Bioactive Potential of Brazilian Plants Used as Food with Emphasis on Leaves and Roots

Fernanda L. B. Mügge, Sarah M. S. Prates, Juliana de Paula-Souza, and Maria G. L. Brandão

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F. L. B. Mügge

Centro Especializado em Plantas Aromáticas, Medicinais e Tóxicas (Ceplamt), Museu de História Natural e Jardim Botânico, Universidade Federal de Minas Gerais (UFMG), Belo Horizonte, Brazil

Zentrum für Molekulare Biologie, Universität Heidelberg, Heidelberg, Germany

S. M. S. Prates

Centro Especializado em Plantas Aromáticas, Medicinais e Tóxicas (Ceplamt), Museu de História Natural e Jardim Botânico, Universidade Federal de Minas Gerais (UFMG), Belo Horizonte, Brazil

Programa de Pós-Graduação em Ciências de Alimentos, Faculdade de Farmácia, Universidade Federal de Minas Gerais (UFMG), Belo Horizonte, Brazil

J. de Paula-Souza

Centro Especializado em Plantas Aromáticas, Medicinais e Tóxicas (Ceplamt), Museu de História Natural e Jardim Botânico, Universidade Federal de Minas Gerais (UFMG), Belo Horizonte, Brazil

Departamento de Botânica, Centro de Ciências Biológicas, Universidade Federal de Santa Catarina (UFSC), Florianópolis, Brazil

M. G. L. Brandão (✉)

Centro Especializado em Plantas Aromáticas, Medicinais e Tóxicas (Ceplamt), Museu de História Natural e Jardim Botânico, Universidade Federal de Minas Gerais (UFMG), Belo Horizonte, Brazil

e-mail: mbrandao@ufmg.br

1 Introduction

Archaeological finds show that plants have been used for millennia as sources of food and medicine in the Americas. Colonizing Europeans indeed learned the use of species such as corn, potatoes, cassava, tomatoes, cocoa, avocado, pineapple, and cashew, from the Amerindians (Maezumi et al. 2018). Native plants continue to be widely used in Brazil, but the intense miscegenation of cultures that occurred over recent centuries has also popularized the use of exotic species (Ferrão et al. 2008). The intense industrialization and urbanization of the country, which started in the 1950s, has deprived the Brazilian population of knowledge about the potential of native plants for use as food and medicine (Domingues et al. 2012; Fernandes 2004). These processes were aggravated by different economic cycles, starting with the exploitation of brazilwood (*Paubrasilia echinata* (Lam.) Gagnon, H.C.Lima & G.P.Lewis, Fabaceae) by the Portuguese. The economy is currently dominated by mining and agribusiness, both of which seriously damage native natural ecosystems (Dean 1996). Today, only 7% of the Atlantic Forest territory remains, while other ecosystems such as the savannas (Cerrado) and dry forests (Caatinga) are rapidly being replaced by monocultures of eucalyptus, sugarcane, soybeans, and livestock (Bockmann et al. 2018; Venâncio et al. 2018). As a consequence, not only knowledge but also the native plant species themselves are being lost (Brandão et al. 2008a, b; Mügge et al. 2016).

In contrast to this scenario, the consumption of healthier food and the transition to plant-based diets are growing in the developed world (Kahleova et al. 2017; Melina et al. 2016). The development of a “bioeconomy”, based on the sustainable use of biodiversity with less impact on the environment is also coming into favor (Valli et al. 2018), and traditional knowledge concerning the use of plant species used as food can be very valuable in this context. Information on species used by local populations in the past can reveal the existence of plants with the potential to be used as functional foods or used as a source of purified biological products. To contribute to this aim, during the last decade, our research group has focused on recovering traditional information about useful Brazilian plants from manuscripts and books published prior to 1960. Each work is carefully searched for data regarding the use of plants, and the information is then publicized (Brandão et al. 2011; Brandão et al. 2012; Breitbach et al. 2013; Fagg et al. 2015; Teixeira et al. 2019). Furthermore, the information is entered into an online database named Dataplant (www.ceplamt.org.br/dataplant), built to organize and make information readily available. Searches can be done through links referring to popular and scientific names, traditional uses, places where the plant occurs, and full texts extracted from original books or documents. To date, Dataplant contains information from 66 documents on 3400 species of Brazilian useful plants.

In two previous studies, we have focused on the search for data concerning native food species. Oliveira et al. (2012) studied the native plant foods recorded in field books of 16 European naturalists who traveled through Brazil in the nineteenth century. More recently, Teixeira et al. (2019) showed data on 504 edible fruits

recovered from the book “Dicionário das plantas úteis do Brasil e das exóticas cultivadas” (Dictionary of Useful Plants of Brazil and Exotic Cultivated), organized by the Portuguese botanist Manoel Pio Corrêa (1874–1934), in 1926. In this study, we present additional data about native plant species used as food, with emphasis on leaves and roots, recovered from books published by nine authors from the sixteenth to the twentieth centuries.

2 Methods

2.1 Search and Organization of Data

Firstly, we did a search in *Dataplant* for plants that were classified as edible (“comestível,” in Portuguese). Then, we searched the data using the key words: “frutos comestíveis” (edible fruits), “raízes comestíveis” (edible roots/tubers), “folhas comestíveis” (edible leaves), “flores comestíveis” (edible flowers), and “brotos comestíveis” (edible sprouts)”. Information from books published by nine authors, living in different regions of Brazil from the sixteenth to the twentieth centuries, were selected. Table 1 shows the names and nationalities of each author, year of publication of their books, the area upon which their studies focused, and the numbers of edible plant species recorded by each one.

