Food Chemistry 153 (2014) 224–233

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Active compounds and medicinal properties of *Myrciaria* genus

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ARTICLE INFO

Article history:
Received 2 July 2013
Received in revised form 16 November 2013
Accepted 17 December 2013
Available online 27 December 2013

Keywords:
Anti-oxidant
Myrciaria
Polyphenols

ABSTRACT

The genus *Myrciaria* occurs in various Brazilian biomes. Its species contains several active components, including phenolic compounds, such as tannins, flavonoids, ellagic acid and anthocyanins. Biological activities reported for *Myrciaria* fruits and leaf and bark extracts include antioxidant, antibacterial and antifungal effects. This work aims to provide an overview of the active compounds of *Myrciaria*, highlighting its secondary metabolites and medicinal properties for stimulating new studies regarding this genus.

1. Introduction

The *Myrciaria* genus belongs to the Myrtaceae family. According to Camlofski (2008) the members of this family are well known due to the great technological potential of its native species and its fruits, with possibilities for industrialisation. The fruits of this family provide a high yield of pulp, which has a pleasant flavour and contains several substances with antioxidant properties. The species of the *Myrciaria* genus is spread across various Brazilian biomes such as the Amazon Forest, Caatinga, Cerrado, Atlantic Forest and Pampa. This genus contains approximately 99 known species (Table 1), 21 of which are native to Brazil (IPNI, 2012). Some *Myrciaria* species grow in domestic gardens, such as "jabuticabeira" [*Myrciaria cauliflora* (Mart.) Berg and *Myrciaria jaboticaba* (Vell.), with Berg being the most widely found], which produce fruits highly appreciated by the population and are consumed in the form of juices, jams, wines and liqueurs; thus, it has a great potential in the food industry. In addition, the fruit contains substances with medicinal characteristics (Fig. 1).

There are few studies reported that address this genus in particular. Therefore, the aim of this paper is to review the *Myrciaria* genus, primarily focusing on their appearance, phytochemical characteristics and the biological activities which have been reported.

2. Distribution of the *Myrciaria* genus

The geographical distribution of *Myrciaria* species occurs in diverse regions, such as Brazil, Bolivia, Paraguay, Argentina, Central America, and South Florida (Table 1). In Brazil, these plants are cultivated mainly in the states of São Paulo, Rio de Janeiro, Minas Gerais and Espírito Santo (Oliveira et al., 2008).

Taxonomic classification for several species of the Myrtaceae family and *Myrciaria* genus is controversial, which leads to difficulties in intensifying research and taxonomic studies. In order to address this issue, authors identify *Myrciaria* species through comparisons with herbarium specimens, literature reviews and analyse using molecular markers. On the basis of this methodology, four different groups of "jabuticabeira" have been defined: *Myrciaria phytrantha* (kiaersk) Mattos, *M. jaboticaba* (Vell) O. Berg., *Myrciaria coronata* Mattos, and *M. cauliflora* (Mart.). O. Berg (Citadin, Danner, & Sasso, 2010). *M. cauliflora* is the most widespread species in Brazil.

3. Active compounds detected in the *Myrciaria* genus

Dark-coloured fruits and their products are commonly consumed in many cultures. Several reports have revealed that these fruits are beneficial for human health, and currently there has been a growing research interest with regard to the products of this fruit used for consumption. Several studies have demonstrated that fruits of *Myrciaria* species present antioxidant activity and a significant anthocyanin content. Anthocyanins are a type of functional pigment found in vegetables, flowers and fruits, which are responsible for their red, blue or violet colour appearance. The anthocyanin structure consists of a C_{15} heterocyclic nucleus

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http://dx.doi.org/10.1016/j.foodchem.2013.12.064

Table 1
Myrciaria species.

