicy, containing multiple seeds(9)(10).

Fresh fruits contain mainly water (81.7 - 84.9% w/w), followed by carbohydrates (4.3 - 10%), fiber (3.9 - 6.1%), protein (0.75 - 3.7%), minerals (0.63 - 1.50 g) and lipids (0.42-0.55%)(9). The average total caloric content is 26.8 kcal/ 100 g of fresh fruit. The main minerals present in the pulp are calcium, magnesium, sodium, potassium and zinc(9)(11). The variation among data is related to edaphoclimatic factors(11) and quantification methods employed.

In addition, cattley guava fruits are a source of vitamin C, fatty acids, polysaccharides, volatile compounds, carotenoids and polyphenols(9). Among the bioactive compounds, ellagic acid and its deoxyhexoside and epicatechin gallate are the main phenol, while all-trans-lutein, all-trans-antheraxanthin and all-trans-β-carotene are the main carotenoids(12) in the literature (Table 1).

Table 1. Concentration of carotenoids and phenolic compounds from cattley guava fruits

Class of compounds	Compounds	Concentration
Carotenoids (µg/g)	9-cis-β-Carotene	1.3(5)
	13-cis- β-Carotene	1.2(5)
	5,6-epoxy-β-Carotene	1.2(5)
	α-Carotene	4.0 – 60.8(5)(13)
	β-Carotene	2.9 – 512.6(5)(13)
	all-trans-Zeaxanthin	137.5(5)
	Cryptoxanthin	0.9(5)
	all-trans-Lutein	557.8(5)
	all-trans-β-Cryptoxanthin	1029.8(5)
Phenolic compound (µg/g fresh fruit)	Epicatechin	263.9 - 2659.5(14)
	Coumaric acid	720.5-2659.5(14)
	Ferulic acid	2.0 – 8.1(14)
	Myricetin	0.1-3.8(14)
	Gallic acid	297.7-726.7(14)
	Chlorogenic acid	60.00 – 801.00(14)
	Galloyl hexoside	74.00(13)
	Digalloyl hexoside	29.00(13)
	Di-HHDP-hexoside isomer	39.00(13)
	HHDP digalloyl hexoside	23.00(13)
	Quercetin	2.0-6.8(14)
	Quercetin hexoside	64.00(13)
	Methyl ellagic acid hexoside	52.00(13)
	Methyl ellagic acid pentoside	56.00(13)
	Vanillic acid hexoside	81.00(13)
	Taxifolin hexoside	117.00(13)
	Eriodictyol hexoside	40.0(13)
	Total phenolic compounds	292.03 – 5638.00(15)(16)

Cattley guava fruit extracts show high antioxidant activity[12] able to neutralize free radicals, reducing the level of oxidative stress in the body, as well as preventing chronic non-communicable diseases[17]. In addition, they exhibit α-glucosidase inhibitory capacity after gastrointestinal digestion, indicating their potential use in the control of type II diabetes[18]. Antidiabetic, anticarcinogenic, antimicrobial, anti-inflammatory and anti-aging effect of *Psidium cattleianum* Sabine are attributed to its polyphenolic composition[9][14].

In vivo studies using rats fed with freeze-dried fruit cattley guava powder showed a remarkable reduction in the parameters altered by the oxidative stress induced by cisplatin. The animals showed reduced levels of glucose, LDL cholesterol, oxidized LDL cholesterol and total cholesterol when compared to the control animals (animals induced by cisplatin not fed with cattley guava)[13]. In addition, animals fed with cattley guava decreased the deposition of fat in the liver, showing an improvement in the lipid profile[13]. More recently, the administration of a cattley guava extract (200 mg / kg / day, for 21 days) in insulin-resistant rats prevented hepatic lipid peroxidation and the formation of reactive oxygen species avoiding hyperglycemia, hypertension and hypertriglyceridemia[19]. The effect of administration of a red cattley guava extract (200 mg / kg / day for 150 days) on the metabolic parameters of Wistar rats fed with a highly palatable diet also prevented changes caused by the diet, such as glucose intolerance, increased weight gain and visceral fat, high serum glucose levels, triacylglycerol, total cholesterol, LDL cholesterol and interleukin-6[20].