Table 1 Authors’ nationalities, phytogeographical domains and regions studied in Brazil, years of the studies and number of plants cited in each publication

Abb ^a	Author/nationality	Area of study	Period in Brazil	Number of plants
SO	Gabriel Soares de Sousa/Portuguese	Atlantic Forest (Bahia state)	1575–1592	5
LI	Friar Cristovão de Lisboa/Portuguese	Amazonia (Maranhão state)	1624–1635	5
PI	Guilherme Piso/Dutch	Atlantic Forest and Caatinga (Pernambuco state)	1637–1644	7
VE	Friar Mariano C. Vellozo/Brazilian	Atlantic Forest and Cerrado (Minas Gerais and Rio de Janeiro states)	Natural	18
SP	Richard Spruce/English	Amazonia (Amazonas and Pará state)	1849–1864	4
CH	Pedro Napoleão Chernoviz/Polish	All regions of Brazil	1840–1855	9
PK	Theodor Peckolt/German	All regions of Brazil	1847–1912	30
CR	Manoel Pio Corrêa/Portuguese	All regions of Brazil	18XX-1934	26
CN	Paul Le Cointe/French	Amazonia	1891–1956	96

^aAbbreviation

To check whether a species was native of Brazil, as well as the current botanic name, was performed using the website “Flora do Brasil”.¹ It is often difficult to identify species from books published between the sixteenth and eighteenth centuries, because taxonomy as we currently know it was established only in the late eighteenth century, and the rules of botanical nomenclature did not exist until the beginning of the twentieth century. In particular, imprecise identification of some of the plants referred by Sousa (1587), Piso (1648), and Lisboa might detract from the accuracy of the study. However, reliability is somewhat increased by the fact that the editors of each of these books have added comments and more precise identification of the described species. Data on recent laboratory studies on bioactivity were obtained from PubMed.

The recorded plants were then divided in two tables: one with species submitted to studies that confirmed its health benefits (Table 2) and another table with the other plants that have not been studied (Table 3). Information about which author cited the plants is also included in the Tables (abbreviated names), as well as citations by other authors also present in Dataplant.

2.2 *Species Cited by Other Authors*

The results obtained from this study were compared with data recorded by European naturalists who lived or travelled in Brazil in previous centuries. The first search was performed in Oliveira et al. (2012), which describes historical data recovered from the nineteenth century (indicated as “1-167” in Tables 1 and 2). Other data were obtained directly from the field books of the naturalists Auguste de Saint-Hilaire (Brandão et al. 2012), George Gardner (Fagg et al. 2015), and Richard Spruce (Santos-Fonseca et al. 2019). Additional data collected by von Martius in Amazonia in the nineteenth century was recorded by Breitbach et al. (2013) and from Corrêa in the twentieth century in Teixeira et al. (2019). Importantly, these naturalists provide detailed information about the plants and its uses. They also provide an adequate coverage of the country in terms of area and phytogeographic domains: von Martius, for example, described plants from the North region (Amazon); Gardner and Burchell from Midwest region (Caatinga and Cerrado); and Saint-Hilaire described species from Southeast and South regions (Cerrado and Atlantic Forest).

¹ See at: <http://floradobrasil.jbrj.gov.br/2010/>

Table 2 Food species cited by the authors submitted to bioactivity studies

Family/species/ popular names		SO	LI	PI	VE	SP	CH	PK	CN	CR	Correlated studies on bioactivity
Aizoaceae <i>Sesuvium portulacastrum</i> (L.) L./Beldroega miúda	Lvs				x			x		x	Antimicrobial, antioxidant (Al-azzawi et al. 2012 ; Chandrasekaran et al. 2011)
Alismataceae <i>Echinodorus macrophyllus</i> (Kunth) Micheli/ Chapéu de couro ^a	Lvs									x	Anti-inflammatory (Silva et al. 2016), nephroprotective (Portella et al. 2012)
Amaranthaceae <i>Amaranthus cruentus</i> L./Caruru	Lvs				x			x			Obesity (Kanikowska et al. 2019), anti- inflammatory (Tang and Tsao 2017)
<i>Amaranthus spinosus</i> L./Bledo	Lvs							x			Antioxidant, nutritional, (Mondal and Maity 2016 , Sarker and Oba 2019), diabetes (Bavarva and Narasimhacharya 2013)
<i>Amaranthus viridis</i> L./Bredo americano	Lvs			x	x			x			Antioxidant, nutritional, (Sarker and Oba 2019), Mondal and Maity (2016), nutritional (Silva et al. 2018)
Anacardiaceae <i>Spondias tuberosa</i> Arruda/Ambu ^{1,2}	Rts	x		x			x			x	Antimicrobial (Santos et al. 2019)
Aquifoliaceae <i>Ilex dumosa</i> Reissek/Mate ^a	Lvs				x					x	Gan et al. (2018)
<i>Ilex integrissima</i> (Vell.) Reissek/ Mate ^a	Lvs									x	Gan et al. (2018)
<i>Ilex paraguariensis</i> A.St.-Hil./Mate ^a	Lvs						x			x	Gan et al. (2018) + Several other studies
<i>Ilex pseudobuxus</i> Reissek/Caúna ^a	Lvs									x	Gan et al. (2018)
<i>Ilex theezans</i> Mart. ex Reissek/Matea	Lvs									x	Gan et al. (2018)
Araceae <i>Caladium bicolor</i> (Aiton) Vent./Ara	Lvs, Rts	x	x				x	x	x	x	Antidiarrheal (Salako et al. 2015)

(continued)

Table 2 (continued)