Species	Synonym	Distribution
Myrciaria alagoana Sobral*	–	Brazil
Myrciaria angustifolia (O.Berg) Mattos	*Myrciaria brevipedunculata* (O.Berg) Mattos; *M. deserti* (Cambess.) O.Berg; *M. dichotoma* D.Legrand; *M. piedadensis* (Kiaersk.) Mattos & D.Legrand; *Eugenia cisplatensis* Cambess. var. *angustifolia* (O.Berg) Lillo; *E. adamantium* Cambess.; *E. decumbens* Cambess.; *E. depauperata* Cambess.; *E. ipehuensis* Barb.Rodr. *ex* Chodat & Hassl.; *E. mugiensis* O.Berg; *E. piedadensis* Kiaersk.; *E. suaveolens* Cambess.; *E. tweediei* Hook. & Arn.; *B. acuminatissimus* (Miq.) O.Berg; *B. acuminatus* O.Berg; *B. affinis* O.Berg; *B. amarus* O.Berg; *B. angustifolius* O.Berg; *B. angustissimus* O.Berg; *B. apiculatus* O.Berg; *B. brunneus* O.Berg; *B. canescens* O.Berg; *B. cisplatensis* Griseb.; *Blepharocalyx salicifolius* (Kunth) O.Berg*; *Myrcia mugiensis* Cambess.; *Myrcianthes cisplatensis* O.Berg var. *angustifolia* O.Berg; *Myrcianthes cisplatensis* O.Berg var. *brevipedunculata*	Brazil
Myrciaria apiculata Barb.Rodr.	*Myrciaria cuspidata* O.Berg*; *M. cuspidata* O.Berg var. *humilis* O.Berg; *M. cuspidata* O.Berg var. *stricta* O.Berg; *M. herbacea* O.Berg; *M. minensis* O.Berg; *M. recurvipetala* Barb.Rodr.; *M. tenella* O.Berg; *M. tenella* var. *elliptica* O.Berg; *M. tenella* (DC.) O.Berg var. *minor* (Cambess.) O.Berg; *M. undulata* O.Berg; *Eugenia alegrensis* Kiaersk.; *E. minensis* Kiaersk.; *E. tenella* DC.; *E. tenella* var. *elliptica* Kiaersk.; *E. tenella* var. *minor* Cambess.; *Myrtus tenella* Mart. ex DC.	Brazil, Paraguay
Myrciaria apiculata Barb.Rodr. ex Chodat & Hassl.	–	Paraguay
Myrciaria arborea D.Legrand var. *rostata* Mattos	–	Belize, Bolivia, Brazil, Caribbean, Colombia, Costa rica, Ecuador, French Guyana, Guatemala, Guyana
Myrciaria aspera Mattos	–	Brazil
Myrciaria atiraensis Barb.Rodr.	*Eugenia bimarginata* DC.*; *E. dicrossa* O.Berg; *E. pardensis* O.Berg; *E. subcordata* O.Berg; *E. umbellaris* O.Berg; *E. umbellata* DC.	Brazil (native)
Myrciaria atiraensis Barb.Rodr. ex Chodat & Hassl.	*Eugenia camporum* Morong; *E. pitanga* (O. Berg) Kiaersk*; *E. pluriflora* DC.; *Luma pitanga* (O. Berg) Herter; *Stenocalyx pitanga* O. Berg*; *Myrtus pitanga* (O. Berg) Kuntze	Argentina, Brazil, Paraguay
Myrciaria aureana Mattos	*Myrciaria phytrantha* (Kiaersk.) Mattos; *Eugenia phytrantha* Kiaersk.; *Plinia aureana* (Mattos) Mattos; *P. phitrantha* (Kiaersk.) Sobral*;	Brazil
Myrciaria baporeti D.Legrand	*Myrciaria hagendorffii* O.Berg; *M. rivularis* O.Berg; *Eugenia hagendorffii* Kiaersk.; *E. rivularis* Cambess.; *Myrcia granulata* R.O.Williams; *Plinia baporeti* (D.Legrand) Rotman; *P. rivularis* (Cambess.) Rotman*; *Siphoneugena baporeti* (D.Legrand) Kausel	Argentina, Brazil, Paraguay, Uruguay
Myrciaria baporetii D.Legrand	*Myrciaria rivularis* var. *baporetii* (D.Legrand) D.Legrand*; *Myrciariopsis baporetii* (D.Legrand) Kausel*; *Plinia baporeti* (D. Legrand) Rotman; *Siphoneugena baporetii* (D.Legrand) Kausel	Paraguay
Myrciaria bipennis O.Berg	*Marlierea bipennis* (O.Berg) McVaugh; *Myrcia bipennis* (O. Berg) McVaugh;	Brazil
Myrciaria borinquena Alain	–	Puerto Rico
Myrciaria cauliflora (Mart.) O.Berg	*Myrciaria jaboticaba* (Vell.) O.Berg; *Eugenia cauliflora* (Mart.) DC.; *E. edulis* Vell; *E. jaboticaba* Kiaersk.; *Guapurium peruvianum* Poir.*; *Myrtus cauliflora* Mart.; *M. jaboticaba* Vell.; *Plinia cauliflora* (Mart.) Kausel*; *P. jaboticaba* (Vell.) Kausel	Bolivia, Brazil, El Salvador, Honduras, Paraguay
Myrciaria ciliolata O.Berg var. *warmingiana* (Kiaersk.) Mattos	*Myrciaria leucophloea* O.Berg var. *warmingiana* (Kiaersk.) Mattos; *Eugenia leucophloea* Kiaersk. var. *warmingiana*	Brazil
Myrciaria cordata O.Berg*	–	Brazil; Guyana; Venezuela
Myrciaria cordifolia D.Legrand	*Plinia cordifolia* (D.Legrand) Sobral*	Brazil
Myrciaria coronata Mattos	*Plinia coronata* (Mattos) Mattos	Brazil
Myrciaria cuspidata O.Berg var. *acuminatissima* O.Berg	–	Brazil
Myrciaria cuspidata O.Berg var. *diffusa* O.Berg	–	Brazil
Myrciaria cuspidata O.Berg var. *difusa* O.Berg	–	Brazil
Myrciaria cuspidata O.Berg var. *latifolia* O.Berg	–	Brazil
Myrciaria delicatula (DC.) O.Berg*	*Myrciaria delicatula* var. *delicatula*; *M. linearifolia* O.Berg; *M. macrocarpa* A.Usteri; *M. maschalantha* (Kiaersk.) Mattos & D.Legrand; *Eugenia delicatula* DC.; *E. maschalantha* Kiaersk.; *Paramyrciaria delicatula* (DC.) Kausel; *P. delicatula* (DC.) Kausel var. *linearifolia* (O.Berg)	Argentina, Brazil, Paraguay
Myrciaria delicatula (DC.) O.Berg var. *acutifolia* O.Berg	–	Brazil
Myrciaria delicatula (DC.) O.Berg var. *angustifolia* O.Berg	–	Brazil
Myrciaria delicatula (DC.) O.Berg var. *conferta* O.Berg	*Eugenia delicatula* DC. var. *conferta* Kiaersk.	Brazil
Myrciaria delicatula (DC.) O.Berg var. *latifolia* O.Berg	–	Brazil
Myrciaria disticha O.Berg*	*Eugenia biseriata* Kiaersk.	Brazil
Myrciaria disticha O.Berg var.	–	Brazil

(*continued on next page*)

Table 1 (*continued*)

