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Phytochemistry and antibacterial potential of the genus *Garcinia*

ag0005 **Vaderament-A. Nchiozem-Ngnitedem[a,b,*], Justus Mukavi[c,d], Leonidah Kerubo Omosa[b], and Victor Kuete[e]**

aff0005 [a]Institute of Chemistry, University of Potsdam, Karl-Liebknecht-Strasse 24-25, D-14476 Potsdam-Golm, Germany

aff0010 [b]Department of Chemistry, University of Nairobi, P.O. Box 30197-00100, Nairobi, Kenya

aff0015 [c]Institute of Pharmaceutical Biology and Phytochemistry, University of Münster, Corrensstrasse 48, D-48149 Münster, Germany

aff0020 [d]School of Pure and Applied Sciences, University of Embu, P.O. Box 6-60100, Embu, Kenya

aff0025 [e]Department of Biochemistry, Faculty of Science, University of Dschang, Dschang, Cameroon

cor1 *Corresponding author. e-mail address: n.vaderamentalexe@gmail.com

Contents

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Abstract

sp0035 Species of the genus *Garcinia* (Clusiaceae) have been used for centuries in different folk medicine for the treatment of several ailments, as well as food supplements. Evidence from previous studies has demonstrated a rich depository of structurally diverse secondary metabolites with a wide array of biological activities. The present chapter summarizes the information on the ethnobotany, phytochemistry, and antibacterial potential of the *Garcinia* genus against drug-sensitive and multi-drug resistant (MDR) phenotypes. A literature survey of the published information was collected from databases such as Google Scholar, PubMed, SciFinder, Scopus, Web of Science, conference proceedings, books, M.Sc., and Ph.D. dissertations. Phytochemical

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studies showed that xanthones, benzophenones, and flavonoids as the main secondary metabolites. Pharmacological investigations with crude extracts and isolated compounds from *G. kola*, *G. lucida*, *G. nobilis* as well as other *Garcinia* species revealed a broad range of antibacterial activity against several drug-sensitive and MDR phenotypes. Among the isolated compounds, α-mangostin, a prenylated xanthone from *G. mangostana* was found to display the most potent antibacterial effects against both Gram-positive and Gram-negative bacteria while (−)-hydroxycitric acid from some *Garcinia* fruits is utilized in the pharmaceutical industry as an anti-obesity agent. Thus, this review demonstrated that there are convincing *in vitro* studies confirming the traditional use of *Garcinia* species to treat bacterial infections. Furthermore, the reviewed data herein would be a valuable reference tool for future researchers seeking to explore the application potentials of *Garcinia* species for the development of antibacterial agents.

Nomenclature

MIC	Minimum Inhibitory Concentration
MBC	Minimum Bactericidal Concentration
G	*Garcinia*
S. aureus	*Staphylococcus aureus*
S. pyogenes	*Streptococcus pyogenes*
S. pneumonia	*Streptococcus pneumoniae*
H. influenzae	*Haemophilus influenzae*
S. typhimurium	*Salmonella typhimurium*
S. enteritidis	*Salmonella enteritidis*
S. typhi	*Salmonella typhi*
E. coli	*Escherichia coli*
K. pneumonia	*Klebsiella pneumonia*
S. mutans	*Streptococcus mutans*
S. viridans	*Streptococcus viridans*
P. gingivalis	*Porphyromonas gingivalis*
S. sobrinus	*Streptococcus sobrinus*
E. aerogenes	*Enterobacter aerogenes*
P. aeruginosa	*Pseudomonas aeruginosa*
P. stuartii	*Providencia stuartii*
V. cholerae	*Vibrio cholerae*
S. flexneri	*Shigella flexneri*
S. epidermidis	*Staphylococcus epidermidis*
MRSA	Methicillin-resistant *Staphylococcus aureus*
MSSA	Methicillin-susceptible *Staphylococcus aureus*
B. subtilis	*Bacillus subtilis*
B. cereus	*Bacillus cereus*
M. smegmatis	*Mycobacterium smegmatis*
M. cheleneoi	*Mycobacterium cheleneoi*
M. xenopi	*Mycobacterium xenopi*
M. intracellulare	*Mycobacterium intracellulare*
VRE	Vancomycin-resistant *Enterococcus*

VSE	Vancomycin-sensitive *Enterococcus*
M. luteus	*Micrococcus luteus*
L. fermentum	*Limosilactobacillus fermentum*
E. faecium	*Enterococcus faecium*
E. faecalis	*Enterococcus faecalis*
S. lugdunensis	*Staphylococcus lugdunensis*
H. pylori	*Helicobacter pylori*
V. vulnificus	*Vibrio vulnificus*
V. fluvialis	*Vibrio fluvialis*
V. parahaemolyticus	*Vibrio parahaemolyticus*
V. metschnikovii	*Vibrio metschnikovii*
V. campbellii	*Vibrio campbellii*
V. rotiferianus	*Vibrio rotiferianus*
L. ivanovii	*Listeria ivanovii*
L. monocytogenes	*Listeria monocytogenes*
L. grayi	*Listeria grayi*.

1. Introduction

p0240 The genus *Garcinia* is the largest genus of the family Clusiaceae (*Guttiferae*) consisting of 404 accepted species (Plants of the World Online, 2021), distributed in the tropics and subtropics of Africa, Asia, Australia, tropical America, and Polynesia (Patil & Appaiah, 2015). Numerous species of *Garcinia* have been utilized in various folklore medicines for the treatment of several ailments including dysentery, HIV/AIDS, eczema, gonorrhoea, hyperkeratosis, urinary tract infections, psoriasis, typhoid, leucorrhoea, sprains, menstrual disorders, chronic ulcers, lymphatitis, wounds, parotitis, suppurations, struma, cough, sore throat and scurvy, oedema, constipation, piles, and rheumatism (Chinsembu, 2016; Dharmaratne, Sakagami, Piyasena, & Thevanesam, 2013; Lim, 2012; Tharachand & Avadhani, 2013; Upaganlawar & Badole, 2013). Earlier phytochemical studies have found species of this genus to be rich sources of secondary metabolites, such as xanthones, flavonoids, bioflavonoids, benzophenones, lactones, triterpenes as well as phenolic and organic acids. Several of these chemical constituents have been shown to possess a plethora of interesting biological properties including antioxidant (Deachathai, Mahabusarakam, Phongpaichit, & Taylor, 2005), antifungal and anthelmintic (Hemshekhar et al., 2011), antiplasmodial (Ritthiwigrom, Laphookhieo, & Pyne, 2013), anti-obesity, anti-diabetic (Ovalle-Magallanes, Eugenio-Pérez, & Pedraza-Chaverri, 2017), anti-HIV, anticancer (Gutierrez-Orozco & Failla, 2013; Ibrahim, Abdallah, El-Halawany, Nafady, & Mohamed, 2019a;

Ibrahim et al., 2019b), anti-cholinesterase, analgesic (Ovalle-Magallanes et al., 2017), antipyretic, antiproliferative, anti-inflammatory (Gutierrez-Orozco & Failla, 2013) and α-glucosidase inhibitory activities (Antia et al., 2010). The present chapter aims to review the antibacterial potential of *Garcinia* species against drug-sensitive and multi-drug resistant (MDR) phenotypes based on the existing literature to provide a platform for prospective researchers to explore the application potentials of these plants for various drug and bioceutical development. Additionally, ethnobotany and the various phytochemicals isolated from this genus will also be summarized.

2. Distribution and botanical description of the genus *Garcinia*

p0245 The genus *Garcinia* (Clusiaceae) is part of the sub-family Clusioideae Engl. and comprises 404 accepted species of dioecious and in several circumstances' apomictic evergreen trees and shrubs (Plants of the World Online, 2021). They are naturally confined to lowland tropical forests across Africa, Asia, Australia, tropical America, and Polynesia (Patil & Appaiah, 2015). In Africa, including Madagascar, and the forested areas in Cameroon, Equatorial Guinea, Gabon, Angola, and the Democratic Republic of the Congo, the genus *Garcinia* forms a significant constituent of the lower strata of dense lowland to submontane rain forests (Achoundong, 1995; Gonmadje et al., 2011). The existence of high levels of sympatric *Garcinia* species in virtually all tropical regions may partly be the reason the genus received little attention from taxonomists owing to its supposed complexity (Sweeney, 2008). This has led to an indecisive scenario where taxonomic studies have mostly focussed on a particular region and as a result contain various inconsistencies and errors (Sosef & Dauby, 2012). This clearly further supports the idea that *Garcinia* is rather a complex and 'difficult' genus. Thus, plant ecologists and foresters are usually content when they have established that their specimen belongs to the genus *Garcinia* (Sosef & Dauby, 2012; Sweeney, 2008). However, identification of the specimen down to an individual species, is characterized by many errors owing to the unresolved taxonomic backbone (Sosef & Dauby, 2012).

p0250 From an ethnobotanical viewpoint, the genus *Garcinia* is perhaps widely cultivated commonly for the highly valued tropical fruits of mangosteen (*G. mangostana* L.) (Sweeney, 2008), a tree native to Peninsula Malaysia (Plants of the World Online, 2021). Consequently, mangosteen, as well as other sympatric species, have become the central focus of pharmacological studies (Heymsfield et al., 1998; Ho, Huang, & Chen, 2002; Mackeen et al., 2000), and a wide array of natural supplements are derived from these species (Balunas, Su, Brueggemeier, & Kinghorn, 2008; Obolskiy, Pischel, Siriwatanametanon, & Heinrich, 2009).

3. Diversity of the genus *Garcinia*

p0255 The genus *Garcinia* displays various features that are of general interest to taxonomists and ecologists. In many regions, the genus is distinguished for its occurrence of high numbers of sympatric species (Ng & Whitmore, 1972; Thomas et al., 2003), and this diversity is primarily notable since species that are both dioecious and agamospermous may be common in the genus (Allem, 2003; Thomas, 1997). Moreover, *Garcinia* species exhibit the highest diversity of floral form, mostly in the androecium, as is found anywhere in angiosperms and as such, there exist many unresolved taxonomic problems around it (Sweeney, 2008). Amidst the African species, the genus is characterized by the dioecism of its species and thus its unisexual flowers, the existence of a foveola at the base of the petiole, the peltate stigma, the ovary with a sole apical ovule per locule, and the berry-like fruit (Sosef & Dauby, 2012).

4. Ethnopharmacological use of plants of the genus *Garcinia*

p0260 The genus *Garcinia* comprises a huge collection of medicinal plants with therapeutic potential. The different plant parts including leaves, bark, stem, fruits, fruits rinds, and flowers have been used worldwide to treat several disorders (Angami et al., 2021; Liu et al., 2016). For instance, the pericarps of mangosteen (also referred to as "monkey fruit") have been used for centuries in the Asian region as traditional medicine in treating skin infections, trauma, dysentery, abdominal pain, and wounds (Peres, Nagem, & de Oliveira, 2000). In addition, the rind of this fruit has been used in Thailand for treating skin conditions, wounds, and diarrhoea; while the pulp has been used to treat fever (Kondo, Zhang, Ji, Kou, & Ou, 2009; Mahabusarakam, Wiriyachitra, & Taylor, 1987). On the West Coast of South India, the dried rind of the fruit of *G. cambogia* Desr., is widely used for culinary purposes, and commercially for "Colombo curing" of fish (Lewis & Neelakantan, 1965). In Indonesian folkloric medicine, *G. atroviridis* leaves' infusion is used to treat stomach pains associated with pregnancy (Grosvenor, Gothard, McWilliam, Supriono, & Gray, 1995). The alcoholic extracts of *G. kola* nuts have widely been used in Ghana and Nigeria by the local population against a wide array of illnesses, for instance, to improve the voice of singers (Irvine, Woody, & Barsett, 1961), treat diarrhoea, dysentery, and headache (Ainslie, 1937). The sap from the stem is used to treat epidermal parasitic skin infections and topical sores (Ayensu, 1978). Likewise, both the seeds and the chew-sticks are believed to exert antibacterial action in the mouth thereby abetting oral hygiene (Madubunyi, 1995). The leaves and seeds of *G. dulcis*, a species mainly confined to southeast Asia, have locally been used in folklore medicine against parotitis, struma, lymphatitis, and other ailments (Iinuma, Tosa, Ito, Tanaka, & Riswan, 1996a).

5. Phytochemistry of *Garcinia species*

p0265 For the past several decades, various *Garcinia* species have been extensively investigated from a phytochemical viewpoint owing to the great role in folklore medicine and remarkable biological potencies of many of its species (Kumar, Sharma, & Chattopadhyay, 2013). The major classes of secondary metabolites reported from the genus *Garcinia* include xanthones, flavonoids, benzophenones, and phenolic acids. To have a detailed picture, phytochemicals that have been isolated from various species of *Garcinia* are summarized in Table 1.

5.1 Phenolic compounds

p0270 Xanthones, which are a class of naturally occurring polyphenolic organic compounds in a few higher plants, fungi, and lichens, have been found to be the major phenolic compounds in this genus (Mazimba, Nana, Kuete, & Singh, 2013; Obolskiy et al., 2009). They are characterized by a unique chemical scaffold represented by an oxygenated tricyclic aromatic system (C_6–C_3–C_6) of the basic parent molecule 9*H*-xanthen-9-one (Mazimba et al., 2013; Vieira & Kijjoa, 2005). The majority of xanthones found in the genus *Garcinia* are normally substituted with a variety of isoprene, methoxyl, hydroxyl, prenyl, geranyl, and phenolic groups at various positions on the A and B rings to give a large diversity of plausible

Table 1 Phytochemicals from *Garcinia* species.