In none of these publications authors report the mechanisms of action related to the extracts. However, in the case of antihyperglycemic activity, it can be related to some of the phenolic compounds present in cattley guava extracts, since these compounds are able to inhibit specific enzymes, such as α-glucosidase and α-amylase[21]. Quercetin, for example, is considered a good inhibitor of digestive enzymes, with an IC_{50} almost 40 times lower than the positive control (acarbose)[22].

Moreover, in Wistar rats with metabolic syndrome effects were observed of red cattley guava extracts on inflammatory and thrombo-regulatory parameters. The cattley guava extract (200 mg / kg / day for 150 days) prevented the increase of the following inflammatory parameters: interleukin-6 and butyryl-cholinesterase in serum, acetylcholinesterase in lymphocytes. Also preventing the decrease in thrombo-regulatory parameters: NTPDase activity in lymphocytes and platelets, and 50-nucleotidase in platelets[23].

Cattley guava hydroalcoholic extracts (75:25 v/v; ethanol-water) showed antimicrobial potential against *Staphylococcus aureus* with minimum inhibitory concentration of 9 mg / mL and minimum bactericidal concentration of 18 mg / mL. In addition, the authors observed that the application of the extract caused a rupture in the cell membrane of the microorganism[24]. Extracts obtained by supercritical CO_2 and cattley guava essential oil showed high total antioxidant activity and inhibitory effects on *S. aureus* and *L. monocytogenes*[25].

Cattley guava fruit has high biological potential, due to its bioactivity, despite not being produced on a commercial scale. Nevertheless, there are several options for its industrialization. For example, red and yellow cattley guava jams were made without the addition of sugar, to promote healthier options for consumers. The results showed that the important bioactive compounds (phenolic compounds, anthocyanins and ascorbic acid) were not lost and these new products may be a good option for the use of cattley guava pulp[26]. The red cattley guava pulp was also encapsulated with excellent results in the retention of bioactive compounds and maintaining antioxidant activity[27].

2.2 Suriname cherry [*Eugenia uniflora* L]

Suriname cherry (or Brazilian cherry) fruits are globular, crowned by persistent sections, with flattened poles presenting seven to ten ribs in the longitudinal direction, and with a slightly acidic and sweet taste[28]. Depending on the genotype, the epicarp varies from green to orange or light red at the beginning of ripening, turning to orange, red or dark purple (almost black) when they are fully ripe[29].

Fresh Suriname cherry fruits differ in composition due to their color (genotype) and edaphoclimatic factors[28]. Yellow fruits have an average content of 84.7% (w/w) moisture, 10.3% carbohydrates, 1.1 to

3.7% protein, 2% fiber, 1.7% minerals and 0.02 to 0.5% lipids. In parallel, the red colored fruits consist of 83.9% (w/w) moisture, 13 to 19% carbohydrates, 0.8 to 5% proteins, 2.2% fiber, 1.1% minerals, and 0.4 to 0.9% lipids. Finally, purple fruits are composed by 81% (w/w) moisture, 14.8 to 19% carbohydrates, 1.2 to 5% protein, 2.4% minerals, and 0.4 to 0, 9% lipids(30)(31)(32)(33).

The pulp of the Suriname cherry fruit has high levels of vitamin C(34); the content is higher in orange, followed by purple and red fruits(34). The fruits are also rich in vitamin A, carotenoids, anti-oxidant compounds with low lipid and caloric levels(35)(36). Extracts of this fruit contain alkaloids, glycosides, flavonoids, tannins, saponins, terpenoids and reducing sugars, where flavonoids and glycosides are the main constituents(37).

The high pulp yield (66 to 88% w/w of the fruit)(35) allows both fresh as well as processed consumption (frozen, dehydrated and freeze-dried sweets, juices, ice creams, liquors or pulps)(38).