Species	Synonym	Distribution
bahiensis O.Berg		
Myrciaria disticha O.Berg var. *fluminensis* O.Berg	–	Brazil
Myrciaria dubia (Kunth) McVaugh*	*Myrciaria caurensis*; *M. divaricata* O.Berg; *M. lanceolata* O.Berg; *M. lanceolata* var. *angustifolia* O.Berg; *M. lanceolata* var. *glomerata* O.Berg; *M. lanceolata* var. *laxa* O.Berg; *M. obscura* O.Berg; *M. paraensis* O.Berg; *M. phillyreoides* O.Berg; *M. riedeliana* O.Berg; *M. spruceana* O.Berg; *Eugenia grandiglandulosa* Kiaersk.; *Marlierea edulis* Nied.; *Psidium dubium* Kunth	Brazil, Venezuela
Myrciaria dumicola Chodat & Hassl.	*Eugenia dumicola* Barb.Rodr.; *E. pyriformis* var. *argentea* Mattos & D. Legrand*; *E. pyriformis* fo. *ponhi* D. Legrand; *E. turbinata* O. Berg; *E. uvalha* Cambess; *Pseudomyrcianthes pyriformis* (Cambess.) Kausel	Paraguay
Myrciaria edulis Skeels	*Myrciaria plicatocostata* O.Berg; *Eugenia edulis* Vell.; *E. plicatocostata* Glaz.; *Hexachlamys edulis* (O. Berg) Kausel & D. Legrand; *Marlierea edulis* Nied.; *Plinia anonyma* Sobral*; *P. edulis* (Vell.) Sobral*; *P. plicatocostata* (O.Berg) Amshoff	Brazil
Myrciaria egensis O.Berg	*Myrcia egensis* (O.Berg) McVaugh; *M. egensis* (O.Berg) Burret	Brazil, Peru
Myrciaria ehrenbergiana O.Berg	*Aulomyrcia ehrenbergiana* (O.Berg) Amshoff; *Myrcia ehrenbergiana* (O.Berg) McVaugh*;	Brazil, Guyana
Myrciaria ferruginea O.Berg;*	–	Brazil
Myrciaria floribunda O.Berg *	*Myrciaria amazonica* O.Berg; *M. arborea* D.Legrand; *M. axillaris* O.Berg; *M. chartacea* O.Berg; *M. ciliolata* (Cambess.) O.Berg; *M. leucophloea* O.Berg; *M. longipes* O.Berg; *M. maragnanensis* O.Berg; *M. maranhensis* O.Berg; *M. maximiliana* O.Berg; *M. prasina* O.Berg; *M. mexicana* Lundell; *M. oneillii* (Lundell) I.M.Johnst.; *M. protracta* (Steud) O.Berg; *M. salzmannii* O.Berg; *M. schuechiana* O.Berg; *M. sellowiana* O.Berg; *M. splendens* O.Berg; *M. tenuiramis* O.Berg; *M. tolypantha* O.Berg; *M. tolypantha* var. *latifolia* O.Berg; *M. uliginosa* O.Berg; *M. verticillata* O.Berg; *Calyptranthes floribunda* (H.West *ex* Willd.) Blume; *Eugenia floribunda* H.West *ex* Willd.; *E. ciliolata* Cambess.; *E. leucophloea* (O.Berg) Kiaersk.; *E. leucophloea* Kiaersk.; *E. maranhensis* Kiaersk.; *E. oneillii* Lundell; *E. salzmannii* Benth.; *Paramyrciaria ciliolata* (Cambess.) Rotman	Belize, Bolivia, Brazil, Caribbean, Colombia, Costa rica, Ecuador, French Guyana, Guatemala, Guyana
Myrciaria glanduliflora (Kiaersk.) Mattos & D.Legrand*	*Eugenia glanduliflora* Kiaersk.	Brazil
Myrciaria glazioviana (Kiaersk.) G.M.Barroso ex Sobral*	*Eugenia cabelludo* var. *glazioviana* Kiaersk.; *Paramyrciaria glazioviana* (Kiaersk.) Sobral	Brazil
Myrciaria glomerata O.Berg	*Eugenia cabelludo* Kiaersk.; *Marlierea antrocola* Kiaersk.; *Paramyrciaria glomerata* (O.Berg) Sobral; *Plinia glomerata* (O.Berg) Amshoff;	Brazil
Myrciaria grandifolia Mattos	*Plinia grandifolia* (Mattos) Sobral; *Plinia grandifolia* Mattos	Brazil
Myrciaria guapurium O.Berg	*Eugenia guapurium* DC.; *Guapurium peruvianum* Poir.*	Peru
Myrciaria guaquica (Kiaersk.) Mattos & D.Legrand	*Eugenia guaquica* Kiaersk.;	Brazil
Myrciaria guaquiea Kiaersk.	*Eugenia guaquiea* Kiaersk.; *Paramyrciaria guaquiea* (Kiaersk.) Sobral*	Brazil
Myrciaria hatschbachii Mattos	*Plinia hatschbachii* (Mattos) Sobral*	Brazil
Myrciaria ibarrae Lundell	*Myrciaria longicaudata* Lundell	Guatemala, Mexico
Myrciaria involucrata O.Berg	*Myrciaria trinitatis* O.Berg; *Plinia involucrata* (O.Berg) McVaugh*; *P. pinnata* L.*	Brazil
Myrciaria itacurubiensis Barb.Rodr.	–	Paraguay
Myrciaria itacurubiensis Barb.Rodr. ex Chodat & Hassl.	–	Paraguay
Myrciaria leptophylla (Barb.Rodrig) Chodat & Hassl.	*Eugenia herbaceae* O.Berg*; *E. leptophylla* Barb.Rodr.	Brazil, Paraguay
Myrciaria leucadendron O.Berg*	–	Brazil
Myrciaria leucophloea O.Berg var. *conferta* O.Berg	–	Brazil
Myrciaria leucophloea var. *laxa* O.Berg	–	Brazil
Myrciaria lituatinervia O.Berg	*Marlierea lituatinervia* (O.Berg) McVaugh*	Guyana
Myrciaria longipes var. *opaca* O.Berg	–	Brazil
Myrciaria longipes var. *pellucida* O.Berg	–	Brazil
Myrciaria marowynensis O.Berg	*Eugenia marowynensis* Miq.	Brazil, Ecuador, French Guyana, Suriname
Myrciaria micrantha O.Berg	*Paramyrciaria delicatula* (DC.) Kausel	Paraguay
Myrciaria micrantha Barb.Rodr. ex Chodat & Hassl.	–	Paraguay
Myrciaria myriophylla O.Berg	*Myrciaria myriophylla* (Casar.) O.Berg; *Blepharocalyx myriophyllus* (Casar.) Morais & Sobral*; *Eugenia myriophylla* Casar.; *Myrcia pinaster* Mart. *ex* O.Berg	Brazil
Myrciaria myrtifolia Alain	–	Puerto Rico
Myrciaria nettiana (Kiaersk.) Mattos & D.Legrand	*Eugenia nettiana* Kiaersk.	Brazil

Table 1 (*continued*)