Family/species/ popular names		SO	LI	PI	VE	SP	CH	PK	CN	CR	Correlated studies on bioactivity
<i>Colocasia esculenta</i> (L.) Schott/Inhame ¹⁻⁴	Rts								x	x	Immunomodulator (Pereira et al. 2018), diabetes (Eleazu et al. 2016)
<i>Xanthosoma sagittifolium</i> (L.) Schott/Mangará ³⁻⁴	Lvs, Rts	x	x					x			Antitumor (Caxito et al. 2015), prevent colon cancer (Jackix et al. 2013), antioxidant (Arruda et al. 2005), antifungal (Schmourlo et al. 2005)
Asteraceae <i>Sonchus oleraceus</i> L./Serralha lisa	Lvs				x		x		x	x	Antioxidant (Mawalagedera et al. 2016); anti-aging agent (Ou et al. 2015)
<i>Ayapana triplinervis</i> (Vahl) R.M.King & H.Rob./Aiapana ^a ¹	Lvs									x	Antioxidant (Taillé et al. 2020)
<i>Acmella oleracea</i> (L.) R.K.Jansen/ Agrião do Pará	Lvs								x	x	Chemical, nutritional (Neves et al. 2019), gastroprotective (Maria- Ferreira et al. 2014 ; Nascimento et al. 2013)
Cactaceae <i>Pereskia aculeata</i> Mill./Ora pro nobis	Lvs				x					x	Antioxidant, antimicrobial (Garcia et al. 2019 ; Souza et al. 2016), improve intestinal motility and lipid profile (Barbalho et al. 2016)
Dioscoreaceae <i>Dioscorea chondrocarpa</i> Griseb./Cará	Rts									x	Antimicrobial (Barnabé et al. 2014)
<i>Dioscorea trifida</i> L.f./Inhame roxo	Rts		x		x				x	x	Food allergy (Mollica et al. 2013)
Euphorbiaceae <i>Manihot esculenta</i> Crantz/Aipim ¹⁻¹⁶	Rts	x	x	x	x	x	x	x	x	x	Several studies
Fabaceae <i>Neptunia oleracea</i> Lour./Juquiry manso	Lvs								x	x	Antioxidant, management of diabetes (Lee et al. 2019)
<i>Pachyrhizus erosus</i> (L.) Urb./Jacatupé	Rts						x				Management of blood glucose (Park et al. 2016 , Santoso et al. 2019)

(continued)

Table 2 (continued)

Family/species/ popular names		SO	LI	PI	VE	SP	CH	PK	CN	CR	Correlated studies on bioactivity
Marantaceae <i>Maranta</i> <i>arundinacea</i> L./ Araruta	Rts					x				x	Antiulcerogenic (Rajashekhara et al. 2014), immunostimulant (Kumalasari et al. 2012)
Nyctaginaceae <i>Boerhavia diffusa</i> L./Tangeraca mansa	Lvs							x			Gastrointestinal disorders, anticancer (Mishra et al. 2014)
<i>Boerhavia erecta</i> L./Ervã tostão de Minas	Lvs							x			Antioxidant, anti- inflammatory (Compaore et al. 2018)
Oxalidaceae <i>Oxalis barrelieri</i> L./Azedinha	Lvs									x	Antidiarrhea (Fokam Tagne et al. 2018)
Piperaceae <i>Peperomia</i> <i>pellucida</i> (L.) Kunth/ Jaboti-membeca	Lvs							x		x	Antimicrobial (Alves et al. 2019)
<i>Piper umbellatum</i> L./Mático ^{1,3,7}	Lvs	x		x	x	x		x		x	Intestinal anti- inflammatory (Arunachalam et al. 2020), anti-gastric ulcer (Silva Junior et al. 2016), anticancer (Iwamoto et al. 2015)
Plumbaginaceae <i>Plumbago</i> <i>scandens</i> L./ Caá-jandiwap, loco ¹	Lvs, Rts			x	x		x		x	x	Antimicrobial <i>Helicobacter pylori</i> (de Paiva et al. 2003 , Wang and Huang 2005)
Polygonaceae <i>Rumex acetosella</i> L./Alecrim de São José	Lvs							x		x	Management of diabetes (Özenver et al. 2020)
<i>Polygonum</i> <i>aviculare</i> L./ Sanguinária	Lvs									x	Pancreatic lipase inhibitions (Park et al. 2019), antioxidant, anti-inflammatory (Granica et al. 2013), antiobesity (Sung et al. 2013), antimicrobial (Salama and Marraiki 2010)

(continued)

Table 2 (continued)

Family/species/ popular names		SO	LI	PI	VE	SP	CH	PK	CN	CR	Correlated studies on bioactivity
Talinaceae <i>Talinum</i> <i>paniculatum</i> (Jacq.) Gaertn./ Língua de vaca	Lvs								x	x	Antimicrobial (Reis et al. 2015)
Tropaeolaceae <i>Tropaeolum</i> <i>pentaphyllum</i> Lam./Capuchinha ³	Lvs/ Rts							x		x	Nutritional, antioxidant (De Bona et al. 2017), antimicrobial (Cruz et al. 2016)

^aUsed as tea. *Lvs* leaves, *Rts* roots.

3 Results and Discussion

Data on the use of Brazilian native plant food species were recovered from books published by nine authors that lived in Brazil during different times in the past five centuries (Table 1). The earliest was the Portuguese Gabriel Soares de Sousa (1540–1592) who lived in Bahia for 17 years. In his book “Tratado Descritivo do Brasil em 1587” (Descriptive Treaty of Brazil in 1587), he gave detailed information specifically about plants from the Atlantic Forest used by the Amerindians. Friar Cristóvão de Lisboa (1583–1652) was a Portuguese who lived in Brazil from 1624 to 1635 and worked in a religious mission in the state of Maranhão; once back in Portugal his observations were published first in 1627 in the book “History of animals and plants of Maranhão” (História dos animais e plantas do Maranhão). As the title suggests, the book has information about animals and plants from the Amazonian region, accompanied by richly detailed high quality drawings which allow identification of the plants (Marques [1996](#)). Also in the seventeenth century, northeast Brazil was invaded by the Dutch, and Guilherme Piso and Marcgrave lived there for 8 years. Later in 1648, back in the Netherlands, they published the book “Historiae Naturalis & Medicae,” in which several native food and medicinal plants used by the Amerindians are described (Piso [1648](#)).