This native fruit also has a high antioxidant potential, especially due to its composition of flavonoids, particularly myricetin and quercetin(38)(39). It also contains carotenoids such as lycopene, γ-carotene and β-cryptoxanthin(2)(29)(40). Table 2 shows the carotenoids and phenolic compounds contained in the Suriname cherry, according to the literature.

Table 2. Concentration of carotenoids and phenolic compounds from Suriname cherry

Class of compounds	Compounds	Concentration (μg/g)
Carotenoids (μg/g)	13-*cis*+15-*cis*)-β-carotene	0.74[a*] (29)
	(9Z)-lycopene	0.56-3.20[c*] (41)
	(9Z)-rubixanthin	2.05-5.09[c] (41)
	(all-*E*)-lycopene	14.00-71.10[b*] (40)
	(all-*E*)-rubixanthin	9.40-11.50[b] (40)
	(all-E)-zeaxanthin	0.82-2.55[c] (41)
	(all-*E*)-α-carotene	0.16[c] (41)
	(all-*E*)-α-cryptoxanthin	0.08[c] (41)
	(all-*E*)-β-carotene	1.22-6.20[c] (41)
	(Z)-rubixanthin	4.40-5.30[b] (40)
	13-*cis*-lycopene	6.99[a] (29)
	all-*E*-lutein	0.42-1.04[c] (41)
	(*E*)-rubixanthin	15.67[a] (41)
	cis-lycopene	96.79[*d] (42)
	(Z)-rubixanthin I	3.62[a] (29)
	(Z)-rubixanthin II	1.61[a] (29)
	Trans-lycopene	109.11[d] (42)
	β-cryptoxanthin	16.00–34.00[e*] (43)
Phenolic compounds (μg/g)	Gallic acid	0.1173[*h] (44)
	Ellagic acid	592.00 – 678.00[*g] (38)
	Galloyl hexoside	114.7[c] (45)
	Galloylquinic acid	54.80[c] (45)
	Salicylic acid	0.006[*f] (44)
	Epicatechin	445.20[d] (42)
	Kaempferol	3.0-6.0[g] (40)(46)
	Myricetin 3-*O*-hexoside	130.25–132.53[h] (43)

Class of compounds	Compounds	Concentration (µg/g)
	Myricetin 3-*O*-pentoside	22.41-25.22[h] (43)
	Myricetin 3-*O*-rhamnoside	226.19 - 279.61[h] (43)
	Myricetin deoxyhexosidegallate	7.85 - 9.91[h] (43)
	Myricetin 3-*O*-deoxyhexoside	228.4[g] (45)
	Myricetin galloyl- deoxyhexoside	23.04[c] (45)
	Cyanidin−3-*O*-glucoside	31.04-1689.67[h] (43)
	Cyanidin-*O*-galactoside	9.10-41.00[g] (42)(47)
	Cyanidin-O-glucoside	69.10-582.90[f] (47)
	Cyanidin 3-*O*-pentoside	8.30[c] (45)
	Cyanidin derivative	51.60[c] (45)
	Delphinidin-*O*-glucoside	0.90 -1.10[g] (42)(47)
	Delphinidin 3-*O*-glucoside	996.50[c] (45)
	Delphinidin-*O*-galactoside	3.20–80.90[g] (47)
	Malvidin-*O*-galactoside	37.2[g] (47)
	Malvidin-*O*-pentoside	16.3[g] (42)
	Malvidin-*O*-acetylhexoside	3.3[g] (47)(42)
	Pelargonidin−3-*O*-glucoside	21.6[c] (45)
	Pelargonidin-*O*-glucoside	1.10-2.40[g] (47)
	Petunidin-*O*-galactoside	7.50[g] (47)
	Isoquercitrin	0.0626[f] (44)
	Quercetin-3-*O*-hexoside	115.80-375.32[h] (43)
	Quercetin-3-*O*-pentoside	27.97-61.68[h] (43)
	Quercetin-3-*O*-rhamnoside	135.34 – 285.04[h] (43)
	Quercetin-galloyl-deoxyhexoside	230.40[c] (45)
	Quercetin 3-*O*-deoxyhexoside	196.8[c] (45)
	Resveratrol	1125.10[h] (48)
	Coumarin	711.80[h] (48)
	Vanillin	0.013[h] (44)
	O-galloyl-D-glucose	60.00 - 890.00[h] (35)
	1,2,6-tri-O-galloyl-β-D-glucose	40.00 – 360.00[h] (35)
	Eugeniflorina D2	1730.00 - 3970.00[h] (35)
	Oenothein B	33100.00 -29900.00[h] (35)