Species	Synonym	Distribution
Myrciaria nitida O.Berg	*Myrciaria polyantha* (Miq.) O.Berg; *Eugenia inaequiloba* DC.; *E. nitida* Benth.; *E. polyantha* Miq.; *Myrcia inaequiloba* (DC.) Lemée*	Brazil
Myrciaria nitida var. *chartacea* O.Berg	–	Guyana
Myrciaria nitida var. *coriacea* O.Berg	–	Guyana
Myrciaria nitida var. *dives* O.Berg	–	Guyana
Myrciaria oblongata Mattos	*Plinia oblongata* (Mattos) Mattos	Brazil
Myrciaria pallida O.Berg*	*Myrciaria sulcata* Mattos	Brazil
Myrciaria perforata O.Berg	*Calyptranthes axillaris* O.Berg; *C. maschalantha* O.Berg; *C. obscura* DC.; *C. tuberculata* O.Berg; *Neomitranthes nitida* Mattos; *N. obscura* (DC.) *N.Silveira**; *N. wilsoniana* Mattos	Brazil
Myrciaria peruviana (Poir.) Mattos	*Guapurium peruvianum* Poir.*; *Plinia peruviana* (Poir.) Govaerts	Bolivia
Myrciaria peruviana var. *trunciflora* Mattos*	*Eugenia rabeniana* Kiaersk.; *Plinia trunciflora* (O. Berg) Kausel	Argentina, Brazil, Paraguay
Myrciaria pilosa Sobral & Couto*	–	Brazil
Myrciaria plicato-costata O.Berg	*Plinia plicato-costata* (O.Berg) Amshoff; *Eugenia plicato-costata* (O.Berg) Glaz.; *Plinia anonyma* Sobral	Brazil
Myrciaria plinioides D.Legrand	–	Brazil
Myrciaria polyantha O.Berg	*Aulomyrcia inaequiloba* (DC.) Amshoff; *Eugenia polyantha* Miq.; *Myrcia inaequiloba* (DC.) D. Legrand	Brazil, French Guyana, Suriname, Venezuela
Myrciaria pseudodichasiantha (Kiaersk.) Mattos & D.Legrand*	*Eugenia pseudodichasianth* Kiaersk.	Brazil
Myrciaria puberulenta B.Holst	–	Venezuela
Myrciaria pumila O.Berg*	*Myrciaria adenodes* (Kiaersk.) Mattos & D.Legrand; *Eugenia adenodes* Kiaersk.; *E. adenodes* Kiaersk	Brazil
Myrciaria quitarensis O.Berg	*Eugenia quitarensis* Benth.; *Myrcia quitarensis* (Benth.) Sagot*	Guyana, Venezuela
Myrciaria racemosa M.L.Kawas.	–	Ecuador
Myrciaria ramiflora O.Berg	*Eugenia coffeifolia* DC*; *E. melinonis* Sagot; *E. sinemariensis* Aubl.	Brazil
Myrciaria rojasii D.Legrand*	*Myrciaria tapiraguayensis* Barb.Rodr.; *Paramyrciaria tapiraguayensis* (Barb.Rodr.) Sobral	Brazil, Paraguay
Myrciaria rubiginosa (Cambess.) O.Berg	*Eugenia rubiginosa* Cambess.; *Eugeniopsis rubiginosa* (Cambess.) O.Berg; *Marlierea rubiginosa* (Cambess.) D.Legrand*;	Brazil
Myrciaria schaueriana O.Berg	*Aulomyrcia schaueriana* (Miq.) Amshoff	French guyana, Suriname
Myrciaria schuechiana var. *deflexa* O.Berg	–	Brazil
Myrciaria schuechiana var. *latifolia* O.Berg	–	Brazil
Myrciaria sericea O.Berg	*Eugenia neosericea* P.O.Morais & Sobral*	Brazil
Myrciaria silveirana D.Legrand	*Aulomyrcia alagoensis* O.Berg; *A. crenulata* O.Berg; *Calyptromyrcia cymosa* O.Berg; *Myrcia adpressepilosa* Kiaersk.; *M. alternifolia* Miq.; *M. amethystina* (O.Berg) Kiaersk.; *M. andaiaensis* Mattos; *M. angustifolia* (O.Berg) Nied.; *M. androsaemoides* (O.Berg) Krug & Urb.; *M. arimensis* Britton; *M. bicudoensis* (O.Berg) Mattos; *M. botrys* (O.Berg) N.Silveira; *M. camapuana* Mattos; *M. campestris* DC.; *M. cassinioides* DC.; *M. collina* S.Moore; *M. corumbensis* Glaz.; *M. crassicaulis* Cambess.; *M. crenulata* (O.Berg) Mattos; *M. cuneata* (O.Berg) Nied.; *M. cymosa* (O.Berg) Nied.; *M. cymosopaniculata* Kiaersk.; *M. daphnoides* DC.; *M. decrescens* (O.Berg) Mattos; *M. dermatophylla* Kiaersk.; *M. diaphanosticta* Kiaersk.; *M. guianensis* (Aubl.) DC*; *M. heringeriana* Mattos; *Myrcianthes cymosa* (O.Berg) Mattos	Brazil
Myrciaria spirito-sanctensis Mattos	–	Brazil
Myrciaria stirpiflora O.Berg	*Eugenia stirpiflora* Krug & Urb.	Caribbean, United States
Myrciaria strigipes O.Berg*	*Paramyrciaria strigipes* (O.Berg) Sobral; *Plinia strigipes* O.Berg	Brazil
Myrciaria strigipes var. *longifolia* O.Berg	–	Brazil
Myrciaria tenella var. *spathulata* O.Berg	*Eugenia tenella* DC. var. *spathulata* (O.Berg ex Mart.) Kiaersk.	Brazil
Myrciaria tolypantha var. *angustifolia* O.Berg	–	Brazil
Myrciaria tolypantha var. *pubescens* O.Berg	–	Brazil
Myrciaria trunciflora O.Berg	*Myrciaria peruviana* (Poir.) Mattos var. *trunciflora* (O.Berg) Mattos; *Eugenia rabeniana* Kiaersk.; *Plinia trunciflora* (O.Berg) Kausel	Argentina, Brazil, Paraguay
Myrciaria vexator McVaugh	–	Costa Rica, Panama, Venezuela
Myrciaria vismeifolia (Benth.) O.Berg	*Eugenia vismeifolia* Benth.	Bolivia, Brazil, French Guyana, Guyana, Panama, Suriname, Venezuela
Myrciaria vismiifolia O.Berg	*Eugenia vismiifolia* Benth	Brazil

* Accepted synonm.