Phytochemicals	**Plant species and constituents**			
	Garcinia kola	***Garcinia lucida***	***Garcinia nobilis***	**Other *Garcinia* species**
Xanthones				
α-Mangostin	nr	nr	nr	+ *G. mangostana* (Asai, Tosa, Tanaka, & Iinuma, 1995; Suzy, Mieke, Warta, & Unang, 2018); *G. speciosa* (Okudaira et al., 2000); *G. cowa* (Kaennakam, Siripong, & Tip-Pyang, 2015)
β-Mangostin	nr	nr	nr	+ *G. cowa* (Kaennakam et al., 2015); *G. mangostana* (Asai et al., 1995; Ibrahim et al., 2019b; Suzy et al., 2018)
γ-Mangostin	nr	nr	nr	+ *G. mangostana* (Asai et al., 1995; Suzy et al., 2018)
Norathyriol	nr	nr	nr	+ *G. mackeaniana* (Ha et al., 2020)
Mangiferin	nr	nr	nr	+ *G. mackeaniana* (Ha et al., 2020)
Allanxanthone C	nr	nr	nr	+ *G. xipshuanbannaensis* (Han et al., 2008); *G. mackeaniana* (Ha et al., 2020)
Garcinones A–E	nr	nr	nr	+ *G. mangostana* (Suzy et al., 2018); *G. cowa* (Kaennakam et al., 2015); *G. xipshuanbannaensis* (Han et al., 2008); *G. mackeaniana* (Ha et al., 2020); *G. mangostana* (Sen et al., 1982; Xu et al., 2014)

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Table 1 (*continued*)

Phytochemicals	**Plant species and constituents**			
	Garcinia kola	***Garcinia lucida***	***Garcinia nobilis***	**Other *Garcinia* species**
1,5,6-Trihydroxy-2-prenyl-6′,6′-dimethyl-2*H*-pyrano-(2′,3′:3,4)xanthone	nr	nr	nr	+ *G. merguensis* (Trisuwan, Rukachaisirikul, Phongpaichit, & Hutadilok-Towatana, 2013); *G. lancilimba* (Yang et al., 2007)
1,6,7-Trihydroxy-6′,6′-dimethyl-2*H*-pyrano (2′,3′:3,2)-4-(3-methyl but-2-enyl)xanthone	nr	nr	nr	+ *G. lancilimba* (Yang et al., 2007)
Xanthone V_1	nr	nr	nr	+ *G. lancilimba* (Sun et al., 2016; Yang et al., 2007)
6-Deoxy-jacareubin	nr	nr	nr	+ *G. lancilimba* (Yang et al., 2007)
Parvifolixanthones A-C	nr	nr	nr	+ *G. lancilimba* (Yang et al., 2007); *G. parvifolia* (Rukachaisirikul, Naklue, Phongpaichit, Towatana, & Maneenoon, 2006); *G. mangostana* (Mohamed, Ibrahim, Shaaban, & Ross, 2014)
Dulxanthones A/B	nr	nr	nr	+ *G. lancilimba* (Yang et al., 2007)
Xanthone V_{1a}	nr	nr	nr	+ *G. lancilimba* (Sun et al., 2016; Yang et al., 2007)
Cudratricusxanthone E	nr	nr	nr	+ *G. lancilimba* (Yang et al., 2007)
Gartanin	nr	nr	+ (Fouotsa et al., 2021)	+ *G. mangostana* (Asai et al., 1995; Xu et al., 2014)
Xanthone I	nr	nr	nr	+ *G. mangostana* (Xu et al., 2014)

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Table 1 (*continued*)

Phytochemicals	Plant species and constituents			
	Garcinia kola	***Garcinia lucida***	***Garcinia nobilis***	**Other *Garcinia* species**
1,3,5-Trihydroxyxanthone	nr	nr	+ (Fouotsa et al., 2014)	nr
1,3,6,7-Tetrahydroxy xanthone	nr	nr	+ (Fouotsa et al., 2014)	+ *G. brasiliensis* (Gontijo et al., 2012)
1,3,5,6-Tetrahydroxy xanthone	nr	nr	+ (Fouotsa et al., 2014)	nr
Oblongixanthones C, F-H	nr	nr	nr	+ *G. oblongifolia* (Trinh et al., 2017)
1,3,6-Trihydroxy-7-methoxy-2,5-bis(3-methyl but-2-enyl) xanthone	nr	nr	nr	+ *G. oblongifolia* (Trinh et al., 2017); *G. cowa* (Mahabusarakam, Chairerk, & Taylor, 2005; Pattalung, Thongtheeraparp, Wiriyachitra, & Taylor, 1994)
Isocowanin	nr	nr	nr	+ *G. oblongifolia* (Trinh et al., 2017)
Cowanin	nr	nr	nr	+ *G. oblongifolia* (Trinh et al., 2017); *G. cowa* (Mahabusarakam et al., 2005; Pattalung et al., 1994); *G. speciosa* (Okudaira et al., 2000)
Cowanol	nr	nr	nr	+ *G. oblongifolia* (Trinh et al., 2017); *G. cowa* (Mahabusarakam et al., 2005; Pattalung et al., 1994); *G. speciosa* (Okudaira et al., 2000)
Rubraxanthone	nr	nr	nr	+ *G. oblongifolia* (Trinh et al., 2017); *G. mangostana* (Mohamed et al., 2014)
Cowagarcinone E	nr	nr	nr	+ *G. oblongifolia* (Trinh et al., 2017); *G. cowa* (Mahabusarakam et al., 2005)

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Table 1 (*continued*)

Phytochemicals	Plant species and constituents			
	Garcinia kola	*Garcinia lucida*	*Garcinia nobilis*	Other *Garcinia* species
Norcowanin	nr	nr	nr	+ *G. oblongifolia* (Trinh et al., 2017); *G. cowa* (Kaennakam et al., 2015; Pattalung et al., 1994)
Cowaxanthone	nr	nr	nr	+ *G. cowa* (Kaennakam et al., 2015; Pattalung et al., 1994)
Xanthochymusxanthones A/B	nr	nr	nr	+ *G. xanthochymus* (Nguyen et al., 2017)
1,7-Dihydroxyxanthone	nr	nr	nr	+ *G. xanthochymus* (Nguyen et al., 2017); *G. lancilimba* (Sun et al., 2016); *Garcinia* sp. (Siridechakorn et al., 2014)
Subelliptenones C, D, F-H	nr	nr	nr	+ *G. xanthochymus* (Nguyen et al., 2017)
12b-Hydroxy-des-D-garcigerrin A	nr	nr	nr	+ *G. xanthochymus* (Nguyen et al., 2017); *G. gerrardii* (Sordat-diserens, Marstona, Hamburgerd, Rogers, & Hostettrnanna, 1989); *G. nervosa* (Wong, Ee, Ismail, Karunakaran, & Jong, 2017)
Globuxanthone	nr	nr	nr	+ *G. xanthochymus* (Nguyen et al., 2017)
1,2,7-Trihydroxyxanthone	nr	nr	nr	+ *G. xanthochymus* (Nguyen et al., 2017)
Symphoxanthone	nr	nr	nr	+ *G. xanthochymus* (Nguyen et al., 2017)
Garcigerrins A/B	nr	nr	nr	*G. gerrardii* (Sordat-diserens et al., 1989)
Cowagarcinones A–D	nr	nr	nr	+ *G. cowa* (Mahabusarakam et al., 2005)
Mangostinone	nr	nr	nr	+ *G. cowa* (Mahabusarakam et al., 2005); *G. mangostana* (Asai et al., 1995)

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Table 1 (*continued*)

Phytochemicals	Plant species and constituents			
	Garcinia kola	***Garcinia lucida***	***Garcinia nobilis***	**Other *Garcinia* species**
Fuscaxanthones A, C, D, F, I	nr	nr	nr	+ *G. cowa* (Kaennakam et al., 2015; Mahabusarakam et al., 2005)
Bannaxanthones A–H	nr	nr	nr	+ *G. xipshuanbannaensis* (Han et al., 2008)
Isojacareubin	nr	nr	nr	+ *G. xipshuanbannaensis* (Han et al., 2008); *G. lancilimba* (Sun et al., 2016)
Garcinexanthones G–I	nr	nr	nr	+ *G. lancilimba* (Sun et al., 2016)
Gentisin	nr	nr	nr	+ *G. lancilimba* (Sun et al., 2016)
Jacareubin	nr	nr	nr	+ *G. lancilimba* (Sun et al., 2016)
Isocudraniaxanthone A	nr	nr	nr	+ *G. lancilimba* (Sun et al., 2016)
1,5,6-Trihydroxy-3,7-dimethoxyxanthone	nr	nr	nr	+ *G. lancilimba* (Sun et al., 2016)
Gerontoxanthone C	nr	nr	nr	+ *G. lancilimba* (Sun et al., 2016)
Lichexanthone	nr	nr	+ (Dzoyem et al., 2015)	nr
1,3,6,7-Tetrahydroxy xanthone	nr	nr	+ (Dzoyem et al., 2015)	nr
1,3,5,6-Tetrahydroxy xanthone	nr	nr	+ (Dzoyem et al., 2015)	nr
1-Hydroxy-3,6,7-tri-*O*, *O*,*O*-triprenylxanthone	nr	nr	+ (Dzoyem et al., 2015)	nr
1,6-Dihydroxy-3,7-di-*O*,*O*-diprenylxanthone	nr	nr	+ (Dzoyem et al., 2015)	nr
Rheediaxanthone A	nr	nr	nr	+ *G. epunctata* (Fotso et al., 2014)

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Table 1 (*continued*)

Phytochemicals	Plant species and constituents			
	Garcinia kola	***Garcinia lucida***	***Garcinia nobilis***	**Other *Garcinia* species**
1,4,6-Trihydroxy-5-methoxy-7-prenylxanthone	nr	nr	nr	+ *G. xanthochymus* (Han et al., 2007)
1,4,5,6-Tetrahydroxy -7-prenylxanthone	nr	nr	nr	+ *G. xanthochymus* (Han et al., 2007)
1,2,5,6-Tetrahydroxy-7-geranylxanthone	nr	nr	nr	+ *G. xanthochymus* (Han et al., 2007)
1,4,5,6-Tetrahydroxy-7,8-diprenylxanthone	nr	nr	nr	+ *G. xanthochymus* (Han et al., 2007)
1,3,5,6-Tetrahydroxy-4,7,8-triprenylxanthone	nr	nr	nr	+ *G. xanthochymus*(Han et al., 2007)
Garciniaxanthone E	nr	nr	nr	+ *G. xanthochymus* (Han et al., 2007)
Kaennacowanols A–C	nr	nr	nr	+ *G. cowa* (Kaennakam et al., 2015)
Pruniflorone C	nr	nr	nr	+ *G. cowa* (Kaennakam et al., 2015)
Cowaxanthone B	nr	nr	nr	+ *G. cowa* (Kaennakam et al., 2015)
Jacareubin	nr	nr	nr	+ *G. cowa* (Kaennakam et al., 2015)
1-Isomagostin	nr	nr	nr	+ *G. cowa* (Kaennakam et al., 2015)
1-Isomagostin hydrate	nr	nr	nr	+ *G. cowa* (Kaennakam et al., 2015)
Garcihombronones A–D	nr	nr	nr	+ *G. hombroniana* (Klaiklay et al., 2013)
Toxyloxanthone B	nr	nr	nr	+ *G. hombroniana* (Klaiklay et al., 2013)
Smeathxanthones A/B	nr	nr	+ (Fouotsa et al., 2012)	+ *G. smeathmannii* (Komguem et al., 2005)

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Table 1 (*continued*)

Phytochemicals	Plant species and constituents			
	Garcinia kola	*Garcinia lucida*	*Garcinia nobilis*	Other *Garcinia* species
Dulcisxanthones H/I/K/L	nr	nr	nr	+ *G. dulcis* (Mahabusarakam, Mecawun, & Phongpaichit, 2016; Thepthong, Phongpaichit, Carroll, Voravuthikunchai, & Mahabusarakam, 2017)
Garciniaxanthone C	nr	nr	nr	+ *G. dulcis* (Mahabusarakam et al., 2016)
Mangostanaxanthones I/II	nr	nr	nr	+ *G. mangostana* (Mohamed et al., 2014)
Merguensinone	nr	nr	nr	+ *G. merguensis* (Trisuwan et al., 2013)
Xanthochymones A/B	nr	nr	nr	+ *G. xanthochymus* (Trisuwan, Boonyaketgoson, Rukachaisirikul, & Phongpaichit, 2014)
Garner xanthone	nr	nr	nr	+ *G. nervosa* (Wong et al., 2017)
6-Deoxyisojacareubin	nr	nr	nr	+ *G. nervosa* (Wong et al., 2017)
3-*O*-methylcowaxanthone	nr	nr	nr	+ *G. cowa* (Na, Song, & Hu, 2013)
7-*O*-methylgarcinone	nr	nr	nr	+ *G. cowa* (Na et al., 2013)
Cuneifolin	nr	nr	nr	+ *G. cuneifolia* (Ee, Phong, Mong, Shaari, & Sukari, 2003)
Garcixanthone A	nr	nr	nr	+ *G. mangostana* (Ibrahim et al., 2019b)
Mangostanaxanthone VIII	nr	nr	nr	+ *G. mangostana* (Ibrahim et al., 2019a)
Benzophenones				
Gakolanone	+(Akoro, Aiyelaagbe, Onocha, & Gloer, 2020)	nr	nr	nr

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Table 1 (*continued*)