*[a]freeze dried pulp; *[b]frozen pulp; *[c]lyophilzed fruit; *[d]juice frozen; *[e]fresh pulp; *[f]lyophilized juice; *[g]fresh fruit; *[h]dried basis.

Purple, orange and red Suriname cherry have the capacity to eliminate free radicals[34], suggesting that the consumption of this fruit may contribute to reduce the risk of developing chronic non-communicable diseases, recurrent of oxidative damage[32]. According to Vinholes and others[22] the consumption of Suriname cherry contributes to the prevention of the development of type 2 diabetes. The purple extract was the most effective in inhibiting α-glucosidase, when compared to extracts of red and orange colors; and still, with an IC_{50} 6 times lower than that of acarbose[22].

Red Suriname cherry was investigated for possible activity in the prevention of obesity, and, consequently, in the metabolic syndrome[49]. It was demonstrated that in rats fed with a highly palatable diet the extract prevents the increase of visceral fat mass, glycemia, total cholesterol and LDL cholesterol. The extract was also able to prevent the reduction of the activity of the antioxidant enzymes superoxide dismutase and catalase. The results showed that Suriname cherry extract exerted anti-hyperglycemic, anti-hyperlipidemic and neuroprotective activities(49). The same study also noted that Suriname cherry seed extracts have activity on sucrose and maltase enzymes, showing a possible antihyperglycemic effect(50).

Another study showed that red Suriname cherry juice resulted in significant inhibition of acetylcholinesterase activity, a target enzyme in strategies for the treatment of Alzheimer's disease(44).

Eugenia uniflora fruit extract showed a protective effect in mice with a depression model: prevented the depressant-like effect induced by chronic unpredictable stress; regulated the activity of acetylcholinesterase; reduced oxidative damage to lipids and reactive oxygen species production, in the prefrontal cortex and hippocampus; and prevented the reduction of glutathione peroxidase in the hippocampus of animals subjected to treatment(51).

Researchers demonstrated the anti-inflammatory action on human gingival epithelial cells using compounds from the purple Suriname cherry juice(52). This activity was tested on human oral cells after stimulation with the oral Gram-negative bacteria *Porphyromonas gingivalis*, which resulted in an 52% inhibition of the release of interleukin-8 stimulated by lipopolysaccharides. These results were associated with the presence of the cyanidin-3-glucoside and oxidoselina-1,3,7(11)-trien-8-one(52).

Tambara and others(45) investigated the effect of purple Suriname cherry extracts on the aging process, using the nematode *Caenorhabditis elegans* (model for the study of the molecular mechanisms of the aging process). The results showed that the ethanolic extract, rich in polyphenols, significantly increased the life span of *C. elegans* by modulating the DAF-16 pathway (a central regulator for various biological processes), without toxic effects. It also improved survival, reproduction and useful life in the pre-and post-exposure to oxidative stress(45).

Ethanol extracts from *Eugenia uniflora* seeds also have antimicrobial potential against *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Salmonella* Typhimurium. These activities were attributed to the polar compounds present in the seeds(50).

Finally, the study by Becker and others(53) demonstrated an antimicrobial effect of essential oil extracted from the Suriname cherry leaf against the bacteria *Enterobacter aerogenes* and *Salmonella* Typhimurium.

In brief, Suriname cherry fruit is a promising source of bioactive compounds that can reduce or reverse the damage caused by reactive oxygen species due to its high antioxidant activity, demonstrating its potential for pharmaceutical and food purposes.