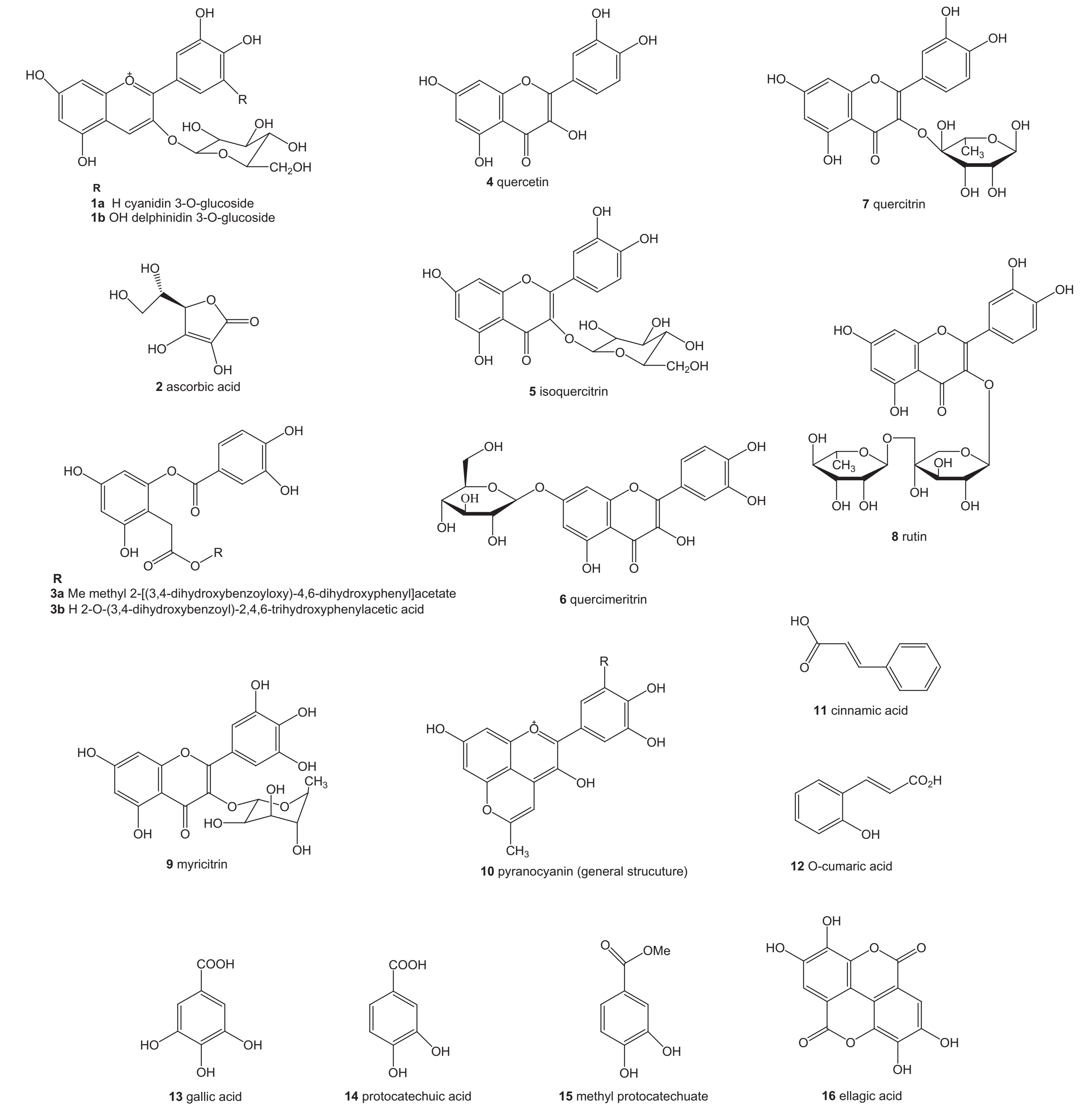

Fig. 1. Molecular structures (**1**–**49**) of the compounds found in *Myrciaria* genus.

(2-phenylbenzopyrilium cation or anthocyanidin), usually attached to at least one sugar residue (Reynertson, Yang, Jiang, Basile, & Kennelly, 2008). Its fruits are known as Brazilian berry because of the high quantity of anthocyanins found in the epicarp, primarily cyanidin-3-*O*-glucoside (**1a**) and delphinidin-3-*O*-glucoside (**1b**) (Wu, Dastmalchi, Long, & Kennelly, 2012).

There are few studies concerning the chemical composition of *M. cauliflora* (Mart.) O. Berg., although the presence of ascorbic acid (**2**), tannins, cyanidins and peonidin glycosides have been reported (Reynertson et al., 2008). Phytochemical constituents of the methanolic extract of jaboticaba were characterised by LC-MS-TOF method and several polyphenols (cyanidin-3-*O*-glucoside (**1a**), delphinidin-3-*O*-glucoside (**1b**), jaboticabin (**3a**), 2-*O*-(3,4-dihydroxybenzoyl)-2,4,6-trihydroxyphenylacetic acid (**3b**), isoquercitrin (**5**), quercimeritrin (**6**), quercitrin (**7**), myricitrin (**9**), ellagic acid (**16**), and syringin (**24**)) were identified in the fruit extracts. In addition, seven gallotannins and two ellagic acid derivatives were identified. The hydro-ethanolic extract from the leaves of *M. cauliflora* contain several compounds, primarily including polyoxygenated derivatives, such as gossypetin-3,8-dimethyl ether-5-*O*-β-glucoside (**25a**), gossypetin-3,5-dimethyl ether (**25b**) and myricetin-3,5,3′-trimethyl ether (**25c**). In addition, some organic acids, such as

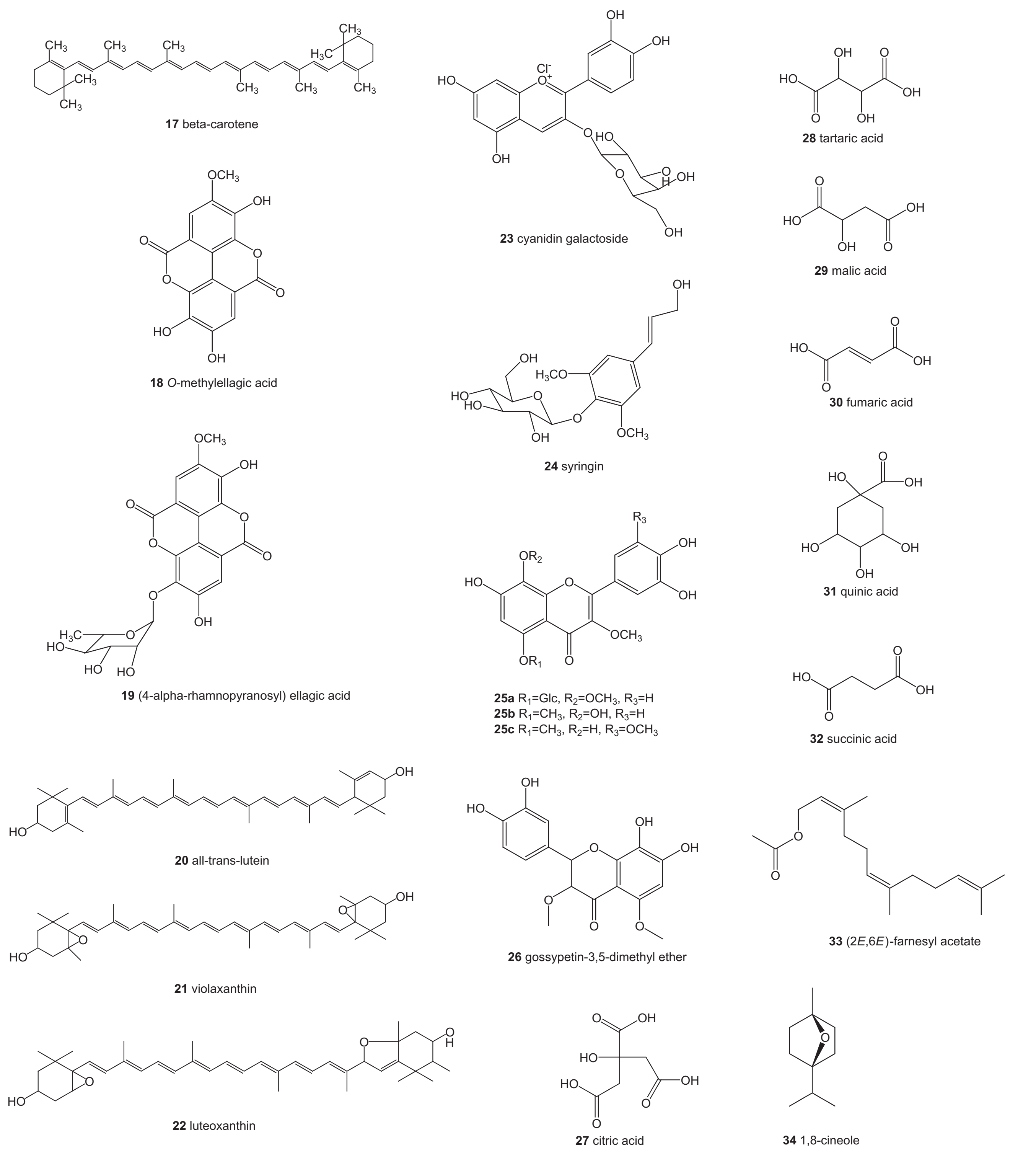

Fig. 1 (*continued*)

oxalic (**26**), citric (**27**), tartaric (**28**), malic (**29**), fumaric (**30**), quinic (**31**) and succinic acid (**32**) were detected in the aqueous extract of *M. cauliflora* epicarp by GC and HPLC methods (Wu et al., 2012).