Phytochemicals	**Plant species and constituents**			
	Garcinia kola	***Garcinia lucida***	***Garcinia nobilis***	**Other *Garcinia* species**
Benthamianone	nr	nr	nr	+ *G. benthamiana* (See et al., 2016)
Congestiflorone	nr	nr	nr	+ *G. benthamiana* (See et al., 2016)
Kolanone	+(Hussain, Owegby, Parimoo, & Waterman, 1982)	nr	nr	–
Oblongifolins A-G	nr	nr	nr	+ *G. oblongifolia* (Hamed et al., 2006); *G. schomburgkianan* (Mungmee, Sitthigool, Buakeaw, & Suttisri, 2013); *G. cowa* (Xu et al., 2010); *G. yunnanensis* (Xu et al., 2008)
Paucinone A-D	nr	nr	nr	+ *G. paucinervis* (Gao et al., 2010)
Xanthochymol	nr	nr	nr	+ *G. xanthochymus* (Acuna, Dastmalchi, Basile, & Kennelly, 2012; Baggett et al., 2005); *G. subelliptica* (Iinuma et al., 1996); *G. huillensis* (Bakana et al., 1987)
Isoxanthochymol	nr	nr	nr	+ *G. xanthochymus* (Baggett et al., 2005); *G. picrorhiza* (Sukandar et al., 2020); *G. subelliptica* (Iinuma et al., 1996); *G. smeathmannii* (Kuete et al., 2007a); *G. huillensis* (Bakana et al., 1987)
Cycloxanthochymol	nr	nr	nr	+ *G. xanthochymus* (Baggett et al., 2005); *G. subelliptica* (Iinuma et al., 1996)

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Table 1 (*continued*)

Phytochemicals	Plant species and constituents			
	Garcinia kola	***Garcinia lucida***	***Garcinia nobilis***	**Other *Garcinia* species**
Aristophenones A/B	nr	nr	nr	+ *G. aristata* (Cuesta-Rubio et al., 2001); *G. xanthochymus* (Baggett et al., 2005); *G. multiflora* (Liu et al., 2010)
Camboginol	nr	nr	nr	+ *G. dulcis* (Deachathai et al., 2005); *G. huillensis* (Bakana et al., 1987); *G. oblongifolia* (Rao, Venkatswamy, & Pendse, 1980)
Cambogin	nr	nr	nr	+ *G. dulcis* (Deachathai et al., 2005); *G. huillensis* (Bakana et al., 1987); *G. pedunculata* (Sahu, Das, & Chatterjee, 1989), *G. cambogia* (Rao et al., 1980); *G. cowa* (Xu et al., 2010); *G. oblongifolia* (Hamed et al., 2006)
Chamuangone	nr	nr	nr	+ *G. cowa* (Sae-Lim, Yuenyongsawad, & Panichayupakaranant, 2019)
Garcicowins A – D	nr	nr	nr	+ *G. cowa* (Xu et al., 2010)
Gambogenone	nr	nr	nr	+ *G. xanthochymus* (Baggett et al., 2005)
Garcimangosone D	nr	nr	nr	+ *G. mangostana* (Huang, Chen, Chen, Huang, & Shieh, 2001)
Garcimultiflorones A – F	nr	nr	nr	+ *G. multiflora* (Chen, Ting, Hwang, & Chen, 2009)

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Table 1 (*continued*)

Phytochemicals	Plant species and constituents			
	Garcinia kola	*Garcinia lucida*	*Garcinia nobilis*	Other *Garcinia* species
Guttiferones A – S	nr	nr	nr	+ *G. dulcis* (Deachathai et al., 2006); *G. xanthochymus* (Acuna et al., 2012); *G. cambogia* (Masullo, Bassarello, Suzuki, Pizza, & Piacente, 2008); *G. smeathmannii* (Kuete et al., 2007a); *G. brasiliensis* (Naldoni et al., 2009); *G. schomburgkianan* (Mungmee et al., 2013); *Garcinia* sp. (Kumar et al., 2013)
Bronianone	nr	nr	nr	+ *G. hambroniana* (Rao et al., 1973)
Eugeniaphenone	nr	nr	nr	+ *G. eugeniaefolia* (Hartati et al., 2008)
Isogarcinol	nr	nr	+ (Fouotsa et al., 2021)	+ *G. purpurea* (Iinuma et al., 1996)
3′,6-Dihydroxy-2,4,4′-trimethoxybenzophenone	nr	nr	+ (Fouotsa et al., 2014)	nr
Garcinol	nr	nr	+ (Fouotsa et al., 2021)	+ *G. preussii* (Biloa et al., 2014); *G. cambogia* (Masullo et al., 2008); *G. purpurea* (Iinuma et al., 1996)
Pedunculol	nr	nr	nr	+ *G. pedunculata* (Sahu et al., 1989)
Semsinones A – C	nr	nr	nr	+ *G. semseii* (Magadula, Kapingu, Bezabih, & Abegaz, 2008)
Garciduols A – C	nr	nr	nr	+ *G. dulcis* (Iinuma et al., 1996a; Iinuma, Tosa, Ito, Tanaka, & Riswan, 1996b)
Clusiaphenone B	nr	nr	nr	+ *G. dulcis* (Deachathai et al., 2005)

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Table 1 (*continued*)

Phytochemicals	Plant species and constituents			
	Garcinia kola	***Garcinia lucida***	***Garcinia nobilis***	**Other *Garcinia* species**
Garciniagifolone	nr	nr	nr	+ *G. preussii* (Biloa et al., 2014)
Garcimultiflorone E	nr	nr	nr	+ *G. preussii* (Biloa et al., 2014)
Garcinialiptone B	nr	nr	nr	+ *G. preussii* (Biloa et al., 2014)
7-*epi*-clusianone	nr	nr	nr	+ *G. preussii* (Biloa et al., 2014); *G. brasiliensis* (Naldoni et al., 2009)
Garcimangosone	nr	nr	nr	+ *G. preussii* (Biloa et al., 2014)
Paucinochymols A – F	nr	nr	nr	+ *G. paucinervis* (Tan et al., 2020)
Epunctanone	nr	nr	nr	+ *G. epunctata* (Fotso et al., 2014)
7-Epiisogarcinol	nr	nr	nr	+ *G. epunctata* (Fotso et al., 2014)
Picrorhizones A – G	nr	nr	nr	+ *G. picrorhiza* (Sukandar et al., 2020)
Garcinopicrobenzophenone	nr	nr	nr	+ *G. picrorhiza* (Sukandar et al., 2020)
30-*Epi*-cambogin	nr	nr	nr	+ *G. picrorhiza* (Sukandar et al., 2020)
(+)-30-*epi*-13,14-didehydroxyisogarcinol	nr	nr	nr	+ *G. picrorhiza* (Sukandar et al., 2020)
Doitunggarcinones A/B	nr	nr	nr	+ *G. propinqua* (Tantapakul et al., 2012)
Vismiaphenone-C	nr	nr	nr	+ *G. pseudoguttifera* (Ali, Goundar, Sotheeswaran, Beaulieu, & Spino, 2000)
Myrtiaphenones A/B	nr	nr	nr	+ *G. pseudoguttifera* (Ali et al., 2000)
Pseudoguttiaphenone A	nr	nr	nr	+ *G. pseudoguttifera* (Ali et al., 2000)

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Table 1 (*continued*)

Phytochemicals	Plant species and constituents			
	Garcinia kola	*Garcinia lucida*	*Garcinia nobilis*	Other *Garcinia* species
Flavonoids				
Kaempferol 3,7-di-*O*-α-rhamnopyranoside	nr	nr	nr	+ *G. dulcis* (Deachathai et al., 2005)
Quercetin 3-*O*-*β*-galactopyranoside	nr	nr	nr	+ *G. dulcis* (Deachathai et al., 2008)
I-4′,I-5,II-5,I-7,II-7 Pentahydroxyflavanone[I-3,II-8]chromone	nr	nr	nr	+ *G. dulcis* (Ansari, Rahman, Barraclough, Maynard, & Scheinmann, 1976)
4′-Hydroxy-7-methoxyflavan	nr	nr	nr	+ *G. dulcis* (Deachathai et al., 2005)
(–)-Epicatechin	nr	nr	nr	+ *G. dulcis* (Deachathai et al., 2005); *G. cf cymosa* (Yuliar, Manjang, Ibrahim, & Achmad, 2013)
Apigenin	nr	nr	nr	+ *G. dulcis* (Deachathai et al., 2005)
Dulcisflavan	nr	nr	nr	+ *G. dulcis* (Deachathai et al., 2005)
Vitexin	nr	nr	nr	+ *G. dulcis* (Deachathai et al., 2005); *G. hombroniana* (Rukachaisirikul et al., 2005a)
(2*R*)-7,4′-Dihydroxylflavan	nr	nr	nr	+ *G. dulcis* (Deachathai et al., 2008)
Rhamnazin	nr	nr	nr	+ *G. dulcis* (Deachathai et al., 2008)
Isolupalbigenin	nr	nr	nr	+ *G. dulcis* (Deachathai et al., 2005)
Lupalbigenin	nr	nr	nr	+ *G. dulcis* (Deachathai et al., 2005)
Derriscannoside A	nr	nr	nr	+ *G. dulcis* (Deachathai et al., 2005)
Sphaerobioside acetate	nr	nr	nr	+ *G. dulcis* (Deachathai et al., 2005)

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Table 1 (*continued*)

Phytochemicals	**Plant species and constituents**			
	Garcinia kola	***Garcinia lucida***	***Garcinia nobilis***	**Other *Garcinia* species**
Dulcisisoflavone	nr	nr	nr	+ *G. dulcis* (Deachathai et al., 2005)
Dulcinoside	nr	nr	nr	+ *G. dulcis* (Deachathai et al., 2005)
Kaempferol 3-*O*-*β*-D-glucopyranosyl-7-*O*-α-L-rhamnopyranoside	nr	nr	nr	+ *G. dulcis* (Deachathai et al., 2005, 2006)
Isoxanthochimol	nr	nr	nr	+ *G. ovalifolia* (Lannang, Noudou, & Sewald, 2013)
Astragalin	nr	nr	nr	+ *G. preussii* (Biloa et al., 2014)
Eriodictyol	nr	nr	nr	+ *G. preussii* (Biloa et al., 2014)
Kaempferol	nr	nr	nr	+ *G. cowa* (Tayana, Suteerapataranon, & Deachathai, 2017)
6-prenylapigenin	nr	nr	nr	+ *G. xanthochymus* (Han et al., 2007)
Biflavonoids				
3″,4′,4′,5,5″,7,7″-Heptahydroxy-3,8″-biflavanone	+ (Akoro et al., 2020)	nr	nr	+ *G. buchananii* (Jackson, Locksley, Scheinmann, & Wolstenholme, 1971)
3″,4′,5,5″,5′,7,7″-Heptahydroxy-4-methoxy-3,8″-biflavanone	+ (Akoro et al., 2020)	nr	nr	nr

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Table 1 (*continued*)

Phytochemicals	Plant species and constituents			
	Garcinia kola	*Garcinia lucida*	*Garcinia nobilis*	Other *Garcinia* species
4′,4′,5,5″,7,7″-Hexahydroxy-3,8″-biflavanone (GB-la)	+ (Akoro et al., 2020; Kapadia, Oguntimein, & Shukla, 1994)	nr	nr	nr
Morelloflavone	nr	nr	nr	+ *G. dulcis* (Ansari et al., 1976; Deachathai et al., 2006); *G. merguensis* (Trisuwan et al., 2013); *G. griffithii* (Salleh, Sazali, Ahmad, & Taher, 2017); *G. multiflora* (Lin et al., 1997); *G. cowa* (Tayana et al., 2017); *G. madruno* (Osorio, Londoño, & Bastida, 2013); *G. schomburgkianan* (Mungmee et al., 2013); *G. brasiliensis* (Gontijo et al., 2012)
Kolaflavanone	+ (Kapadia et al., 1994)	nr	nr	nr
GB-1	+ (Kapadia et al., 1994)	nr	nr	+ *G. preussii* (Messi et al., 2012)
GB-2	+ (Kapadia et al., 1994)	nr	nr	+ *G. xanthochymus* (Konoshima, Ikeshiro, & Miyahara, 1970); *G. preussii* (Messi et al., 2012)
Morelloflavone-7′-sulfate	nr	nr	nr	+ *G. dulcis* (Saelee, Phongpaichit, & Mahabusarakam, 2015)

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Table 1 (*continued*)

Phytochemicals	Plant species and constituents			
	Garcinia kola	*Garcinia lucida*	*Garcinia nobilis*	Other *Garcinia* species
GB-2a	nr	nr	nr	+ *G. dulcis* (Ansari et al., 1976; Deachathai et al., 2006); *G. xanthochymus* (Konoshima et al., 1970); *G. preussii* (Messi et al., 2012); *G. multiflora* (Lin et al., 1997)
Volkensiflavone	nr	nr	nr	+ *G. dulcis* (Ansari et al., 1976; Deachathai et al., 2006); *G. xanthochymus* (Konoshima et al., 1970); *G. merguensis* (Trisuwan et al., 2013); *G. madruno* (Osorio et al., 2013); *G. schomburgkianan* (Mungmee et al., 2013)
Podocarpusflavone A	nr	nr	nr	+ *G. dulcis* (Deachathai et al., 2006; Harrison et al., 1994)
I3,II8-Biapigenin	nr	nr	nr	+ *G. dulcis* (Harrison et al., 1994); *G. xanthochymus* (Konoshima et al., 1970); *G. griffithii* (Salleh et al., 2017)
Dulcisbiflavonoid A	nr	nr	nr	+ *G. dulcis* (Saelee et al., 2015)
O-methylfukugetin	nr	nr	nr	+ *G. dulcis* (Thepthong et al., 2017)
Amentoflavone	nr	nr	nr	+ *G. dulcis* (Ansari et al., 1976; Thepthong et al., 2017); *G. xanthochymus* (Lyles, Negrin, Khan, He, & Kennelly, 2014); *G. merguensis* (Trisuwan et al., 2013); *G. madruno* (Osorio et al., 2013)