2.3 Guabiroba [*Campomanesia xanthocarpa* Berg]

Guabiroba is a yellow-orange fruit with acid and sweet flavor, which can be consumed fresh or processed as jelly, ice cream, liquor or tea(7). The fresh fruits of guabiroba have a moisture content varying between 79-83% (w/w), 8-16% carbohydrates, 6 to 10% fiber, 1 to 5.5% proteins, and 0.1 to 3.7% lipids. Thus, as in other native fruits, the composition is directly affected by edaphoclimatic factors(5)(54).

The fruit contains macro and micronutrients: proteins (1.08 g / 100 g), fats (0.12 g / 100 g), reduced sugar (8.3 g / 100 g, being fructose 4.0 g / 100 g; glucose 4.3 g / 100 g), mineral salts (iron 3.52, calcium 28.45, phosphorus 25.3 mg / 100 g, potassium 1.53 mg / 100 g)(54).

This fruit stands out for its content of vitamin C, minerals, vitamin A, and it is considered rich in fiber(55), with a high content of soluble fiber, mainly pectin(56), and also in phenolic compounds, including chlorogenic acid, and carotenoids with high antioxidant potential(5)(57)(58).

Anthocyanins, such as cyanidin-3-*O*-glucoside, delfinidin-3-*O*-glucoside and pelargonidin-3,5-diglucoside(59), have already been identified in guabiroba fruits, as well as cryptoxanthine, lutein and β-carotene(5)(60), the latter representing more than 40% of the total of these bioactive compounds(55). The individual carotenoids and phenolic compounds reported in the literature are presented in Table 3.

Table 3. Concentration of carotenoids and phenolic compounds from guabiroba

Class of compounds	Compound	Concentration (μg/g)
Carotenoid	β-Carotene	123-3.43 x 10 [5][59][60]
	β-Carotene 5,6-epoxide	8490 [5]
	13-*cis*-β-Carotene	5860 [5]
	9-*cis*-β-Carotene	4750 [5]
	α-Carotene	56-1.66 x 10 [5][55][59][60]
	Lycopene	0.9-8.3 [55][59][60]
	β-Cryptoxanthin	93-152 [55][59][60]
	Cryptoxanthin	1.21×10^5 [5]
	Lutein	15-8.19 x 10 [5][55][59][60]
	Violaxanthin	2.8 [47][50]
	Zeaxanthin	8.9-3.25 x 10 [5][47][62]
	Total carotenoids	207-3.06 x 10 [55][59]
Phenolic Compounds	Galangin	1516.6 [61]
	Methyl galangin	1422.4 [61]
	Hesperidin	195.8 [61]
	Geraldone	503.1 [61]
	Cirsimaritin	494.8 [61]
	2',4'-Dihydroxy-5'-methyl-6'-methoxychalcone	P [62]
	2',4'-Dihydroxy-3',5'-dimethyl-6'-methoxychal-cone	P [63]
	2'-Hydroxy-3'-methyl-4',6'-dimethoxychalcone	P [62]
	2',6'-Dihydroxy-3'-methyl-4'-metoxychalcone	P [63]
	5-Hydroxy-7-methoxy-8- methylflavanone	P [62]
	7-Hydroxy-5-methoxy-6-methylflavanone	P [62]
	Cyanidin-3-*O*-glucoside	P [59]
	Delphinidin-3-*O*-glucoside	P [59]
	Pelargonidin-3,5-diglucoside	P [59]
	Total Phenolic compound	2.2 – 90300 [5][54]

*P= present, but not quantified.

The biological effects of guabiroba consist of anti-proliferative, anti-obesity, hypoglycemic and hypolipidemic activities[7]. The compound 5-hydroxy-7-methoxy-8-methylflavanone isolated from guabiroba extracts proved to be effective against melanoma, breast, ovarian, kidney, lung, prostate and colon cells, without being toxic to vero cells (normal cell), showing antiproliferative activity of these extracts[62].