Other polyphenolic compounds isolated from the methanolic extract of *M. cauliflora* are gallic acid (**13**), protocatechuic acid (**14**), epi-gallocatechin-3-*O*-gallate (**35**), quercetin-3-*O*-β-galactoside (**36**), kaempferol (**37**), quercetin (**4**), kaempferol-3-*O*-α-arabinofuranoside (**38**), quercetin-3-*O*-α-arabinofuranoside (**39**) and myricetin-3-*O*-rhamnoside (**40**) (Hussein, Hashem, Seliem, Lindequist, & Nawwar, 2003).

The content of ellagic acid (**16**) and total phenols decreases with ripening, and a similar tendency was observed for the total tannin content. This decrease could be associated with the loss of astringency during the jaboticaba ripening. This phenomenon is similar to that observed in other fruits such as strawberries (Abe, Lajolo, & Genovese, 2011).

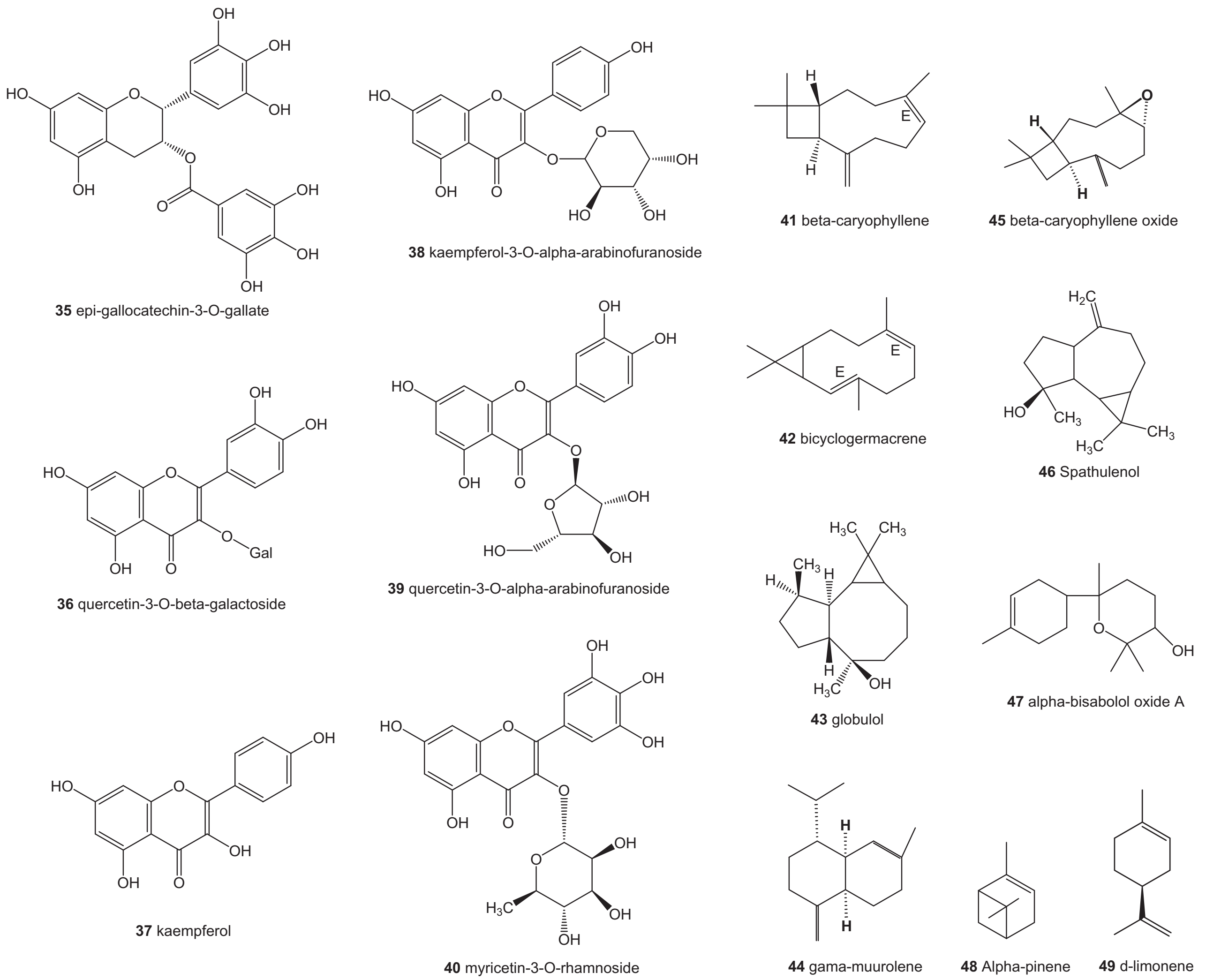

Fig. 1 (*continued*)

When fruit extracts from *M. cauliflora* were subjected to bioactivity-guided fractionation using the DPPH assay, a depside, methyl 2-[(3,4-dihydroxybenzoyloxy)-4,6-dihydroxyphenyl]acetate (jabuticabin), was isolated (**3a**). In addition, other substances have been identified, such as depside 2-*O*-(3,4-dihydroxybenzoyl)-2,4,6-trihydroxyphenylacetic acid (**3b**), quercetin (**4**), isoquercitrin (**5**), quercimeritrin (**6**), quercitrin (**7**), rutin (**8**), myricitrin (**9**), pyranocyanins (**10**), cinnamic acid (**11**), *O*-coumaric acid (**12**), gallic acid (**13**), protocatechuic acid (**14**), methyl protocatechuate (**15)** and ellagic acid (**16**) (Einbond, Reynertson, Luo, Basile, & Kennelly, 2004).