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Table 1 (*continued*)

Phytochemicals	**Plant species and constituents**			
	Garcinia kola	***Garcinia lucida***	***Garcinia nobilis***	**Other *Garcinia* species**
Fukugiside	nr	nr	nr	+ *G. xanthochymus* (Konoshima et al., 1970); *G. dulcis* (Thepthong et al., 2017); *G. madruno* (Osorio et al., 2013); *G. schomburgkianan* (Mungmee et al., 2013)
Xanthochymusside	nr	nr	nr	+ *G. xanthochymus* (Konoshima et al., 1970)
GB-1a	+ (Kabangu, Galeffi, Aonzo, Nicoletti, & Messana, 1987)	nr	nr	+ *G. xanthochymus* (Konoshima et al., 1970)
Kolaviron	+ (Michel et al., 2016)	nr	nr	nr
Preussianone	nr	nr	nr	+ *G. preussii* (Messi et al., 2012)
Manniflavanone	nr	nr	nr	+ *G. preussii* (Messi et al., 2012)
Amento-4″-methylether	nr	nr	nr	+ *G. griffithii* (Salleh et al., 2017)
3,8″-Binaringenin	nr	nr	nr	+ *G. griffithii* (Salleh et al., 2017)
3,8″-Binaringenin-7′′-O-glucoside	nr	nr	nr	+ *G. griffithii* (Salleh et al., 2017)
Morelloflavone-7″-*O*-glucoside	nr	nr	nr	+ *G. griffithii* (Salleh et al., 2017)
GB-1a 7″-*O*-β-glucoside	nr	nr	nr	+ *G. multiflora* (Lin et al., 1997)

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Table 1 (*continued*)

Phytochemicals	Plant species and constituents			
	Garcinia kola	*Garcinia lucida*	*Garcinia nobilis*	Other *Garcinia* species
Garcinianin	+ (Ajayi et al., 2014)	nr	nr	nr
7″-*O*-(6‴′-acetyl)-glucoside of Morelloflavone	nr	nr	nr	+ *G. madruno* (Osorio et al., 2013)
Spicataside	nr	nr	nr	+ *G. madruno* (Osorio et al., 2013)
Morelloflavone-4′″-*O*-*β*-D-glycosyl	nr	nr	nr	+ *G. brasiliensis* (Gontijo et al., 2012)
Kolaflavone	+ (Kabangu et al., 1987)	nr	nr	nr
Terpenoids				
31-Nor-9*β*,19-cyclolanost-24-en-3*β*-ol	nr	+ (Nyemba, Mpondo, Connolly, & Rycroft, 1990)	nr	nr
24 *R*,25- and 24 *S*,25-Epoxy-31-nor-9*β*,19-cycIolanostan-3*β*-ol	nr	+ (Nyemba et al., 1990)	nr	nr
9*β*,19-Cyclolanost-24-ene-3*β*,30-diol	nr	+ (Nyemba et al., 1990)	nr	nr
Betulinic acid	nr	nr	+ (Fouotsa et al., 2021)	+ *Garcinia sp.* (Pandey et al., 2015)

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Table 1 (*continued*)

Phytochemicals	Plant species and constituents			
	Garcinia kola	*Garcinia lucida*	*Garcinia nobilis*	Other *Garcinia* species
Zeorin	nr	nr	+ (Fouotsa et al., 2021)	nr
Friedelin	nr	nr	+ (Fouotsa et al., 2014)	+ *G. dulcis* (Harrison et al., 1994); *G. epunctata* (Fotso et al., 2014); *G. griffithii* (Salleh et al., 2017); *G. prainiana* (Mawa & Said, 2012); *G. orthoclada* (Andrianjakaniaina et al., 2018); *G. smeathmannii* (Kuete et al., 2007a); *G. cowa* (Tayana et al., 2017)
3α-Hydroxyfriedel-2-one	nr	nr	+ (Fouotsa et al., 2014)	nr
Scortechterpenes A & B	nr	nr	nr	+ *G. scortechinii* (Sukpondma et al., 2005)
Germacra-4(15),5*E*,10(14)-trien-1*β*-ol	nr	nr	nr	+ *G. scortechinii* (Sukpondma et al., 2005)
Stigmasterol	nr	nr	nr	+ *G. nervosa* (Wong et al., 2017); *G. epunctata* (Fotso et al., 2014); *G. prainiana* (Mawa & Said, 2012); *G. cowa* (Tayana et al., 2017)
β-sitosterol	nr	nr	nr	+ *G. nervosa*; *G. cowa* (Tayana et al., 2017)
3*β*-Acetoxy-9*α*-hydroxy-17,14-Friedolanostan-14,24-dien-26-oic acid	nr	nr	nr	+ *G. hombroniana* (Jamila, Khan, Khan, Khan, & Khan, 2016)
Garcihombronanes F – J	nr	nr	nr	+ *G. hombroniana* (Klaiklay et al., 2013; Rukachaisirikul et al., 2005a)

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Table 1 (*continued*)

Phytochemicals	Plant species and constituents			
	Garcinia kola	***Garcinia lucida***	***Garcinia nobilis***	**Other *Garcinia* species**
Garcihombronanes B – E	nr	nr	nr	+ *G. hombroniana* (Rukachaisirikul et al., 2005a)
Methyl (25 *R*)− 3*β*-hydroxy-23-oxo-9,15-Lanostadien-26-oate	nr	nr	nr	+ *G. hombroniana* (Rukachaisirikul et al., 2005a)
Ovalifolones A/B	nr	nr	nr	+ *G.ovalifolia* (Lannang et al., 2013)
Endodesmiadiol	nr	nr	nr	+ *G.ovalifolia* (Lannang et al., 2013)
Canophyllol	nr	nr	nr	+ *G.ovalifolia* (Lannang et al., 2013); *G. griffithii* (Salleh et al., 2017)
Canophyllal	nr	nr	nr	+ *G.ovalifolia* (Lannang et al., 2013)
Garcinane	nr	nr	nr	+ *G.ovalifolia* (Lannang et al., 2013)
Garcihombronanes K – L	nr	nr	nr	+ *G. hombroniana* (Klaiklay et al., 2013)
(22*Z*,24*E*)− 3*β*,9*α*-Dihydroxy-17,14-friedolanosta-14,22,24-trien-26-oic acid	nr	nr	nr	+ *G. hombroniana* (Klaiklay et al., 2013)
(22Z,24E)− 3*β*-Hydroxycycloart-14,22,24-trien − 26-oic acid	nr	nr	nr	+ *G. hombroniana* (Jamila et al., 2016)
3β, 23α-Dihydroxy-17,14-friedolanostan-8,14,24-trien-26-oic acid	nr	nr	nr	+ *G. hombroniana* (Klaiklay et al., 2013)
Lupeol	nr	nr	nr	+ *G. epunctata* (Fotso et al., 2014); *G. orthoclada* (Andrianjakaniaina et al., 2018)
16β-Hydroxylupeol	nr	nr	nr	+ *G. epunctata* (Fotso et al., 2014)

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Table 1 (*continued*)

Phytochemicals	Plant species and constituents			
	Garcinia kola	*Garcinia lucida*	*Garcinia nobilis*	Other *Garcinia* species
Betulin	nr	nr	nr	+ *G. epunctata* (Fotso et al., 2014); *G. orthoclada* (Andrianjakaniaina et al., 2018)
Squalene	nr	nr	nr	+ *G. griffithii* (Salleh et al., 2017)
β-Amyrin	nr	nr	nr	+ *G. griffithii* (Salleh et al., 2017); *G. orthoclada* (Andrianjakaniaina et al., 2018)
Eupha-8, 24- diene 3-β-ol	nr	nr	nr	+ *G. prainiana* (Mawa & Said, 2012)
Teraxerone	nr	nr	nr	+ *G. prainiana* (Mawa & Said, 2012)
Teraxerol	nr	nr	nr	+ *G. prainiana* (Mawa & Said, 2012)
24-methylenecycloartanol	+ (Ajayi et al., 2014)	nr	nr	nr
Lupenone	nr	nr	nr	+ *G. cowa* (Tayana et al., 2017)
Ursane-3,12-diol	nr	nr	nr	+ *G. orthoclada* (Andrianjakaniaina et al., 2018)
Oleanolic acid	nr	nr	nr	+ *G. orthoclada* (Andrianjakaniaina et al., 2018)
Urs-12-en-28-al	nr	nr	nr	+ *G. orthoclada* (Andrianjakaniaina et al., 2018)
Friedelinol	nr	nr	nr	+ *G. orthoclada* (Andrianjakaniaina et al., 2018)
α-Amyrin	Nr	nr	nr	+ *G. orthoclada* (Andrianjakaniaina et al., 2018)
(*E*)-Hexacos-9-ene	nr	nr	nr	+ *G. orthoclada* (Andrianjakaniaina et al., 2018)

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Table 1 (*continued*)

Phytochemicals	**Plant species and constituents**			
	Garcinia kola	***Garcinia lucida***	***Garcinia nobilis***	**Other *Garcinia* species**
Cyclotetracosane	nr	nr	nr	+ *G. orthoclada* (Andrianjakaniaina et al., 2018)
1-Docosene	nr	nr	nr	+ *G. orthoclada* (Andrianjakaniaina et al., 2018)
(*E*)-Eicos-3-ene	nr	nr	nr	+ *G. orthoclada* (Andrianjakaniaina et al., 2018)
1-Octadecene	nr	nr	nr	+ *G. orthoclada* (Andrianjakaniaina et al., 2018)
1-Hexadecene	nr	nr	nr	+ *G. orthoclada* (Andrianjakaniaina et al., 2018)
2,4-Di-tert-butylphenol	nr	nr	nr	+ *G. orthoclada* (Andrianjakaniaina et al., 2018)
Cycloartenol	+ (Ajayi et al., 2014)	nr	nr	nr
Achilleol A	nr	nr	nr	+ *G. semseii* (Magadula et al., 2008)
Ursolic acid	nr	nr	nr	+ *Garcinia sp.* (Pandey et al., 2015)
Alkaloids				
Dihydrochelerythrine	nr	+ (Fotie, Bohle, Olivier, Gomez, & Nzimiro, 2007)	nr	nr

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Table 1 (*continued*)

Phytochemicals	**Plant species and constituents**			
	Garcinia kola	***Garcinia lucida***	***Garcinia nobilis***	**Other *Garcinia* species**
6-Acetonyldihydrochelerythrine	nr	+ (Fotie, Bohle, Olivier, Gomez, & Nzimiro, 2007)	nr	nr
Lucidamine A	nr	+ (Fotie, Bohle, Olivier, Gomez, & Nzimiro, 2007)	nr	nr
Garciniavalline	nr	nr	nr	+ *G. Parvifolia* (Lathifah et al., 2010)
Cleistopholine	nr	nr	nr	+ *G. Parvifolia* (Lathifah et al., 2010)
O-Methylmoschatoline	nr	nr	nr	+ *G. Parvifolia* (Lathifah et al., 2010)
(-)-Oliveridine	nr	nr	nr	+ *G. Parvifolia* (Lathifah et al., 2010)
(-)-Oliveroline	nr	nr	nr	+ *G. Parvifolia* (Lathifah et al., 2010)
Phenolic acids				
Protocatechuic acid	nr	nr	nr	+ *Garcinia sp.* (Pandey et al., 2015)
Ferulic acid	nr	nr	nr	+ *Garcinia sp.* (Pandey et al., 2015)
Vanillic acid	nr	nr	nr	+ *Garcinia sp.* (Pandey et al., 2015)
Caffeic acid	nr	nr	nr	+ *Garcinia sp.* (Pandey et al., 2015)
Gallic acid	nr	nr	nr	+ *G. ovalifolia* (Lannang et al., 2013)

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Table 1 (*continued*)

Phytochemicals	**Plant species and constituents**			
	Garcinia kola	***Garcinia lucida***	***Garcinia nobilis***	**Other *Garcinia* species**
Garcinoic acid	+ (Michel et al., 2016)	nr	nr	nr
Miscellaneous				
Garcinia acid	+ (Michel et al., 2016)	nr	nr	+ *Garcinia sp.* (Pandey et al., 2015)
Citric acid	nr	nr	nr	+ *Garcinia sp.* (Bheemaiah & Kushalappa, 2019)
Doitungbiphenyls A/B	nr	nr	nr	+ *Garcinia sp.* (Siridechakorn et al., 2014); *G. esculenta* (Zheng et al., 2021)
Schomburgbiphenyl	nr	nr	nr	+ *Garcinia sp.* (Siridechakorn et al., 2014)
Nigrolineabiphenyls A/B	nr	nr	nr	+ *Garcinia sp.* (Siridechakorn et al., 2014): *G. nigrolineata* (Rukachaisirikul et al., 2005b); *G. schomburgkianan* (Mungmee et al., 2013)
3-Hydroxy-4-geranyl-5-methoxybiphenyl	nr	nr	nr	+ *G. mangostana* (Dharmaratne, Piyasena, & Tennakoon, 2005)
Oblongifoliagarcinines A–D	nr	nr	nr	+ *G. oblongifolia* (Wu, Ke, Yang, & Ye, 2008)
Garciesculenbiphenyls A/B	nr	nr	nr	+ *G. esculenta* (Zheng et al., 2021)
Aucuparin	nr	nr	nr	+ *G. schomburgkianan* (Mungmee et al., 2013)
Garcibiphenyl C	nr	nr	nr	+ *G. schomburgkianan* (Mungmee et al., 2013)

(+): present; (nr): not reported.