Hypoglycemic activity was observed in obese rats (induced with a high-calorie diet), where a 15% reduction in the plasma glucose level of the animals was observed[64].

Acetylsalicylic acid is widely used as a treatment for the prevention of atherosclerotic disease; however, it can produce hemorrhagic events, including gastric ulcers[65]. Guabiroba extracts have been compared to acetylsalicylic acid, proving to be safer than the drug against stomach injuries, with a positive effect on improving blood circulation[66].

Regginato and others[67] evaluated the antihyperglycemic and hypolipidemic effects of guabiroba seed extract in hyperglycemic rats, observing that the application of the extract in concentrations of 400 mg / kg promoted a decrease in blood glucose levels in the animals, as well as an increase in muscle and liver glycogen, and reduced enzyme activities of saccharose and maltase. In addition, the same dose of extract decreased serum levels of LDL cholesterol, while the application of the 200 mg / kg dose promoted an increase in HDL cholesterol levels(67).

The use of guabiroba in the formulation of new products is encouraged, but it is important that the compounds remain preserved(60). Santos and others(60) found that the content of carotenoids that remain in jellies after fruit industrialization is maintained at up to 30% of the initial concentration, being quite promising as functional food. In addition, the encapsulation of guabiroba pulp with Poly (d,l-lactic-co-glycolic) acid reduced the generation of reactive oxygen species in non-cancer cells(68).

2.4 Guabiju [*Myrcianthes pungens* Berg]

Guabiju is a spherical and velvety fruit, purplish when maturity, succulent and with yellowish and edible pulp. It has an astringent flavor (with more or less pungency) when ripe, and sweet(4)(69). Fruits contain a maximum of two seeds of 6 to 7 mm, which are smooth and have a thin coat(70)(71). The peel is thick persistent calyx and changes from brownish green to dark purple during ripening(1)(13)(71)(72).

The fruit is highly perishable, with a maximum shelf life of 3 days(73), because it is extremely fragile in structure, requiring special care in the harvest(4). Freeze-drying or freezing the pulp are options for its conservation that enable the maintenance of most bioactive compounds(74), especially anthocyanins, phenolic compounds and carotenoids(75). The concentration of anthocyanins increases during storage at room temperature (25 ^{o}C)(75).

As for the nutritional composition, the guabiju hard fruits have a moisture content ranging from 81 to 85% (w/w). Evaluating the other compounds on a dry basis, fruits have 4.9 to 64.6% (w/w) of carbohydrates, 4.4 to 32.4% of fiber, 0.6 to 8.4 % of proteins, and 0.3 to 0.8 % lipids(13)(73)(76).

Fruits are rich in phenolic compounds(77)(80)(81) especially anthocyanins and flavonoids, responsible for the purplish color of the bark, containing also carotenoids, mainly in the pulp(82).

Among the phenolic compounds in guabiju gallic acid, isoquercitrin, hiperoside, quercetin, quercitrin, and delphinidin 3-β-*D*-glucoside were found; and as anthocyanins, cyanidin 3-*O*-glycoside, malvidin-3-*O*-glycoside, cyanidin chloride, malvidin chloride and peonidin chloride. Malvidin 3-*O*-glycoside was the main anthocyanin found in the fruit(76).

Some carotenoids are also found in the pulp and bark of guabiju, such as lutein, zeaxanthin, β-cryptoxanthin, α and β-Carotene(69). Table 4 shows the carotenoids and individual phenolic compounds found in guabiju fruits.

Studies demonstrate guabiju high antioxidant potential(78), which increases during its maturation(80). This potential is closely linked to the gastroprotective(76) and anti-cholesterolemic effects(13) contributing to the prevention and recovery from chronic diseases. Studies relate the phytochemicals of the fruit to anticholinesterase(78) and anti-chemotactic effects(82)(83)(84).

Gastroprotective activity has already been linked to the ingestion of guabiju fruit extracts. Animal models with an acute ulcer received methanolic extracts of bark, pulp and leaves, and showed a defense capacity of the gastric mucosa, reducing the relative area of the lesion when compared to the control(76).