From the Portuguese invasion in 1500 to the next three centuries, Brazilian territory was under strict control in order to prevent natural resources of being exploited by other countries. In 1808, the Portuguese royal family fled to Rio de Janeiro from Portugal after Napoleon Bonaparte’s invasion. They lived in Brazil for the next 13 years, a period that was characterized by notable progress in the country’s economy, culture and science, such as the creation of the first School of Medicine in Salvador and the Botanical Garden of Rio de Janeiro. Foreigners finally had permission to enter the country and many European naturalists came to Brazil. They explored all regions of the country and identified new plant species and gathered information on their use by the local communities (Brandão et al. [2008a, b](#); Oliveira et al. [2012](#)). Among these naturalists was the English Richard Spruce (1817–1893), who lived in the Amazon for 17 years. After his death, Wallace edited his “Notes of

Table 3 Brazilian plant foods not studied and authors who cited their uses

Families/species/popular names/parts used	Authors								
	SO	LI	PI	VE	SP	CH	PK	CN	CR
Alstromeriaceae									x
<i>Alstroemeria caryophyllaea</i> Jacq./Madressilva/Rts									
<i>Alstroemeria monticola</i> Mart. ex Schult. & Schult.f./Carajurú/Rts							x		
<i>Bomarea edulis</i> (Tussac) Herb./Jaranganha/Rts									x
Amaranthaceae							x		
<i>Blutaparon vermiculare</i> (L.) Mears/Caá-ponga/Lvs									
Amaryllidaceae							x		x
<i>Zephyranthes candida</i> (Lindl.) Herb./Carapitaia/Rts									
Anacardiaceae		x		x					x
<i>Spondias venulosa</i> (Engl.) Engl./Acaia/Rts									
Apiaceae									x
<i>Eryngium nudicaule</i> Lam./Gravatazinho/Rts									
Aquifoliaceae									x
<i>Ilex affinis</i> Gardner/Congonha ^a /Lvs									
<i>Ilex brasiliensis</i> (Spreng.) Loes./Erva mate ^a /Lvs									x
<i>Ilex conocarpa</i> Reissek/Congonha ^a /Lvs									x
<i>Ilex chamaedryfolia</i> Reissek/Congonha ^a /Lvs									x
<i>Ilex diuretica</i> Mart. ex Reissek/Congonha ^a /Lvs									x
<i>Ilex paltorioides</i> Reissek/Congonha ^a /Lvs									x
Araceae								x	
<i>Dracontium asperum</i> K.Koch/Taja de cobra/Rts									
<i>Urospatha caudata</i> (Poepp.) Schott/Apê/Rts							x	x	x
<i>Xanthosoma riedelianum</i> (Schott) Schott/Mangarito/Rts									x
<i>Xanthosoma striatipes</i> (Kunth & C.D.Bouché) Madison/Banana do brejo/Rts ³							x		x
Arecaceae									x
<i>Euterpe oleracea</i> Mart./Açaí/Lvs/Spr ^{6,7,14}									
Asteraceae				x					x
<i>Erechtites valerianifolius</i> (Wolf) DC./Caruru/Lvs									
<i>Pacourina edulis</i> Aubl./Pacurina/Lvs								x	x
Balanophoraceae							x		
<i>Langsdorffia hypogaea</i> Mart./Espiga de sangue/Flw									
<i>Lophophytum mirabile</i> Schott & Endl./Batata escamas/Rts									x
<i>Ombrophytum peruvianum</i> Poepp. & Endl./Parasita/Rts									x
Bignoniaceae								x	x
<i>Dolichandra unguis-cati</i> (L.) L.G.Lohmann/Poampé/Rts									
Campanulaceae									x
<i>Centropogon cornutus</i> (L.) Druce/Crista de peru/Lvs									

(continued)

Table 3 (continued)