Myrciaria dubia (Kunth) McVaugh, popularly known as "camu-camu," is noted for being an important source of antioxidants such as vitamin C (2), β-carotene (17) and phenolic compounds (Vidigal, Minim, Carvalho, Milagres, & Goncalves, 2011). Despite the great commercial potential of camu-camu, few works have been published regarding its phytochemical content. Screening of the phenolic content of *Myrciaria* fruits revealed that the hydroethanolic extract from *M. dubia* fruits presented higher levels of total phenols than *Myrciaria vexator* McVaugh and *M. cauliflora*. Reynertson et al. (2008) found that the total phenolic content in camu-camu fruits was higher than in *Malpighia emarginata* fruits (acerola). Among the phenolic compounds present in *M. dubia* fruits include flavanols, flavanones, anthocyanins, catechin (4), flavan-3-ol, and rutin (8). Cyanidin-3-glucoside (1a) was identified as the major anthocyanin in fruits, followed by delphinidin 3-glucoside (1b).

In addition, the fruits are rich in carotenoids, such as β-carotene (**17**), violaxanthin (**21**) and luteoxanthin (**22**). All-*trans*-lutein (**20**) is the major carotenoid, ranging from 45% to 55% of the total carotenoid content. In addition to the colourant properties, carotenoids possess several others functions, such as vitamin A activity, cancer-preventing effects, cardiovascular protective effects and can reduce the risk of cataracts. Camu-camu fruits at different stages of maturity exhibit different DPPH antioxidant capacities, which increase during ripening (Chirinos, Galarza, Betalleluz-Pallardel, Pedreschi, & Campos, 2010).

The methanolic extract of leaves from *M. dubia* have been found to contain ellagic acid (**16**), 4-*O*-methylellagic acid (**18**) and 4-(α-rhamnopyranosyl) ellagic acid (**19**) (Akter, Oh, Eun, & Ahmed, 2011).

M. vexator, found in Mesoamerica and northern areas of South America, produces edible fruits, known as blue grape or false jaboticaba, which are consumed in some localities as fresh fruits or as processed jellies and drinks. From the hydromethanolic extract of *M. vexator* fruits, the following compounds were isolated: cyanidin-3-*O*-glucoside (**1a**), delphinidin-3-*O*-glucoside (**1b**), jaboticabin (**3a**), 2-*O*-(3,4-dihydroxybenzoyl)-2,4,6-trihydroxyphenylace tic acid (**3b**), ellagic acid (**16)**, quercitrin (**7**), rutin (**8**), myricitrin (**9**), protocatechuic acid (**14**), methyl protocatechuate (**15**) and cyanidin galactoside (**23**) (Dastmalchi et al., 2012).

Several species of the Myrtaceae family are rich in essential oils, many of which have antimicrobial activity. Essential oil from the stems of *Myrciaria floribunda* (H. West ex Willd.) O. Berg, popularly known as "camboin amarelo," contains sesquiterpenes (72.2%) and the major compound was found to be (2*E*, 6*E*)-farnesyl acetate (**33**) (19.9%). Monoterpenes are the primary group present in the essential oils from leaves (53.9%) and flowers (55.4%), and the compound 1,8-cineole (**34**) is the major constituent of essential oil from both the sources (38.4% and 22.8%, respectively) (Tietbohl et al., 2012).

The constituents of essential oils from the leaves of *Myrciaria trunciflora* Mart. (O. Berg) [syn. *Plinia trunciflora* (O. Berg.) Kausel], popularly known as "jaboticaba-de-cabinho," were analysed by GC-FID-MS and 21 compounds were identified. Although hydrocarbon sesquiterpenes (24.79%) were identified, oxygenated sesquiterpenes were found to be the major constituents (48.09%). The main constituents identified were β-caryophyllene (8.2%) (**41**), bicyclogermacrene (10.6%) (**42**), globulol (10.8%) (**43**), and γ-muurolene (**44**). Essential oils from other *Myrciaria* species have been analysed and the major compounds identified were as follows: β-caryophyllene (**41**) and its oxide (**45**) and caryophyllene oxide (39.3%) for *Myrciaria edulis* oil; β-caryophyllene (9.2%) (**41**) for *Myrciaria peruviana* var. *trunciflora* Mattos (syn. *P. trunciflora)* oil; spathulenol (27.2%) **(46)** for *M. cauliflora* oil; and α-bisabolol oxide A **(47)** for *M. cordifolia* oil (Apel, Sobral, Zuanazzi, & Henriques, 2006).

Volatile components in camu-camu fruits have been identified by GC–MS (gas chromatography–mass spectrometry) and twenty-one compounds were detected; majority of the compounds were terpenes (98%), predominated with α-pinene (66%) (**48**) and *d*-limonene (24%) (**49**), and β-caryophyllene (**41**) among the sesquiterpenes, was found to be the major compound (Franco & Shibamoto, 2000).

4. Biological properties of the *Myrciaria* genus

In addition to the colourant properties, anthocyanins can be associated with flavouring properties that enhance the palatability of food leading to healthy food habits. There are several articles regarding these pigments, reporting anti-carcinogenic, antioxidant, antiviral and anti-inflammatory activities, which are in agreement with the properties exhibited by foods that have considerable anthocyanin content. Furthermore, anthocyanins are antimutagenic and cancer chemopreventive and have an effect on type 2 diabetes and Alzheimers disease. The consumption of foods rich in anthocyanins has been linked to a reduction in weight gain, regulation of hormones involved in obesity, and improvement of insulin resistance in mice (Prior et al., 2010). Therefore, plant extracts rich in such compounds are potentially useful as therapeutics.

4.1. Antioxidant effects

Leite et al. (2011) observed that rats fed with a diet mixed with lyophilised epicarp from *M. cauliflora* exhibited an increased antioxidant potential in the plasma of rats, which can be attributed to the anthocyanin content of the epicarp. However, it was observed that excessive consumption of anthocyanins present in jaboticaba peel caused a reduction in antioxidant activity, emphasising the need to establish a recommended daily intake for these substances (Leite et al., 2011).

M. vexator fruits exhibit an antiradical activity, as determined by the ABTS method, which was found to be much higher than that of the so-called "superfruits", such as blueberries (Akter et al., 2011; Leite et al., 2011).

Camu-camu (*M. dubia*) fruits were found to have powerful antioxidative and anti-inflammatory properties *in vivo* in humans and this activity could be attributed to the presence of vitamin C, anthocyanins and β-carotene (Inoue, Komoda, Uchida, & Node, 2008). As well known, plants rich in carotenoids are known to have several biological functions, such as cancer-preventing effects and are protective against cardiovascular diseases. In addition, they reduce the risk of cataracts (Van den Berg et al., 2000).