A qualitative study with extracts of guabiju showed that the extracts inhibit the enzyme acetylcholinesterase having an action similar to the medications used in the treatment of symptoms of Alzheimer's disease(79). An *in vivo* study of guabiju fruits showed a protective effect against the oxidative stress caused by cisplatin in animals that consumed a diet that included the fruits. The levels of total cholesterol, low-density lipoproteins (LDL) and oxidized low-density lipoprotein (Ox-LDL) in the plasma and fat in the liver decreased without increasing body weight after consumption of the fruit diet(71).

The extracts of guabiju leaves have been shown to be effective against *Strongyloides venezuelensis* and may be a possible drug against strongyloidiasis(85), a silent, underdiagnosed and very neglected helminth disease(86).

Table 4. Concentration of carotenoids and phenolic compounds from guabiju

Class of compounds	Compounds	Concentration
Carotenoids (µg/100g dry fruit)	Lutein	1022.23 [13][71]
	Zeaxanthin	126.72 [13][71]
	β-Cryptoxanthin	1634.36 [13][71]
	α-Carotene	192.80 [13][71]
	β-Carotene	2012.84 [13][71]
Total carotenoid (µg/100g dry fruit)		4989.00 [13][71]
Phenolic compounds (µg/g dry fruit)	Gallic acid	43.79- 148.2 [1]
	3,4-Dihydroxybenzoic acid	0.60-0.83 [1]
	Salicylic acid	P* [81]
	Syringic acid	4.30-5.03 [1]
	Caffeic acid	0.25 [1]
	Chlorogenic acid	0.06 [1]
	ρ-coumaric acid	0.80-1.12 [81]
	Ferulic acid	P* [1]
	Sinapic acid	0.16 [1]
	Quercetin	2.70-82.41 [81]
	(+)-Catechin	0.48-16.80 [81]
	(-)-Epigallocatechin gallate	9.72-40.60 [81]
	(+)-Epicatechin	0.11 [1]
	Isorhamnetin	0.86 [81]
	Kaempferol	1.50-9.01 [1]
	Naringenin	0.08-0.20 [81]
	Pinocembrin	P* [1]
	Syringaldehyde	P* [13]
	Delphinidin 3-β-*D*-glucoside	4249.31 [13][71]
	Cyanidin 3-*O*-glycoside	134.57 [13][71]
	Malvidin 3-*O*-glycoside	7223.51 [13][71]
	Cyanidin chloride	232.74 [13][71]
	Malvidin chloride	111.21 [13][71]
	Peonidin chloride	195.20 [13][71]
Total phenolic compound		137.29-1739-28 [13][71]

*P= present, but not quantified.

2.5 Uvaia [*Eugenia pyriformis*]

The uvaia fruit is rounded, 2 to 4 cm in diameter, with a very thin skin, slightly velvety and yellow gold in color, with orange ripeness. The pulp has a succulent, sweet, acidic and aromatic flavor[78] and can be consumed fresh[78][87][88]. However, it is an extremely perishable fruit and an interesting alternative for processing it in the form of jelly, yogurt, ice cream, frozen pulps, juices and jams[79][87][88][89], in addition to wines and vinegars[87][88]. The pulp is rich in vitamin C and contains considerable amounts of vitamin A and the B complex[5][59]. Despite this, and because it is often acid, fruits are usually consumed in the form of juice, jelly, liqueurs, jam, ice cream and sweets[90].

Fresh fruits contain, on average, 90% (w/w) water[91][92]. When evaluating fruits on a dry basis, an average of 44% carbohydrates, 42% fiber, 5.5% minerals, 5.5% proteins and 2.2% lipids are found[87]. The fruit is also rich in calcium, magnesium, potassium and iron[87][59][91][93].

Uvaia fruit has higher antioxidant activity (3246 g/g DPPH) than mangaba (3385 g/g DPPH) and açaí (3778 g/g DPPH)[94].