Families/species/popular names/parts used	Authors								
	SO	LI	PI	VE	SP	CH	PK	CN	CR
Cannaceae							x		x
<i>Canna paniculata</i> Ruiz & Pav./Paca vira/Rts									
<i>Canna glauca</i> L./Achira/Rts			x	x		x	x	x	x
Cardiopteridaceae									x
<i>Citronella paniculata</i> (Mart.) R.A.Howard/ Congoinha ^a /Lvs ²									
Convolvulaceae									x
<i>Distimake tuberosus</i> (L.) A.R. Simões & Staples/Jetuca/Rts									
Dioscoreaceae									x
<i>Dioscorea bahiensis</i> Kunth/Cará/Rts									
<i>Dioscorea cinnamomifolia</i> Hook./Cará assú/Rts				x					x
<i>Dioscorea dodecaneura</i> Vell./Cará barbado/Rts									x
<i>Dioscorea fodinarum</i> Kunth/Cará/Rts									x
<i>Dioscorea glandulosa</i> (Klotzsch ex Griseb.) Kunth/ Cará/Rts									x
<i>Dioscorea hassleriana</i> Chodat/Cará coco/Rts				x					x
<i>Dioscorea heptaneura</i> Vell./Cará branco/Rts									x
<i>Dioscorea lacerdae</i> Griseb./Cará/Rts									
<i>Dioscorea laxiflora</i> Mart. ex Griseb./Caratinga bravo/ Rts								x	x
<i>Dioscorea leptostachya</i> Gardner/Cará/Rts									x
<i>Dioscorea multiflora</i> Mart. ex Griseb./Cará/Rts									x
<i>Dioscorea ovata</i> Vell./Cará inhame/Rts									x
<i>Dioscorea piperifolia</i> Humb. & Bonpl. ex Willd./ Cará/Rts								x	x
<i>Dioscorea sinuata</i> Vell./Caratinga brava/Rts				x					x
<i>Dioscorea stegelmanniana</i> R.Knuth/Cará/Rts									x
<i>Dioscorea trifoliata</i> Kunth/Caranambú/Rts									x
Euphorbiaceae									x
<i>Manihot caerulea</i> Pohl/Maniçoba/Rts									
<i>Manihot caerulea</i> Pohl ssp. <i>caerulea</i> /Maniçoba/Rts									x
<i>Manihot dichotoma</i> Ule/Maniçoba/Rts									x
<i>Manihot glaziovii</i> Müll.Arg./Maniçoba/Rts									x
<i>Manihot violacea</i> Pohl/Maniçoba/Rts									x
Fabaceae									x
<i>Luetzelburgia auriculata</i> (Allemão) Ducke/Pau chapada/Rts									
Heliconiaceae									x
<i>Heliconia psittacorum</i> L.f./Pacová catinga/Rts									
Humiriaceae					x			x	
<i>Humiria balsamifera</i> (Aubl.) A.St.-Hil./Umiri/Rts									

(continued)

Table 3 (continued)

Families/species/popular names/parts used	Authors								
	SO	LI	PI	VE	SP	CH	PK	CN	CR
<i>Sacoglottis guianensis</i> Benth./Achua/Rts								x	
Icacinaceae								x	x
<i>Casimirella ampla</i> (Miers) R.A.Howard/Mairá/Rts									
<i>Leretia cordata</i> Vell./Mata fome/Rts									x
Iridaceae									x
<i>Phalocallis coelestis</i> (Lehm.) Ravenna/Bibi/Rts									
Malvaceae									x
<i>Abutilon megapotamicum</i> (Spreng.) A.St.-Hil. & Naudin/Benção de Deus/Lvs									
<i>Abutilon purpurascens</i> K.Schum./Benção de Deus/Flw									x
<i>Hibiscus bifurcatus</i> Cav./Algodão do brejo/Rts								x	x
<i>Sphaeralcea bonariensis</i> (Cav.) Griseb./Malvaisco/Lvs, Flw						x			x
Marantaceae									x
<i>Goepertia allouia</i> (Aubl.) Borchs. & S.Suárez/Tupinambor/Rts									
<i>Goepertia tuberosa</i> (Vell.) Borchs. & S.Suárez/Caeté/Rts			x	x			x		
<i>Ischnosiphon arouma</i> (Aubl.) Körn./Arumá membeca/Rts							x	x	x
<i>Ischnosiphon petiolatus</i> (Rudge) L.Andersson/Arumá/Rts								x	
<i>Thalia geniculata</i> L./Arumarana/Rts							x	x	x
Nyctaginaceae								x	x
<i>Neea theifera</i> Oerst./Caparrosa ^a /Lvs									
Nymphaeaceae								x	
<i>Victoria amazonica</i> (Poepp.) J.E.Sowerby/Uapé/Rts									
Oxalidaceae									x
<i>Oxalis hirsutissima</i> Mart. & Zucc./Azedinha/Lvs									
Phytolaccaceae							x		x
<i>Phytolacca rivinoides</i> Kunth & Bouché/Espinafre Guiana/Lvs									
<i>Phytolacca thyrsoiflora</i> Fenzl. ex J.A.Schmidt/Carurú/Lvs									x
Piperaceae							x		
<i>Peperomia transparens</i> Miq./Língua de sapo/Lvs									
Poaceae							x		
<i>Gynerium sagittatum</i> (Aubl.) P.Beauv./Arina/Spr									
Polygonaceae							x		x
<i>Rumex brasiliensis</i> Link/Labaça/Lvs									
Portulacaceae									x
<i>Portulaca halimoides</i> L./Beldroega/Lvs									
<i>Portulaca mucronata</i> Link/Beldroega/Lvs							x		

(continued)

Table 3 (continued)

Families/species/popular names/parts used	Authors								
	SO	LI	PI	VE	SP	CH	PK	CN	CR
<i>Portulaca pilosa</i> L./Alecrim de São José/Lvs ^{1,2}									x
Solanaceae									x
<i>Solanum commersonii</i> Poir./Batata silvestre/Rts									
<i>Solanum alternatopinnatum</i> Steud./Caruru de espinho/Lvs				x					x
Talinaceae									x
<i>Talinum fruticosum</i> (L.) Juss./Beldroega grande/Lvs									
Tropaeolaceae							x		x
<i>Tropaeolum brasiliense</i> Casar./Capuchinha do Brasil/Lvs									
Typhaceae								x	x
<i>Typha domingensis</i> Pers./Tabua/Rts									

^aUsed as tea. *Lvs* leaves, *Rts* roots, *Flw* flowers, *Spr* sprouts.

a botanist in Amazonas and the Andes” (1908), providing them with a bibliographic introduction (Seaward 2000).