derivatives (Pinto, Sousa, & Nascimento, 2005; Vieira & Kijjoa, 2005). Based on the nature of the substitution pattern on the parent skeleton, this class of compounds can be subdivided, into simple oxygenated xanthones, glycosylated xanthones, prenylated xanthones, and their derivatives, xanthone dimers, xanthonolignoids and miscellaneous (Pinto et al., 2005). Another special class of xanthones, polyprenylated caged xanthones, has been found to naturally occur in the genus *Garcinia* (Han & Xu, 2009). Caged xanthones are characterized by a unique 4-oxa-tricyclo [4.3.1.$0^{3,7}$]dec-8-en-2-one framework, wherein a highly substituted tetrahydrofuran ring with three quaternary carbon centers is contained (Anantachoke, Tuchinda, Kuhakarn, Pohmakotr, & Reutrakul, 2012). The best representative of this class of compounds is gambogic acid, first isolated from the resin of *G. hanburyi* (Guo et al., 2006).

p0275 The second class of phenolic compounds reported from *Garcinia* species is benzophenone derivatives, particularly oxidized and polyisoprenylated benzophenones (PIBs) (Kumar et al., 2013). These derivatives contain 2,4,6,3′,4′-pentahydroxy benzophenone (maclurin) as the basic scaffold (Cuesta-Rubio, Padron, Castro, Pizza, & Rastrelli, 2001; Cuesta-Rubio, Piccinelli, & Rastrelli, 2005; Eyong, Kuete, & Efferth, 2013). The structural modification involves the substitution of the A ring by prenyl moieties while the B ring can be unsubstituted or undergo prenylation, geranylation, and cyclization to yield a wide diversity of structurally unique derivatives with bi-, tri-, and/or tetracyclic ring systems (Cuesta-Rubio et al., 2005; Wu, Long, & Kennelly, 2014). Bronianone, first reported from the stem wood of *G. hombroniana* was the first PIB derivative isolated from the family Clusiaceae (Rao, Venkataraman, & Yemul, 1973). Other benzophenones with unique structural frameworks include rearranged benzophenones (Tantapakul et al., 2012) and caged polyisoprenylated benzophenones (Hamed et al., 2006) have also been reported from this genus.

p0280 Flavonoids, which comprise a diverse class of polyphenolic compounds occurring naturally in all terrestrial plants have also been reported from the genus *Garcinia* (Deachathai et al., 2005; Han et al., 2007). They comprise a basic scaffold with fifteen (15) carbon atoms organized in a C_6-C_3-C_6 framework (Feng, Hao, & Li, 2017; Ngameni et al., 2013). Flavones (Han et al., 2007), flavanones (Klaiklay, Sukpondma, Rukachaisirikul, Hutadilok-Towatana, & Chareonrat, 2011), isoflavones (Deachathai et al., 2005), flavonols (Murthy, Dalawai, Dewir, & Ibrahim, 2020), flavanols (Chinsembu, 2016), and anthocyanins (Murthy, Dandin, Dalawai, Park, & Paek, 2019) are the major subclasses of flavonoids that have been isolated from the species of *Garcinia*. Biflavonoids which are essentially dimers of flavanone–flavone, flavone–flavone, and flavone–flavonol amalgamations linked by a C-C or C-O-C bond is another subclass of flavonoids reported to occur in various species of this genus (Murthy et al., 2020). Additional miscellaneous phenolic compounds isolated from *Garcinia* include phenolic acids. They are largely classified into benzoic acid derivatives containing a C_6-C_1 skeleton and cinnamic acid derivatives containing a C_6-C_3 framework.

5.2 Terpenoids

p0285 Terpenoids, also termed isoprenoids are secondary metabolites derived from five-carbon isoprene units organized and modified in diverse ways (Bruneton, 1999). Based on the number of isoprene units "building block", terpenoids are classified as hemiterpenoids (C-5), monoterpenoids (C10), sesquiterpenoids (C-15), diterpenoids (C-20), sesterterpenoids (C-25), triterpenoids (C-30), tetraterpenoids (carotenoids) (C-40) and polyterpenoids (C- > 40) (Awouafack, Tane, Kuete, & Eloff, 2013; Murthy et al., 2020; Sandjo & Kuete, 2013a; 2013b; Tchimene, Okunji, Iwu, & Kuete, 2013). *Garcinia* species are known to contain triterpenoids (Murthy et al., 2020) and sesquiterpene derivatives (Sukpondma, Rukachaisirikul, & Phongpaichit, 2005) as minor constituents. Additionally, monoterpenoids (volatiles) (Murthy et al., 2020) as well as rare terpenoids, garcinielliptones (Weng, Lin, Tsao, & Wang, 2003), with a new skeleton have also been reported.

5.3 Alkaloids

p0290 Generally, alkaloids are naturally occurring, organic, nitrogen-containing compounds, which are typically alkaline due to the presence of a heterocyclic ring containing a nitrogen atom (Wansi, Devkota, Tshikalange, & Kuete, 2013). Previous phytochemical studies have only reported two classes of alkaloids from the genus *Garcinia* namely; benzophenanthridines (Fotie, Bohle, Olivier, Gomez, & Nzimiro, 2007) and aporphine derivatives (Lathifah, Rahim, Sudrajat, & Khairi, 2010).

5.4 Organic acids

p0295 Organic acids are biosynthesized in plants by means of the incomplete oxidation of photosynthetic products and characterize the stored pools of carbon accrued because of different transient times of conversion of compounds in metabolic pathways (Igamberdiev & Eprintsev, 2016). The genus *Garcinia* is a rich source of organic acids, and this is attributable to the sour taste and high acidity of *Garcinia* fruits (Anju & Rameshkumar, 2016). Among the different acids isolated from *Garcinia* fruit rinds, hydroxycitric acid (HCA) (1, 2-dihydroxypropane-1,2,3-tricarboxylic acid) is the major and most significant one, being an anti-obesity agent and a chiral molecule of extensive utility in chiral synthesis (Jena, Jayaprakasha, Singh, & Sakariah, 2002). Other acids such as garcinia acid, malic acid, ascorbic acid, tartaric acid, oxalic acid, and citric acid have also been reported in *Garcinia* fruits (Murthy et al., 2020).

6. Antibacterial activity of *Garcinia species* against drug-sensitive and multidrug-resistant phenotypes

p0300 *Antibacterial activity of* Garcinia kola. The antibacterial effects against clinical pathogens of different parts of *G. kola* (Heckel) have intensively been investigated (Gangoué-Piéboji et al., 2009). For instance, the ethanolic extract of this species displayed antibacterial potency against four respiratory tract bacteria including Gram-positive (*Staphylococcus aureus*, *Streptococcus pyogenes,* and *Streptococcus pneumoniae*) and Gram-negative (*Haemophilus influenzae*) pathogens. The results reported as minimum inhibitory concentrations (MIC) and minimum bactericidal concentrations (MBC) disclose that the MIC of this extract ranged from 8×10^{-5} μg/mL to 1.8 μg/mL, while MBC ranged from 1.35×10^{-1} μg/mL to 4.2 μg/mL against the tested pathogenic microbes (Akoachere et al., 2002). Duro and colleagues also reported the MIC of the ethanolic extract against *S. aureus* (MIC, 0.5 mg/mL) and *Klebsiella pneumonia* (MIC, 0.25 mg/mL) with MBC values of 1.0 and 0.5 mg/mL, respectively (Duro, Hafsat, Odeh, Yahaya, & Salawu, 2015). In another study, Djague and co-workers reported the anti-salmonella potencies of the leaves, roots, and stems of *G. kola* against Gram-negative (*Salmonella typhimurium*, *Salmonella enteritidis,* and *Salmonella typhi*) bacteria with MIC ranging from 125 to 1000 μg/mL (Djague, Lungai, Toghueo, Melogmo, & Fekam, 2020). More recently, Ewelike et al. showed that the methanolic leaf extract of *G. kola* inhibited the growth of some bacteria including *Escherichia coli*, *S. aureus,* and *K. pneumoniae* with MIC of 25 mg/mL (against *E. coli* and *S. aureus*) and 50 mg/mL (towards *K. pneumoniae*) while its aqueous extract had a MIC value of 25 mg/mL (each) against *S. aureus* and *E. coli* (Ewelike, Okammadu, Ogwudire, & Nnadozie, 2021). The antibacterial activity of botanicals from the genus *Garcinia* is summarized in Table 2.

Table 2 Antibacterial activities of *Garcinia* species against drug-sensitive and drug-resistant bacteria.

Bacterial species and strains	**Plant species and MIC values in μg/mL**		
	Garcinia kola	***Garcinia lucida***	**Other *Garcinia* species**
Staphylococcus aureus	316.2 (GKF) (Jude, Chekwube, & Hannah, 2020)	nr	*G. dulcis*: MIC of 128 μg/mL (Mahabusarakam et al., 2016)
ATCC 29213	nr	250 (GLB) and 500 (GLL) (Dzoyem et al., 2013)	nr
ATCC 25923	nr	nr	*G. scortechinii*: MIC of 512 μg/mL (Rukachaisirikul et al., 2005b). *G. dulcis*: MIC of 32 μg/mL (Thepthong et al., 2017)
Sk1	nr	nr	*G. scortechinii*: MIC of 512 μg/mL (Rukachaisirikul et al., 2005b). *G. dulcis*: MIC of 64 μg/mL (Thepthong et al., 2017)
MRSA, ATCC33591	nr	1000 (GLL) (Dzoyem et al., 2013)	*G. dulcis*: MIC of 128 μg/mL (Mahabusarakam et al., 2016) *G. parvifolia*: MIC> 512 μg/mL (Rukachaisirikul, Trisuwan, Sukpondma, & Phongpaichit, 2008)
Streptococcus faecalis NCIB 775	5000 (GKS) (Adegboye, Akinpelu, & Okoh, 2008)	nr	nr
Streptococcus faecalis	nr	nr	*G. griffithii:* MIC of 225 μg/mL (Salleh et al., 2017)

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Table 2 *(continued)*

Bacterial species and strains	Plant species and MIC values in μg/mL		
	Garcinia kola	*Garcinia lucida*	Other *Garcinia* species
Streptococcus epidermidis			
LIO	313 (GKS) (Adegboye et al., 2008)	nr	nr
ATCC 12228	nr	250 (GLB) and 500 (GLL) (Dzoyem et al., 2013)	nr
Micrococcus luteus NCIB 196	157 (GKS) (Adegboye et al., 2008)	nr	nr
Corynebacterium sporogenes NCIB 532	1250 (GKS) (Adegboye et al., 2008)	nr	nr
Corynebacterium pyogenes LIO	313 (GKS) (Adegboye et al., 2008)	nr	nr
Bacillus anthracis LIO	625 (GKS) (Adegboye et al., 2008)	nr	nr
Bacillus cereus NCIB 6349	1250 (GKS) (Adegboye et al., 2008)	nr	nr
Bacillus polymyxa LIO	1250 (GKS) (Adegboye et al., 2008)	nr	nr
Bacillus subtilis	nr	nr	*G. griffithii:* MIC of 450 μg/mL (Salleh et al., 2017)
Bacillus subtilis NCIB 3610	1250 (GKS) (Adegboye et al., 2008)	nr	nr

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Table 2 (*continued*)

Bacterial species and strains	Plant species and MIC values in μg/mL		
	Garcinia kola	*Garcinia lucida*	Other *Garcinia* species
Bacillus stearothermophilus NCIB 8222	79 (GKS) (Adegboye et al., 2008)	nr	nr
Streptococcus pneumoniae			
ATCC 33400	62.5 (GKS) (Bosso, Innalegwu, & Negative, 2018)	nr	nr
Stretococcus pyogenes		nr	nr
JCM 5674	> 1024 (GKS) (Bosso et al., 2018)	nr	nr
Escherichia coli			
ATCC8739	512 (GKS) (Lacmata et al., 2012)	64 (GLB) (Ngaffo et al., 2021); 512 (GLS) (Lacmata et al., 2012)	nr
ATCC10536	512 (GKS) (Lacmata et al., 2012)	512 (GLS) (Lacmata et al., 2012)	nr

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Table 2 *(continued)*

Bacterial species and strains	Plant species and MIC values in μg/mL		
	Garcinia kola	*Garcinia lucida*	Other *Garcinia* species
Escherichia coli	275.4 (GKF) (Jude et al., 2020)	nr	*G. griffithii:* MIC of 450 μg/mL (Salleh et al., 2017); *G. dulcis*: MIC of 128 μg/mL (Mahabusarakam et al., 2016); *G. preussii*: MIC> 128 μg/mL (Messi et al., 2012)
AG100A	1024 (GKS) (Lacmata et al., 2012)	2048 (GLB) (Ngaffo et al., 2021); 256 (GLS) (Lacmata et al., 2012)	nr
AG102	256 (GKS) (Lacmata et al., 2012)	128 (GLB) (Ngaffo et al., 2021); 512 (GLS) (Lacmata et al., 2012)	nr
AG100	256 (GKS) (Lacmata et al., 2012)	256 (GLS) (Lacmata et al., 2012)	nr
$AG100A_{Tet}$	256 (GKS) (Lacmata et al., 2012)	256 (GLB) (Ngaffo et al., 2021); 512 (GKS) (Lacmata et al., 2012)	nr
W3110	512 (GKS) (Lacmata et al., 2012)	256 (GLB) (Ngaffo et al., 2021); 256 (GLS) (Lacmata et al., 2012)	nr
MC4100	512 (GKS) (Lacmata et al., 2012)	256 (GLS) (Lacmata et al., 2012)	nr
ATCC25292	nr	500 (GLB) (Dzoyem et al., 2013)	nr
NCIB 86	157 (GKS) (Adegboye et al., 2008)	nr	nr

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Table 2 (*continued*)