The phytochemicals present in the fruit are phenolic acids, flavonoids and carotenoids[2]. The main carotenoid parents found by Pereira and others[5] were: lutein, zeaxanthin, α and β-carotene. The seed has phenolics, flavonoids and high antioxidant activity[91]. The concentration of carotenoids and individual phenolic compounds is shown in Table 5.

The residue from the processing of ground uvaia pulp (peels and seeds) is an appropriate and promising alternative as a natural color in confectionery (sugar hard-panning confections)[95], and has antileishmanial antifungal and antiproliferative activities[96].

In an *in vivo* study, the administration of uvaia juice in the treatment group caused a significant reduction in the concentration of protein carbonyls in the rat liver (47.4%), which was associated with a 29% increase in catalase activity in addition to other biochemical parameters, demonstrating that this native fruit reduces oxidative damage, improves antioxidant efficiency and attenuates the oxidative damage to proteins caused by free radicals[97]. In addition, the extract showed anti-chemotactic, anti-inflammatory and antioxidant activities[98].

The study by Stieven and others[98] found that the essential oil obtained from uvaia has antimicrobial activity against *Staphylococcus aureus* and *Escherichia coli*.

Table 5. Concentration (µg/g) of carotenoids and phenolic compounds in uvaia

Class of compounds	Compounds	Concentration (µg/g)
Carotenoids	Lutein	307000.49[a*] (5)
	All-trans-lutein	86000.00[b]
	Zeaxanthin	40000.38[a] (5)
	β-carotene 5,6-epoxide	16000.39[a] (5)
	Cryptoxanthin	159000.09[a] (5)
	13-cis-β-carotene	38000.30[a] (5)
	α-carotene	124000.39[a] (5)
	β-carotene	191000.00[a] (5)
	9-cis-β-carotene	32000.27[a] (5)
	9-cis-neoxanthin	22.8[b*] (93)
	All-trans-neochrome	11.7[b] (93)
	Cis-antheraxanthin	22.1[b] (93)
	9-cis-violaxanthin	19.4[b] (93)
	All-trans-zeaxanthin	56.00[b] (93)
	All-trans-zeinoxanthin	78.4[b] (93)
	All-trans-β-cryptoxanthin	521.1[b] (93)
	9-cis-β-cryptoxanthin	68.1[b] (93)
	All-trans-α-carotene	14.2[b] (93)
	All-trans-β-carotene	170.9[b] (93)
Total carotenoid		909.33[a] (5)
Phenolic compounds	Galloyl hexoside	5.1 (93)
	Gallic acid	27.5 – 346.1[b] (93)(6)
	Galloyl hexoside isomer	1.8[b] (93)
	Dicaffeic acid	2.0[b] (93)
	Caffeic acid	5.2[b] (6)
	Gallic acid derivative	14.8[b] (93)
	Trigalloyl acid lactonized	13.8[b] (93)
	Galloyl-bis-HDDP hexoside	19.3[b] (93)
	Quercetin deoxyhexoside	4.8[b] (93)
	Chlorogenic Acid	27.2- 42.3[b] (6)
	ρ-coumaric acid	0.92 – 2.90[b] (6)
	Ferulic acid	2.30 – 3.40[b] (6)
	Rutin	0.83 – 1.1[b] (6)
	Myricitin	22.90 - 29.50[b] (6)
	Quercetin	114,20 – 180.90[b] (6)
	Kaempferol	2.60 – 13.40[b] (6)
Total Phenolic compound		255.90 – 588.30[b] (6)

*a dry fruit; b fresh fruit.

4. Conclusions

Brazil has a wide variety of native fruits, still unexplored, with high potential for commercial and/or industrial use. The native fruits mentioned in this review should be stimulated for consumption given their high nutritional value, rich contents of vitamins and minerals, and especially of phenolic compounds and carotenoids. Moreover, diseases such as diabetes, cardiovascular diseases and some types of cancer could be avoided through the ingestion of these natives, showing that their use should be stimulated.

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Author contribution statement

All authors contributed to the writing and the critical review of the content.

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