It is also important to highlight the efforts of the first Brazilian botanist, Friar José Mariano da Conceição Vellozo. Friar Vellozo was born in 1741 in Minas Gerais and died in Rio de Janeiro, in 1811. From an early age, he was interested in botany. In 1755 he started his religious life in Rio de Janeiro and in 1771 he moved to São Paulo, where he started teaching the indigenous people, simultaneously having the opportunity to learn about the uses and original names of native plants. He was commissioned by the Portuguese Crown to compile an extensive botanical inventory of the Flora in Rio de Janeiro and its surroundings. The result is the work “*Florae Fluminensis*,” completed in 1790, which consists of one volume containing the botanical descriptions of 1639 species of plants, native and exotic, and a further 11 volumes of drawn illustrations. Vellozo was a pioneer in this type of work, and the “*Florae*” includes valuable information on the use of about 300 plants, including those used as food (Brandão 2019).

The most recent authors cited here studied plants in the nineteenth and early twentieth centuries. The Polish medical doctor P. Chernoviz (1812–1882) and the German pharmacist Theodor Peckolt, (1822–1912), lived in Rio de Janeiro and wrote important books containing information on hundreds of useful and medicinal native plants (Peckolt and Peckolt 2016; Ricardo et al. 2017). In 1947 the French Paul Le Cointe (1870–1956) published the book “*Amazônia Brasileira*” (Brazilian Amazon), with information on hundreds of plants, their traditional uses, and economic viability. The Portuguese botanist Manoel Pio Corrêa (1874–1934) included description of roots and leaves used as food in his book “*Dicionário das plantas úteis do Brasil e das exóticas cultivadas*” (Dictionary of Useful Plants of Brazil and Exotic Cultivated), organized in 1926, and his previous work entitled “*Flora do Brasil*” (Brazilian Flora), published in 1909. Although these authors did their own field work and research, they also declare that they used information present in

previous sources. We can consider, therefore, that the presence of plants mentioned by previous authors (e.g., Saint-Hilaire, von Martius) is a validation of their uses as food.

A total of 630 plant species used as food were cited in the studied books. Of these, 514 are fruits, most of them already discussed in Teixeira et al. (2019). Thus, in this work, we emphasize the remaining 116 plants, which have other parts used as food. Table 1 shows that Corrêa cited the highest number of species (96) followed by Peckolt (30) and Le Cointe (26). Among the authors that published their works before or during the eighteenth century, Vellozo cited the greatest number of food plants. A total of 18 species was described in his work, while Chernoviz, Piso, Lisboa, and Sousa cited 9, 7, 5, and 5 plants, respectively. Vellozo was Brazilian, and his familiarity with local customs certainly allowed him to have more proximity to the population in order to acquire traditional knowledge. In total, from the works of the 9 authors, 64 roots/tubercles, 52 leaves, 3 flowers, and 2 sprouts were cited as food (Tables 2 and 3).

Among the roots, the use of *Manihot esculenta* Crantz tubers (aipim, cassava, Euphorbiaceae) was described by all the authors. Cassava tubers are rich in special carbohydrates that release glucose slowly in the body without generating blood glucose spikes (Okafor et al. 2017; Udemé et al. 2015). This composition helps maintain high energy levels for longer, being useful for high performance athletes, and makes this food very suitable for management of diabetes. Cassava is also rich in vitamins A, B1, B2, and C and can be consumed by people and animals. Due to its high benefits, cassava was considered by the Food and Agriculture Organization of the United Nations (FAO/UN) as the most relevant food of the twentieth century (FAO 2013). Other five species of *Manihot* were also recorded by Corrêa (*M. caerulescens* Pohl, *M. caerulescens* Pohl subsp. *caerulescens*, *M. dichotoma* Ule, *M. glaziovii* Müll.Arg., *M. violacea* Pohl.), but their potential has not been verified to date.

Other useful roots are those from *Spondias tuberosa* Arruda (Anacardiaceae), *Caladium bicolor* (Aiton) Vent., and *Xanthosoma sagittifolium* (L.) Schott (Araceae), cited by different authors along the centuries. They have also been submitted to laboratory studies, which confirmed their health benefits (Table 2). These plants showed antioxidant (Arruda et al. 2005), antimicrobial (Santos et al. 2019; Schmourlo et al. 2005), and antitumoral (Caxito et al. 2015) and could also have the capacity to prevent colon cancer (Kackix et al. 2013). Table 2 shows that roots of *Colocasia esculenta* (L.) Schott (Araceae) and *Maranta arundinacea* (Marantaceae) have immunomodulatory activity. Immunomodulators are substances that act directly on the immune system, strengthening its defenses and improving its functions. These effects have been associated to saponins and some types of polysaccharides. The adaptogenic effect of ginsengs roots, for example, is associated with the presence of saponins (Metwaly et al. 2019; Shi et al. 2019), while for mushrooms and seaweed, the effects are associated to saccharides (Ling et al. 2017; Mallard et al. 2019). Saponins and some types of polysaccharides, as starch, are very common in roots, and the effects observed for *C. esculenta* were correlated to the presence of saponins (Azubuike et al. 2018; Eleazu et al. 2016; Pereira et al.

2018). Other less known edible roots, but also cited along the centuries, are *Plumbago scandens* L. (Plumbaginaceae), *Spondias venulosa* (Engl.) Engl. (Anacardiaceae), *Canna glauca* L. (Cannaceae), and *Goeppertia tuberosa* (Vell.) Borchs. & S.Suarez (Marantaceae). The use of roots of *P. scandens* was cited by Piso and Vellozo; *P. scandens* roots were recently shown to have activity against *Helicobacter pylori*, what could help in the management of gastric ulcers and prevent cancer (de Paiva et al. 2003; Wang and Huang 2005).