Bacterial species and strains	Plant species and MIC values in μg/mL		
	Garcinia kola	*Garcinia lucida*	Other *Garcinia* species
Enterobacter aerogenes			
ATCC13048	512 (GKS) (Lacmata et al., 2012)	128 (GLB) (Ngaffo et al., 2021); 256 (GLS) (Lacmata et al., 2012)	nr
EA3	512 (GKS) (Lacmata et al., 2012)	256 (GLS) (Lacmata et al., 2012)	nr
EA289	512 (GKS) (Lacmata et al., 2012)	1024 (GLB) (Ngaffo et al., 2021); 512 (GLS) (Lacmata et al., 2012)	nr
EA294	512 (GKS) (Lacmata et al., 2012)	128 (GLB) (Ngaffo et al., 2021); 256 (GLS) (Lacmata et al., 2012)	nr
EA27	256 (GKS) (Lacmata et al., 2012)	256 (GLB) (Ngaffo et al., 2021); 256 (GLS) (Lacmata et al., 2012)	nr
EA298	512 (GKS) (Lacmata et al., 2012)	128 (GLB) (Ngaffo et al., 2021); 256 (GLS) (Lacmata et al., 2012)	nr
CM64	256 (GKS) (Lacmata et al., 2012)	2048 (GLB) (Ngaffo et al., 2021); 256 (GLS) (Lacmata et al., 2012)	nr

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Table 2 (*continued*)

Bacterial species and strains	Plant species and MIC values in μg/mL		
	Garcinia kola	*Garcinia lucida*	Other *Garcinia* species
Enterobacter cloacae			
BM47	256 (GKS) (Lacmata et al., 2012)	256 (GLS) (Lacmata et al., 2012)	nr
BM67	128 (GKS) (Lacmata et al., 2012)	128 (GLS) (Lacmata et al., 2012)	nr
ECC169	256 (GKS) (Lacmata et al., 2012)	256 (GLS) (Lacmata et al., 2012)	nr
Pseudomonas aeruginosa	691.8 (GKF) (Jude et al., 2020)	nr	*G. dulcis*: MIC of 128 μg/mL (Mahabusarakam et al., 2016); *G. preussii*: MIC > 512 μg/mL (Messi et al., 2012)
ATCC 27853	nr	1000 (GLB) (Dzoyem et al., 2013)	nr
ATCC 10145	> 1024 (GKS) (Bosso et al., 2018)	nr	nr
PA01	512 (GKS) (Lacmata et al., 2012)	128 (GLB) (Ngaffo et al., 2021); 512 (GLS) (Lacmata et al., 2012)	nr
PA124	1024 (GKS) (Lacmata et al., 2012)	256 (GLB) (Ngaffo et al., 2021); 256 (GLS) (Lacmata et al., 2012)	nr

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Table 2 (*continued*)

Bacterial species and strains	Plant species and MIC values in µg/mL		
	Garcinia kola	*Garcinia lucida*	Other *Garcinia* species
Klebsiella pneumoniae			
ATCC11296	512 (GKS) (Lacmata et al., 2012)	128 (GLB) (Ngaffo et al., 2021); 256 (GLS) (Lacmata et al., 2012)	nr
KP55	512 (GKS) (Lacmata et al., 2012)	256 (GLB) (Ngaffo et al., 2021); 128 (GLS) (Lacmata et al., 2012)	nr
KP63	512 (GKS) (Lacmata et al., 2012)	256 (GLB) (Ngaffo et al., 2021); 512 (GLS) (Lacmata et al., 2012)	nr
K2	512 (GKS) (Lacmata et al., 2012)	256 (GLS) (Lacmata et al., 2012)	nr
K24	512 (GKS) (Lacmata et al., 2012)	256 (GLS) (Lacmata et al., 2012)	nr
BYK-9	62.5 (GKS) (Bosso et al., 2018)	nr	nr
NCIB 418	79 (GKS) (Adegboye et al., 2008)	nr	nr
Providencia stuartii			
ATCC29916	512 (GKS) (Lacmata et al., 2012)	128 (GLB) (Ngaffo et al., 2021); 256 (GLS) (Lacmata et al., 2012)	nr

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Table 2 *(continued)*

Bacterial species and strains	Plant species and MIC values in μg/mL		
	Garcinia kola	*Garcinia lucida*	Other *Garcinia* species
NEA16	256 (GKS) (Lacmata et al., 2012)	128 (GLB) (Ngaffo et al., 2021); 256 (GLS) (Lacmata et al., 2012)	nr
PS2636	128 (GKS) (Lacmata et al., 2012)	256 (GLB) (Ngaffo et al., 2021); 128 (GLS) (Lacmata et al., 2012)	nr
PS299645	256 (GKS) (Lacmata et al., 2012)	128 (GLS) (Lacmata et al., 2012)	nr
Vancomycin-resistant *Enterococcus faecalis* (VRE)	nr	1000 (GLL) (Dzoyem et al., 2013)	nr
V. vulnificus			
AL042	625 (GKS) (Penduka & Okoh, 2011)	nr	nr
AL048	625 (GKS) (Penduka & Okoh, 2011)	nr	nr
Vibrio fluvialis			
AL004	625 (GKS) (Penduka & Okoh, 2011)	nr	nr
AL019	313 (GKS) (Penduka & Okoh, 2011)	nr	nr

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Table 2 (*continued*)

Bacterial species and strains	Plant species and MIC values in µg/mL		
	Garcinia kola	*Garcinia lucida*	Other *Garcinia* species
AL022	625 (GKS) (Penduka & Okoh, 2011)	nr	nr
AL040	625 (GKS) (Penduka & Okoh, 2011)	nr	nr
AL031	625 (GKS) (Penduka & Okoh, 2011)	nr	nr
***Vibrio* sp.**			
AL020	313 (GKS) (Penduka & Okoh, 2011)	nr	nr
AL021	625 (GKS) (Penduka & Okoh, 2011)	nr	nr
Vibrio parahaemolyticus			
EL009	625 (GKS) (Penduka & Okoh, 2011)	nr	nr
AL030	625 (GKS) (Penduka & Okoh, 2011)	nr	nr
AL032	313 (GKS) (Penduka & Okoh, 2011)	nr	nr
AL043	625 (GKS) (Penduka & Okoh, 2011)	nr	nr
AL045	313 (GKS) (Penduka & Okoh, 2011)	nr	nr

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Table 2 (*continued*)

Bacterial species and strains	Plant species and MIC values in μg/mL		
	Garcinia kola	***Garcinia lucida***	**Other *Garcinia* species**
AL049	313 (GKS) (Penduka & Okoh, 2011)	nr	nr
Vibrio metschnikovii			
AL023	625 (GKS) (Penduka & Okoh, 2011)	nr	nr
Listeria ivanovii			
LAL 2	157 (GKS) (Penduka & Okoh, 2012)	nr	nr
Listeria ivanovii			
LAL 10	625 (GKS) (Penduka & Okoh, 2012)	nr	nr
LAL 11	157 (GKS) (Penduka & Okoh, 2012)	nr	nr
LDB 3	313 (GKS) (Penduka & Okoh, 2011)	nr	nr
LDB 7	313 (GKS) (Penduka & Okoh, 2011)	nr	nr
LDB 9	625 (GKS) (Penduka & Okoh, 2011)	nr	nr

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Table 2 (*continued*)

Bacterial species and strains	Plant species and MIC values in μg/mL		
	Garcinia kola	*Garcinia lucida*	Other *Garcinia* species
LDB 10	313 (GKS) (Penduka & Okoh, 2011)	nr	nr
LDB 11	313 (GKS) (Penduka & Okoh, 2011)	nr	nr
LDB 12	625 (GKS) (Penduka & Okoh, 2011)	nr	nr
Listeria ivanovii			
LEL 1	625 (GKS) (Penduka & Okoh, 2012)	nr	nr
LEL 9	313 (GKS) (Penduka & Okoh, 2012)	nr	nr
LEL 10	625 (GKS) (Penduka & Okoh, 2012)	nr	nr
LEL 16	313 (GKS) (Penduka & Okoh, 2012)	nr	nr
LEL 17	313 (GKS) (Penduka & Okoh, 2012)	nr	nr
LEL 18	313 (GKS) (Penduka & Okoh, 2012)	nr	nr
LEL 30	625 (GKS) (Penduka & Okoh, 2012)	nr	nr

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Table 2 (*continued*)

Bacterial species and strains	Plant species and MIC values in µg/mL		
	Garcinia kola	*Garcinia lucida*	Other *Garcinia* species
Listeria monocytogenes	–	nr	nr
LAL 8	157 (GKS) (Penduka & Okoh, 2012)	nr	nr
Listeria grayi	–	nr	nr
LAL 12	313 (GKS) (Penduka & Okoh, 2012)	nr	nr
LAL 15	157 (GKS) (Penduka & Okoh, 2012)	nr	nr

Garcinia kola fruits (GKF); *Garcinia kola* seeds (GKS); *Garcinia lucida* barks (GLB); *Garcinia lucida* seeds (GLS); *Garcinia lucida* leaves (GLL); (nr): not reported.

p0305 Phytochemical investigation of *G. kola* (seeds) for antibacterial application led to the isolation of three heterocyclic secondary metabolites termed cycloartenol (**1**), 24-methylenecycloartanol (**2**), and garcinianin (**3**) (Ajayi, Moody, Fukushi, Adeyemi, & Fakeye, 2014). Equimolar mixture (**1**+**2**) displayed antibacterial effect against *Streptococcus mutans* and *Streptococcus viridans* with MIC values of 170 and 380 μg/mL, respectively. A biflavonoid (garcinianin (**3**) had activity (MIC, 100 μg/mL) towards *S. mutans,* but displayed statistically no significant effect against *S. viridans*, and *S. aureus*. Further, (8*E*)− 4-geranyl-3,5-dihydroxybenzophenone (**4**) and δ-garcinoic acid (**5**) isolated from the commercial seeds of *G. kola* displayed antibacterial potency against *Porphyromonas gingivalis* (MIC, 31.3–62.5 μM) and *Streptococcus sobrinus* (MIC, 15.6–31.3 μM) (Hioki et al., 2020). The antibacterial activity of phytochemicals from the genus *Garcinia* is summarized in Table 3, meanwhile, their corresponding chemical structures are shown in Fig. 1.

p0310 *Antibacterial activity Garcinia lucida*. A Cameroonian edible plant *G. lucida* (bark) was screened for its antibacterial potency against MDR Gram-negative bacteria phenotypes expressing efflux pumps (*Escherichia coli*, *E. aerogenes*, *K. pneumoniae*, *P. aeruginosa,* and *P. stuartii* strains). The MIC values of this extract against tested microorganisms ranged from 64 to 2048 μg/mL. Strong activity (MIC < 100 μg/mL) was observed against *E. coli* ATCC8739, moderate activity (100 ≤ MIC ≤ 512 μg/mL) against 80% of pathogenic microbes, and low activity (MIC ≥ 512 μg/mL) towards 15% of bacteria. In addition, ~60% of tested bacteria had an MBC/MIC ≤ 4 (Table 2) indicating their bactericidal effects (Ngaffo et al., 2021).

p0315 *Antibacterial activity of Garcinia nobilis*. Crude extract from *Penicillium* sp. endophyte purified from the leaves of *G. nobilis* displayed anti-mycobacterial effect (MIC, 62.5 μg/mL). Penialidins A-C (**6–8**), citromycetin (**9**), *para*-hydroxyphenylglyoxalaldxime (**10**), and brefeldin A (**11**) were reported as the main active ingredients with MICs values of 62.5, 62.5, 15.6, 31.2, 62.5 and 250 μg/mL, respectively compared to the standard drug rifampicin (MIC, 0.62 μg/mL) against *M. smegmatis* (Jouda et al., 2016a). In parallel to this, these compounds were found to be equal to or more potent than ampicillin and chloramphenicol against five bacteria strains (*Vibrio cholerae* SG24, CO6, NB2, PC2, and *Shigella flexneri* SDINT) with MICs of 0.5–128 μg/mL (Jouda et al., 2016b). Moreover, penialidins B (**7**) and C (**8**) showed a broad spectrum of activity against clinically important Gram-positive and Gram-negative risk group 2 bacterium with MIC values of 5–10 μg/mL. It is noteworthy that penialidin C showed

Table 3 Antibacterial activities of phytochemicals from *Garcinia* species against drug-sensitive and drug-resistant bacteria.