Camu-camu juice presented similar properties to ascorbic acid, which can be attributed to the presence of unknown substances, besides vitamin C or other compounds, which are capable of modulating the kinetics of vitamin C *in vivo*. A daily consumption of 70 mL of camu-camu juice for a week was capable of reducing urinary 8-hydroxydesoxyguanosine, a biomarker of DNA damage; this did not occur with equivalent amounts of isolated ascorbic acid (Inoue et al., 2008).

4.2. Anti-inflammatory activity

The leaves and peel of the fruits of *M. cauliflora* are astringent and are popularly used as a remedy for diarrhea and skin irritation. Other indications include asthma, intestinal inflammation and hemoptysis. Moreover, it has been demonstrated that depsides and anthocyanins of jaboticaba fruits can reduce inflammation caused by exposure to cigarette smoke (Dastmalchi et al., 2012). These compounds present strong antioxidant and anti-inflammatory properties, and some of these are of interest because of their potential to treat chronic obstructive pulmonary disease (COPD). The anti-inflammatory activity of jaboticaba against COPD renders this fruit an emerging functional food for smokers, to reduce the lung damage in these patients. Fruits of *M. vexator* exhibit activity against COPD, primarily because of their antioxidant capacity and polyphenol content (Dastmalchi et al., 2012).

4.3. Hypoglycemic and hypolipidemic activities

The consumption of freeze–dried jaboticaba peel increased HDL-cholesterol (41.7% in animals fed with 2% freeze–dried peel jaboticaba, when compared with the control group) and reduced insulin resistance in obese rats (hyperinsulinemia was lower in animals that received freeze–dried jaboticaba peel) (Lenquiste, Batista, Marineli, Dragano, & Maróstica, 2012). The compound 4-(α-rhamnopyranosyl) ellagic acid, obtained from the methanolic extract of *M. dubia* leaves, exhibited strong inhibition against human recombinant aldose reductase, which was 60-fold higher than that of quercetin. Aldose reductase inhibitors are important in preventing the reduction of glucose to sorbitol and reducing diabetic complications (Akter et al., 2011).

4.4. Antifungal and antiproliferative activities

The hydroethanolic extracts (80%) of *M. cauliflora* leaves exhibited antifungal activity *in vitro* against strains of *Candida albicans* (dilution to 1:2) and *Candida krusei* (crude extract), whereas the hydroethanolic extract from stem barks exhibited antifungal activity against the strains tested: *C. albicans* (dilution to 1:2), *Candida guilliermondii* (dilution to 1:8) and *C. krusei* (dilution to 1:8) (Diniz, Macêdo-Costa, Pereira, Pereira, & Higino, 2010).

The polar fraction of jaboticaba peel presented antiproliferative effects against leukemia cells (K-562) and the non-polar extract exhibited activity against prostate cancer cells (PC-3). The micronucleus test in mice using the polar extract of jaboticaba (*M. cauliflora*) peel induced no DNA damage and mutagenic effects (Leite-Legatti et al., 2012).

4.5. Antibacterial activity

Myoda et al. (2010) recently studied the effects of several concentrations of methanolic extract of camu-camu juice residue from the seed and peel on the following microorganisms: *Staphylococcus aureus, Escherichia coli and Saccharomyces cerevisiae.* The extract exhibited antimicrobial activity against *S. aureus*, which was probably because of the lipophilic compounds present in the extract.

Hydromethanolic extracts from the leaves of *M. cauliflora* presented effective antibacterial activity against *Streptococcus mitis*, *S. mutans*, *S. sanguinis*, *S. oralis*, *S. salivarius* and *Lactobacillus casei*, when compared with chlorhexidine 0.12%, revealing a strong potential for finding new agents active against bacteria that cause tooth decay (Macedo-Costa et al., 2009).

4.6. Anticholinesterase activity

Essential oils obtained from the flowers and leaves of *M. floribunda* had an IC_{50} value of 1583 and 681 μg/ml (both low mild values), respectively, in an acetylcholinesterase inhibitory bioassay (Tietbohl et al., 2012). Leaf essential oils of *M. trunciflora* presented activity against *Candida dubliniensi* and *C. albicans*. It was suggested that this activity may be associated with the sesquiterpene content in the oil and that the essential oils from these species could be exploited as medicinal sources (Lago et al., 2011).

4.7. Anti-plasmodium activity

When evaluated against *Plasmodium falciparum*, the dichloromethanic and ethanolic extracts from the cortex of *M. dubia* exhibited CI_{50} value of 3 and 6 μg/ml, respectively. These values are close to those of others species that have known activity against *P. falciparum*, such as *Remijia peruviana* (CI_{50} = 7.4 μg/mL), *Cinchona officinalis* (CI_{50} = 4.2 μg/mL), and *Cinchona pubescens* (CI_{50} = 1 μg/ml) (Ruiz, Maco, Cobos, Gutierrez-Choquevilca, & Roumy, 2011).

4.8. Gastroprotective activity

The aqueous ethanolic extract from leaves of *M. peruviana* var. *trunciflora* Mattos (syn. *P. edulis*) did not reveal acute toxicity in mice treated with 5 g/kg *p.o*. and also showed promising antiulcer activity in rats with HCl/ethanol-induced ulcers (100, 200, and 400 mg/kg *p.o.*); thus, revealing to be more potent than lanzoprazole. The triterpenoids present in leaves of *M. peruviana* var. *trunciflora* probably play the gastroprotective role in the ulcer induced models used in this study (Ishikawa et al., 2008).

4.9. Toxicity, genoxic, and antigenotoxic effects

The genotoxic and antigenotoxic potential of *M. dubia* juice was evaluated in blood cells of mice after acute, subacute and chronic treatment. After treatment, no signs of toxicity were observed and no cell death occurred, indicating that camu-camu fruits should be safe for human consumption; however, studies at a greater depth are necessary. In addition, camu-camu presented antigenotoxic activity in an *ex vivo* test (comet assay) (Silva et al., 2012).

5. Conclusions

In spite of the evidence regarding the potential of *Myrciaria* species as a source for obtaining useful compounds, few studies about the chemical composition and biological activity of the species belonging to this genus have been reported. Furthermore, most of the existing studies have concentrated on *M. cauliflora*, *M. dubia*, and *M. vexator*, other species possess a vast diversity of active compounds. Therefore, more investigations in others species of the *Myrciaria* genus may be promising because the quimiotaxonomic similarity within the species that have been studied reveals great potential in discovering new molecules with biological importance.

The data described in this paper reveal several species with great potential for food and pharmaceutical applications due to the high molecular diversity found in this genus, with several properties that could be explored. Biological activities such as antioxidant, anti-inflammatory, hypoglycemic, hypolipidemic, antifungal, antiproliferative, antibacterial, anticholinesterase, anti-*Plasmodium* and gastroprotective effects have been reported and the main chemical compounds correlated with these properties have been isolated. The knowledge obtained from this review should be useful for further exploitation of the several resources of the *Myrciaria* genus.

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