The tubercles of Dioscoreaceae (yams) have been used in the human diet for millennia. Many species have economic importance, due to the presence of diosgenin, which is used as a prototype for oral contraceptive in the pharmaceutical development (Hata et al. 2003). The most important species cultivated for their edible tubers include *D. alata*, originating from Asia, *D. cayenensis*, and *D. rotundata* from West Africa. The tubercles of these species contain several nutrients, including carbohydrates, amino acids, minerals, thiamine, riboflavin, niacin, and ascorbic acid. Diosgenin and allantoin constitute the main secondary bioactive metabolites (Mollica et al. 2013) and have also been shown to possess anti-inflammatory and immunomodulatory properties (Chen et al. 2015). Sixteen species of *Dioscorea* were cited by Corrêa, and four of them (*D. cinnamomifolia* Hook., *D. hassleriana* Chodat, *D. sinuata* Vell., and *D. trifida* L.f.) were also registered by Vellozo in the eighteenth century. The use of *D. trifida* was also observed by Lisboa and Le Cointe in Amazonia. Extracts from the roots were shown to be active in reducing inflammatory parameters associated with food allergies and were suggested to have the potential to prevent and treat this condition (Mollica et al. 2013).

Among plants with leaves that can be used as food, we present 52 species in Tables 2 and 3, with *Piper umbellatum* L. (Piperaceae) being cited by six among the nine studied authors, including Friar Vellozo. In recent studies this species has shown important results as intestinal anti-inflammatory (Arunachalam et al. 2020), anti-gastric ulcers (Silva Junior et al. 2016), and anticancer (Iwamoto et al. 2015). Other six species were also cited by Vellozo and have shown positive results in studies of bioactivity (Table 2), *Sesuvium portulacastrum* (L.) L. (Aizoaceae), which has antioxidant and antimicrobial activities (Al-azzawi et al. 2012; Chandrasekaran et al. 2011); *Amaranthus cruentus* L. (Amaranthaceae) which is anti-inflammatory (Tang and Tsao 2017) and useful in management of obesity (Kanikowska et al. 2019); *A. viridis* L., which has antioxidant properties and has high nutritional potential (Sarker and Oba 2019; Silva et al. 2018); *Sochus oleraceus* L. (Asteraceae), that also has activity as antioxidant (Mawalagedera et al. 2016) and as anti-aging agent (Ou et al. 2015); and *Pereskia aculeata* Mill. (Cactaceae), that has antioxidant and antimicrobial activities (Garcia et al. 2019; Souza et al. 2016) and improves intestinal motility and lipid profile (Barbalho et al. 2016). All these species have been recently considered as non-conventional food plant species (“plantas alimentícias não convencionais – PANCs,” in Portuguese). They are plants of spontaneous development, easily found in gardens, backyards, and even on street sidewalks (Kinupp and Lorenzi 2014). Unfortunately, many of the PANC species are considered by the general population as weeds, which is why they are little used in food. Species of PANCs can have significantly higher contents of minerals, fibers, antioxidants, and

proteins when compared to domesticated plants. The greater quantity of PANCs used today in Brazil corresponds to exotic plants, introduced in the country mainly by the Portuguese and Africans, brought as slaves. It is important to highlight that the plants presented in Tables 2 and 3 are native to Brazil. The species cited especially by the authors from the sixteenth to the eighteenth centuries, were most likely originally domesticated by Amerindians. An example is *Pereskia aculeata* Mill. (Ora-pro-nobis, Cactaceae, Table 2). Vellozo wrote that "...Africans use ora-pro-nobis instead of hibiscus..." *P. aculeata* is a native species while many species of hibiscus were introduced in Brazil from Africa. The use of PANCs as food has been highly encouraged in Brazil today and has been adopted by a high percentage of the population, and species present in Tables 1 and 2 are important in this movement due to their historical uses and bioactivities.

Leaves are also frequently used as tea, and the caffeinated tea-like beverages have been very popular all over the world, for centuries. Tea from *Camellia sinensis* L. (Theaceae), for example, has been consumed for millennia in India, China, and other Asian countries, but became very popular in England in the seventeenth century (Gomes 2019). When the Portuguese royal family came to Brazil in the nineteenth century, there was an interest in the introduction of the *C. sinensis*. Negotiations were made with China and the government brought in some tea seedlings and a few hundred Chinese for their cultivation. This attempt, however, was not successful, as the full development of the plant was not achieved, mainly due to the poor choice of planted species. On the other side, we have mate tea, produced from leaves of the tree *Ilex paraguariensis* A.St-Hil. (Aquifoliaceae), which has been consumed for millennia by Amerindians living in Argentina, Brazil, Chile, Paraguay, and Uruguay. The Jesuits cultivated mate tea on their missions in Paraguay in the sixteenth century, but formal taxonomic description of the plant, by the French naturalist Auguste de Saint-Hilaire, occurred only in the nineteenth century (Brandão et al. 2012). The French naturalist Aimé Bonpland, who explored the northern parts of South America with Alexander von Humboldt, studied the culture of mate extensively and described the best methods for cultivation, collection and preparation of tea (Corrêa-Filho 1957; Linhares 1969). Currently, mate tea is consumed worldwide as an alternative to coffee and black tea. Studies have demonstrated that leaves of *C. sinensis* and *I. paraguariensis* have similar chemical characteristics. Both are rich in polyphenols, proteins, enzymes, caffeine, carbohydrates, and inorganics, which provide beneficial properties for health. Several recent studies have confirmed activities as antimicrobial, antioxidant, anti-obesity, anti-diabetic, and cardiovascular protective effects (Gan et al. 2018). Data about other ten *Ilex* species were found in the consulted bibliography (marked with ^a in Tables 2 and 3). They show the presence of phenolics and choleric activity in previous studies (Gan et al. 2018), but have not been investigated in more recent research. The leaves of *Echinodorus macrophyllus* (Kunth) Micheli (Alismataceae), *Ayapana triplinervis* (Vahl) R.M.King & H.Rob. (Asteraceae), *Citronella paniculata* (Mart.) R.A.Howard (Cardiopteridaceae), and *Neea theifera* Oerst. (Nyctaginaceae) are also used as tea. Only the first two have been studied and found to have antioxidant activities (Taïlé et al. 2020) and to show anti-inflammatory and nephroprotective