Bacterial species and strains	Plant species and MIC values in μg/mL or μM
Bacillus cereus	*G. cowa*: 8–64 μg/mL (garciniacowones A−D (**91−94**)); 64 μg/mL (cowaxanthone (**77**)); 2–4 μg/mL (garcinianones A (**95**) and B (**96**)); 4 μg/mL (mangostanin (**97**)); 64 μg/mL (fuscaxanthone A (**31**)); 32 μg/mL (7-*O*-methylgarcinone E (**98**)); 8 μg/mL (α-mangostin (**16**)); 17 μg/mL (β-mangostin (**17**)); and 4 μg/mL (rubraxanthone (**35**)) (Sriyatep et al., 2015; Trisuwan & Ritthiwigrom, 2012)
Bacillus subtilis	*G. cowa*: 8–64 μg/mL (garciniacowones A−C (**91−93**)); 64 μg/mL (cowaxanthone (**77**)); 2 μg/mL (garcinianones A (**95**) and B (**96**)); 8 μg/mL (mangostanin (**97**)); 64 μg/mL (fuscaxanthone A (**31**)); 32 μg/mL (7-*O*-methylgarcinone E (**98**)); 8 μg/mL (α-mangostin (**16**)); 4 μg/mL (β-mangostin (**17**)); and 2 μg/mL (rubraxanthone (**35**)) (Sriyatep et al., 2015) *G. cowa*: 31.2 μg/mL (chamuangone (**99**)) (Sakunpak, Matsunami, Otsuka, & Panichayupakaranant, 2017)
Staphylococcus aureus	*G. cowa*: 64 μg/mL (garciniacowone B (**92**)); 64 μg/mL (garcinianones A (**95**) and B (**96**)); 64 μg/mL (mangostanin (**97**)); 64 μg/mL (α-mangostin (**16**)) (Sriyatep et al., 2015) *G. scortechnii*: 4–32 μg/mL (scortechinones B (**88**), C (**100**), H (**101**), I (**89**), J (**102**), M (**103**), N (**104**), P (**105**), F (**106**)) (Rukachaisirikul et al., 2000; 2005c) *G. cowa*: 31.2 μg/mL (chamuangone (**99**)) (Sakunpak et al., 2017) *G. cowa*: 2 μg/mL (garciniacowone (**107**)); 16 μg/mL (cowaxanthone (**77**)); 8 μg/mL (norcowanin (**108**)); 32 μg/mL (cowanin (**33**)); 8 μg/mL (cowanol (**109**)) (Siridechakorn et al., 2012) *G. dulcis*: 16 μg/mL (dulcisxanthone J (**110**)); 32 μg/mL (garciniaxanthone C (**111**)); 4 μg/mL (12b-hydroxy-des-D-garcigerrin A (**112**)); 32 μg/mL (subelliptenone B (**113**)); 32 μg/mL (globuxanthone (**114**)); 32 μg/mL (symphoxanthone (**115**)); 32 μg/mL (griffipavixanthone (**116**)) (Thepthong et al., 2017) *G. xanthochymus*: 64 μg/mL (xanthochymone C (**117**)) (Trisuwan et al., 2014) *G. cowa*: 2 μg/mL (cowanone (**118**)); 4 μg/mL (9-hydroxycalabaxanthone (**30**)) (Trisuwan & Ritthiwigrom, 2012)

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Table 3 (*continued*)

Bacterial species and strains	Plant species and MIC values in μg/mL or μM
MRSA	*G. scortechinii*: 128, 2 and 64 μg/mL (scortechinones A–C (**121**, **88**, **100**), respectively) (Rukachaisirikul, Kaewnok, Koysomboon, Phongpaichit, & Taylor, 2000)
	G. parvifolia: 19.5 μM (rubraxanthone (**35**)) (Rukachaisirikul et al., 2006)
	G. parvifolia: 32 μg/mL (parvifoliol B (**122**)); 64 μg/mL (nigrolineaisoflavone A (**123**)) (Rukachaisirikul et al., 2008)
	G. cowa: 64 μg/mL (garciniacowones A−B and D (**91−92, 94**)); 64 μg/mL (garcinianones A (**95**) and B (**96**)); 64 μg/mL (α-mangostin (**16**)); 64 μg/mL (rubraxanthone (**35**)) and 64 μg/mL (6-O-methylmangostanin (**120**)) (Sriyatep et al., 2015)
	G. cowa: 2 μg/mL (garciniacowone (**107**)); 16 μg/mL (cowaxanthone (**77**)); 16 μg/mL (norcowanin (**108**)); 4 μg/mL (cowanin (**33**)); 2 μg/mL (cowanol (**109**)); 8 μg/mL (cowagarcinone E (**34**)) (Siridechakorn et al., 2012; Trisuwan & Ritthiwigrom, 2012)
	G. dulcis: 16 μg/mL (dulcisxanthone J (**110**)); 32 μg/mL (garciniaxanthone C (**111**)); 4 μg/mL (12b-hydroxy-des-D-garcigerrin A (**112**)); 32 μg/mL (globuxanthone (**114**)); 64 μg/mL (griffipavixanthone (**116**)) (Thepthong et al., 2017)
	G. xanthochymus: 64 μg/mL (xanthochymone C (**117**)) (Trisuwan et al., 2014)
	G. cowa: 0.5 μg/mL (cowanone (**118**)); 4 μg/mL (9-hydroxycalabaxanthone (**30**)) (Trisuwan & Ritthiwigrom, 2012)
MRSA 1 and 2	*G. mangostana*: 3.9 μg/mL (garmoxanthone (**124**)); 31.2–62.4 μg/mL (mangostanol (**125**)); (3-isomangostin hydrate (**126**)); 62.4 μg/mL (br-xanthone A (**127**)); (gartanin (**128**)); 15.6 μg/mL (isogarcinol (**46**)); 3.9 μg/mL (garcinone E (**60**)); 3.9 μg/mL (dulxanthone A (**129**)); 62.4 (nigrolineaxanthone T (**130**)) (Wang, Liao, Huang, Tang, & Cai, 2018)
Streptococcus pyogenes	*G. cowa*: 7.8 μg/mL (chamuangone (**99**)) (Sakunpak et al., 2017)
Streptococcus viridans	*G. cowa*: 15.6 μg/mL (chamuangone (**99**)) (Sakunpak et al., 2017)

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Table 3 (*continued*)

Bacterial species and strains	Plant species and MIC values in μg/mL or μM
Enterococcus sp.	*G. cowa*: 31.2 μg/mL (chamuangone (**99**)) (Sakunpak et al., 2017)
Escherichia coli	*G. cowa*: 64 μg/mL (garciniacowone B (**92**)); 64 μg/mL (garcinianones A (**95**) and B (**96**)); 64 μg/mL (fuscaxanthone A (**31**)); 64 μg/mL (α-mangostin (**16**)); 64 μg/mL (rubraxanthone (**35**)) and 64 μg/mL (fuscaxanthone C (**119**)) (Sriyatep et al., 2015)
Salmonella typhimurium	*G. cowa*: 64 μg/mL (garciniacowones A−B and D (**91−92,94**)); 64 μg/mL (garcinianones A (**95**) and B (**96**)); 64 μg/mL (α-mangostin (**16**)) and 64 μg/mL (rubraxanthone (**35**)) and 64 μg/mL (6-*O*-methylmangostanin (**120**)) (Sriyatep et al., 2015)
Pseudomonas aeruginosa	*G. cowa*: 64 μg/mL (rubraxanthone (**35**)) (Sriyatep et al., 2015)

equipotent activity (MIC, 5 μg/mL) against clinically relevant *S. aureus* and *B. Subtilis* compared to streptomycin (Jouda et al., 2014). The antibacterial activity of isolates is reported in Table 3 and their corresponding structures in Fig. 1. The crude extract and four polyketides bearing a xanthone scaffold (3-dimethyl-2-geranyl-4-prenylbellidifolin (**12**), smeathxanthone A (**13**), 8-hydroxycudraxanthone G (**14**), and morusignin I (**15**)) isolated from the stem bark of *G. nobilis* exhibited antibacterial (*E. coli*, *E. aerogenes*, *K. pneumoniae*, *P. stuartii* and *P. aeruginosa*) and anti-mycobacterial (*M. tuberculosis* H37Rv, MTCS1 and 2) activities (Fouotsa et al., 2013). The extract acted upon 13/15 (86.6%) tested bacteria with MIC, 64–512 μg/mL. The best activity was recorded against *E. coli* ATCC10536 (MIC, 64 μg/mL). Among the isolates (**12** > **15** > **13**=**14**) and in order of decreasing activities, 3-dimethyl-2-geranyl-4-prenylbellidifolin (**12**) performed the best against all pathogenic microorganisms. Interestingly, this compound was more potent than chloramphenicol (MIC ≥ 512 μg/mL) against *E. coli* AG102 (MIC, 64 μg/mL).

p0320 *Antibacterial activity of other Garcinia species*. The isolation of α-mangostin (**16**), a biprenylated xanthone from the hexane fraction obtained from the peels of *G. mangostana* showed antibiofilm properties against *S. aureus* strains (reference strain NCTC 6571 and two hospital isolates MRSA 252 and MSSA 15981) with MIC in the range of 4.6–9.2 μmol/L. The MBC value of α-mangostin was 2-fold higher than MIC indicating its lethal effect (Phuong et al., 2017). *G. mangostana* was also found to be active against *S. aureus* (MIC, 39 μg/mL), *S. epidermidis* (MIC, 39 μg/mL), and myriads MRSA strains (MICs, 39–1.250 μg/mL). The activity of this extract was attributed to the presence of α-mangostin (MIC, 1.95 μg/mL) (Chomnawang, Surassmo, Wongsariya, & Bunyapraphatsara, 2009). Moreover, α-mangostin (**16**) exhibited antibacterial effect against *B. subtilis* (MIC, 3.9 μM), *S. aureus* (MIC, 7.8 μM), and several *Mycobacterium* species (MIC, 3.7 μM, each) including *M. smegmatis*, *M. cheleneoi M. xenopi* and *M. intracellulare* (Al-Massarani et al., 2013). Furthermore, α-mangostin (**16**) and its β-analogue (**17**) inhibited the growth of MRSA-SK1 with a MIC value of 16 μg/mL (each) (Siridechakorn, Phakhodee, Ritthiwigrom, & Promgool, 2012), *S. aureus* (MIC, 4 and 64 μg/mL, respectively) and MRSA (MIC, 2 and 8 μg/mL, respectively) (Trisuwan & Ritthiwigrom, 2012). γ-Mangostin (**18**) also showed antibacterial activity against methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococcus* (VRE), and vancomycin-sensitive *Enterococcus* (VSE) strains as well as *E. coli* NCTC 10418 with MICs values of 3.13–12.5 μg/mL (Dharmaratne et al., 2013). Other tricyclic xanthones with antibacterial activity include doitunggarcinone D (**19**), macluraxanthone (**20**),