activities (Portella et al. 2012; Silva et al. 2016). It is interesting to observe that these species belong to different families, and this fact increases the possibility of finding potential bioactive substances with different structures and activities. In addition, three flowers (*Langsdorffia hypogaea* Mart./Balanophoraceae, *Abutilon purpurascens* K.Schum, and *Sphaeralcea bonariensis* (Cav.) Griseb./Malvaceae), and two sprouts (*Gynierium sagittatum* (Aubl.) P.Beauv./Poaceae and *Euterpe oleracea* Mart, Arecaceae) were cited by the authors, but the potentials of none of them have been evaluated to date.

The recovery of old eating habits, using different species as food, is considered a strategy for health promotion (Bataglion et al. 2015; Teixeira et al. 2019). Previous studies have shown that phytochemicals, such as phenolic compounds and alkaloids commonly present in plants, can modulate inflammation and improve health problems associated with many degenerative and/or chronic diseases (Oliveira et al. 2014). This has stimulated a renewed interest in accessing plant foods in biodiversity centers, due to the high levels of bioactive substances, capable of preventing such as obesity, diabetes, cancer, coronary heart disease, and Alzheimer's (Neri-Numa et al. 2018). The polyphenols present in the leaves, for example, act as antioxidants due to their capacity to stabilize free radicals by breaking the chain of oxidative reactions and/or retarding the formation of free radicals in oxidizable matrices. These processes work as a defense mechanism of the human body, controlling lipid peroxidation and preventing the development of the degenerative diseases. Table 4 shows that 12 plants with antioxidant activity which is correlated with the presence of phenolics. Ou et al. (2015), for example, show the activity of an extract from *Sonchus oleraceus* L. (Asteraceae) as anti-aging in vitro. In the same

Table 4 Species whose consumption has been suggested to treat or prevent diseases

Plant with antioxidant effect (leaves)	Correlated diseases
<i>Sonchus oleraceus</i> L.	Anti-ageing effect
<i>Amaranthus cruentus</i> L. <i>Boerhavia erecta</i> L. <i>Echinodorus macrophyllus</i> (Kunth) Micheli <i>Polygonum aviculare</i> L. <i>Piper umbellatum</i> L.	Anti-inflammatory (many diseases)
<i>Piper umbellatum</i> L. <i>Xanthosoma sagittifolium</i> (L.) Schott	Antitumor/prevent colon cancer
<i>Amaranthus spinosus</i> L. <i>Colocasia esculenta</i> (L.) Schott <i>Neptunia oleracea</i> Lour.	Diabetes
<i>Pereskia aculeata</i> Mill.	Improves intestinal motility (constipation)
<i>Amaranthus viridis</i> L. <i>Pereskia aculeata</i> Mill. <i>Polygonum aviculare</i> L.	Lipid metabolism (cardiovascular)
<i>Echinodorus macrophyllus</i> (Kunth) Micheli <i>Sonchus oleraceus</i> L.	Nephroprotective
<i>Amaranthus cruentus</i> L. <i>Polygonum aviculare</i> L.	Obesity

way, Carey et al. (2017) have demonstrated that extract from açai (*Euterpe oleracea* Mart., Arecaceae) is rich in phenolics, was also effective in prevent age-related cognitive deficits in aged rats. Studies have also shown a positive correlation in the ingestion of antioxidant substances as antidiabetic/antiobesity agents, and this effect occurs by different mechanisms (Cox et al. 2015). Other studies have shown correlation between anti-obesity effects of capsaicin with the presence of flavonoids and polyphenols. The authors have demonstrated that this effect can occur due to changes in the gut microbiota that led to significant impacts on the host's metabolism (Roopchand et al. 2015; Shen et al. 2017; van Dorsten et al. 2012). We can consider that encouraging the consumption of the plants from Table 2 represent an important tool to prevent these diseases, because of their beneficial use for centuries and studies that confirm their relevance as functional foods. We also argue that species from Table 3, and all other cited in historical documents, should have priority in the studies on bioactivity for developing biological products. Detailed, critical studies are essential in order to validate – or invalidate – claims concerning bioactivity and specificity, so that those plants with beneficial properties can be better exploited.

Brazil has the most diverse flora of the world, with 38,700 species approximately, which corresponds to 26.5% of the total of known species (Ulloa et al. 2017). The plants listed in this study confirm the great variety of native plant foods supplied by the Brazilian flora. The data recovered from this historical review covered four of the six main phytogeographic domains of the country: Atlantic Forest, Cerrado, Caatinga, and Amazonia. This information is also important because it was recorded in a time that Brazil's vegetation was still preserved, and the interactions between the Amerindians and the new inhabitants were frequent. The commercialization and management of these plants can also contribute to biodiversity conservation and improve the income of local populations.

4 Conclusion

In this study we collected written references to the traditional use of leaves and roots of native Brazilian plant species and summarize their suggested bioactive properties. These plants may have a great potential for use as functional foods, despite most of them being unknown to the population and to science. The valorization of biodiversity, through sustainable use of underexploited species, is a way to slow down the erosion of genetic diversity in remote regions, while studies with these plants can lead to development of innovative bio-products with high commercial value. We argue that incentives for better use of the species listed in this study must be considered and they should be included in agricultural programs that are done throughout the country.

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