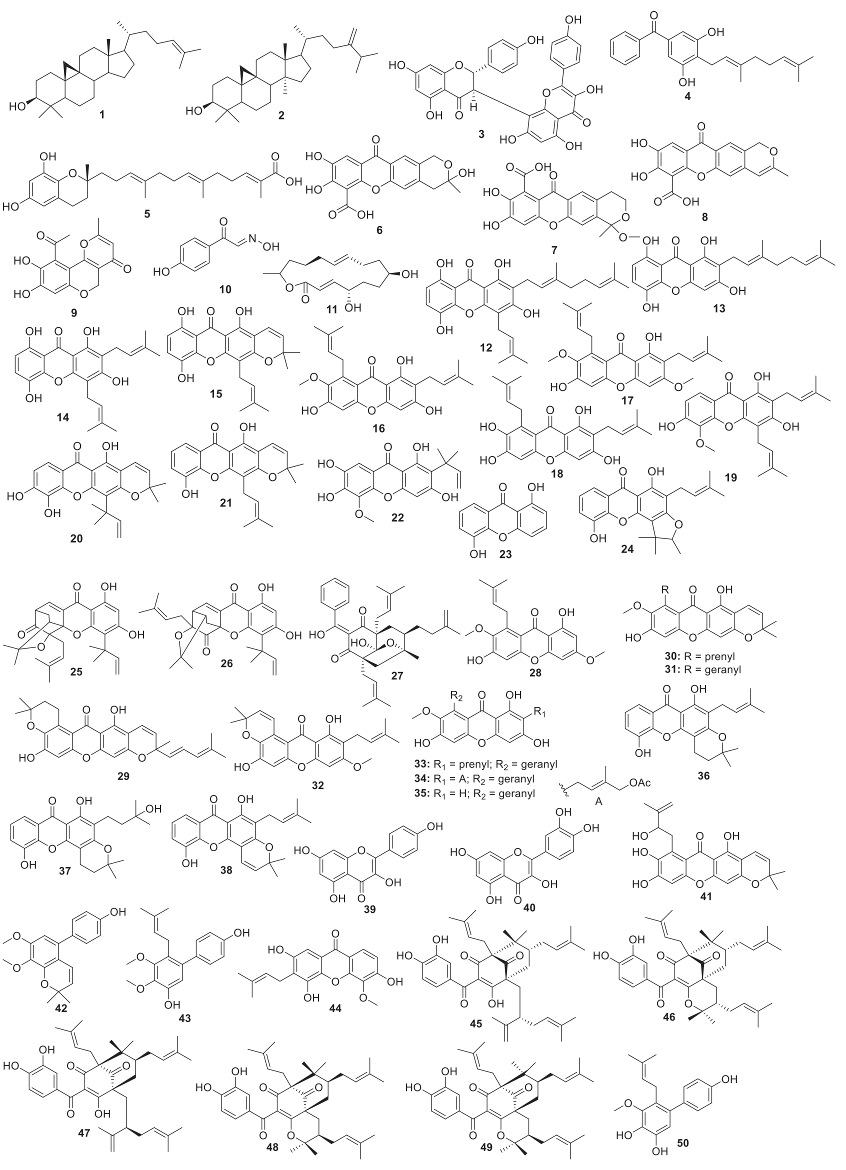

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Fig. 1 Chemical structures of antibacterial compounds from *Garcinia* species: cycloartenol (**1**), 24-methylenecycloartanol (**2**), garcinianin (**3**), (8*E*)– 4-geranyl-3,5-dihydroxybenzophenone (**4**), δ-garcinoic acid (**5**), penialidins A-C (**6–8**), citromycetin (**9**), *para*-hydroxyphenylglyoxalaldxime (**10**), brefeldin A (**11**), 3-dimethyl-2-geranyl-4-prenylbellidifolin (**12**), smeathxanthone A (**13**), 8-hydroxycudraxanthone G (**14**), morusignin I (**15**), α-mangostin (**16**), β-mangostin (**17**), γ-mangostin (**18**), doi-tunggarcinone D (**19**), macluraxanthone (**20**), trapezifolixanthone (**21**), cudraxanthone L (**22**), 1,5-dihydroxy xanthone (**23**), caloxanthone L (**24**), bractatin (**25**), neobractatin (**26**), xerophenone A (**27**), garcicowanones A (**28**) and B (**29**), 9-hydroxycalabaxanthone (**30**), fuscaxanthone A (**31**), cowaxanthone D (**32**), cowanin (**33**), xanthochymone E (**34**), rubraxanthone (**35**), nigrolineaxanthones Q (**36**) and Y (**37**), ananixanthone (**38**), 3′-deoxyquercetin (**39**), quercetin (**40**), (±) garciesculenxanthone C (**41**), garciesculenbiphenyl A (**42**) doitungbiphenyl B (**43**), morusignin D (**44**), garcinol (**45**), isogarcinol (**46**), xanthochymol (**47**), isoxanthochymol (**48**), cycloxanthochymol (**49**), [1,1-biphenyl]-2-(3-methyl-2-butenyl)-3-methoxy-4,4,5,6-tetraol (**50**), 5-hydroxyflavone (**51**), 1,5-dihydroxyxanthone (**52**), 1,4,8-trihydroxy-2-isoprenylxanthone (**53**), 1,3,5- trihydroxyxanthone (**54**), 1,3,6,7-tretrahydroxyxanthone (**55**), rhamnazin (**56**), 2,4-dihydroxy-6-propylbenzoate benzyl (**57**), norathyriol (**58**), allanxanthone C (**59**), garcinone E (**60**), bannanxanthone E (**61**), amentoflavone (**62**), 4′-methoxyamentoflavone (**63**), cheffouxanthone (**64**), bangangxanthone A (**65**), smeathxanthone B (**66**), friedelin (**67**), triacontanyl caffeate (**68**), guttiferone I (**69**), 7-epiclusianone (**70**), guttiferone-A (**71**), goudotianones 1 (**72**) and 2 (**73**), 1,3,7-trihydroxy-2-isoprenylxanthone (**74**), 1,5,6-trihydroxyxanthone (**75**), 1,6,7-trihydroxyxanthone (**76**), cowaxanthone (**77**), isojacareubin (**78**), fukugiside (**79**), nigrolineaxanthone F (**80**), latisxanthone D (**81**), brasilixanthone (**82**), nigrolineaxanthone N (**83**), 8-desoxygartanin (**84**), doitunggarcinone B (**85**), dulxanthone B (**86**), 10-*O*-methylmacluraxanthone (**87**), scortechinones B (**88**) and I (**89**) and W (**90**), garciniacowones A–D (**91**–**94**)), garcinianones A (**95**) and B (**96**), mangostanin (**97**), 7-*O*-methylgarcinone E (**98**), chamuangone (**99**), scortechinones C (**100**) and H (**101**) and J (**102**) and M (**103**) and N (**104**) and P (**105**), and F (**106**), garciniacowone (**107**), norcowanin (**108**)), cowanol (**109**), dulcisxanthone J (**110**), garciniaxanthone C (**111**), 12b-hydroxy-des-D-garcigerrin A (**112**), subelliptenone B (**113**), globuxanthone (**114**), symphoxanthone (**115**), griffipavixanthone (**116**), xanthochymone C (**117**), cowanone (**118**), fuscaxanthone C (**119**), 6-*O*-methylmangostanin (**120**), scortechinone A (**121**), parvifoliol B (**122**), nigrolineaisoflavone A (**123**), garmoxanthone (**124**), mangostanol (**125**), 3-isomangostin hydrate (**126**), br-xanthone A (**127**), gartanin (**128**), dulxanthone A (**129**), nigrolineaxanthone T (**130**).

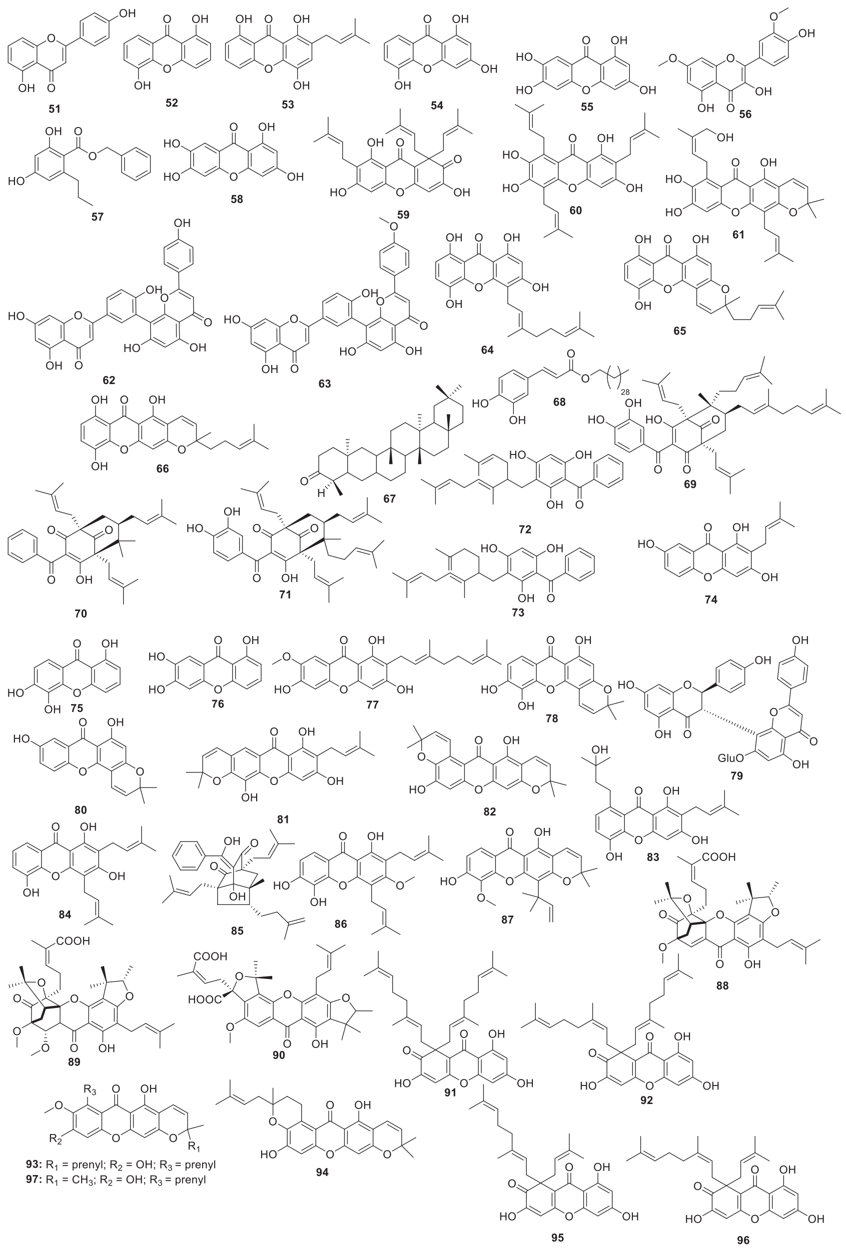

Fig. 1 *(continued on next page)*

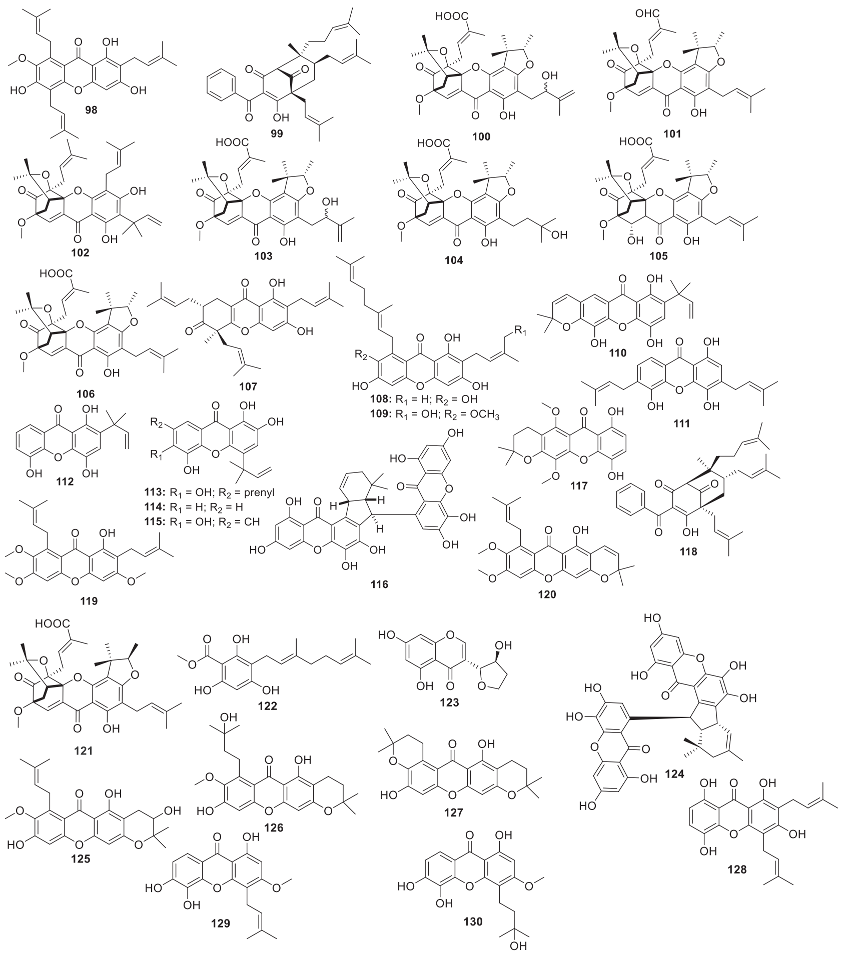

Fig. 1

trapezifolixanthone (**21**), cudraxanthone L (**22**), 1,5-dihydroxy xanthone (**23**), caloxanthone L (**24**), bractatin (**25**), neobractatin (**26**) and xerophenone A (**27**) isolated from the roots extract of *G. propinqua*. These compounds displayed antibacterial effects *vis-à-vis B. cereus* TISTR 688 and *B. subtilis* TISTR 088 with MIC, 1–64 μg/mL. Excellent activity (MIC < 10 μg/mL) against *B. cereus* TISTR 688 and *B. subtilis* was recorded for compounds **20**, **22**, and **25**. In addition, all compounds displayed weak activity (MIC, 128 μg/mL) against *E. coli* TISTR 780 and *S. typhimurium* TISTR 292 (Meesakul et al., 2016).

p0325 Prenylated xanthones (α-mangostin (**16**), β-mangostin (**17**), garcicowanones A/B (**28** and **29**), 9-hydroxycalabaxanthone (**30**), fuscaxanthone A (**31**), cowaxanthone D (**32**), cowanin (**33**), cowagarcinone E (**34**) and rubraxanthone (**35**)) isolated from the immature fruits of *G. cowa* showed a broad spectrum of antibacterial activities (MIC, 0.25–128 μg/mL) against *B. cereus* TISTR 688, *B. subtilis* TISTR 008, *M. luteus* TISTR 884, *S. aureus* TISTR 1466 (Gram-positive bacteria), and *E. coli* TISTR 780, *P. aeruginosa* TISTR 781, *S. typhimurium* TISTR 292, *S. epidermidis* ATCC 12228 (Gram-negative bacteria) (Auranwiwat, Trisuwan, Saiai, Pyne, & Ritthiwigrom, 2014). In general, excellent activity for xanthones **16**, **17**, **28**, and **34–35** was noted against *B. cereus* TISTR 688 and *B. subtilis* TISTR 008 (MIC, 0.25–4 μg/mL) and *M. luteus* TISTR 884 (MIC, 1–16 μg/mL). The observed MIC values against these bacteria were similar in some cases to vancomycin (MICs, 0.25 μg/mL). Moreover, *S. epidermidis* ATCC 12228 was sensitive to all xanthones with MIC values of 0.5–4 μg/mL compared to gentamicin (standard drug) (MIC, 0.25 μg/mL) on *S. epidermidis*. Nigrolineaxanthones Q (**36**) and Y (**37**), ananixanthone (**38**), 3′-deoxyquercetin (**39**), and quercetin (**40**) purified from the leaves extract of *G. nigrolineata* showed different levels of antibacterial activity. Gram-positive (*B. cereus*, *M. luteus*, *S. aureus*, *Staph. epidermidis* and *S. mutans*) were more sensitive to all isolates than Gram-negative (*E. coli*, *P. aeruginosa*, *S. typhimurium* and *S. flexneri*) bacteria with MIC, 8–128 μg/mL. Nigrolineaxanthone Q (**36**) had the best activity against *M. luteus* with a MIC value of 8 μg/mL (Raksat, Maneerat, Andersen, Pyne, & Laphookhieo, 2019). (±) Garciesculenxanthone C (**41**), garciesculenbiphenyl A (**42**) doitungbiphenyl B (**43**), and morusignin D (**44**) were reported as main active secondary metabolites (MIC, values ranging from 6.25 to 50 μg/mL) from *G. esculenta* against *S. aureus* Newman, USA300 LAC, USA400 MW2, and Mu50 strains. Of these metabolites, (±) garciesculenxanthone C (**41**, MIC, 12.5 μg/mL) showed the best antistaphylococcal potency against tested strains (Zheng et al., 2021).

p0330 Chromatographic separation of two *Garcinia* species afforded five benzophenone derivatives termed garcinol (**45**), isogarcinol (**46**), xanthochymol (**47**), and a mixture of isoxanthochymol (**48**) and cycloxanthochymol (**49**) (Iinuma et al., 1996). The MIC values of all isolates ranged from 3.13 to 25 μg/mL (against MRSA and methicillin-sensitive *S. aureus* (MSSA)). Xanthochymol (**47**, MIC, 3.13–6.25 μg/mL) was the most active against MRSA strains, exhibiting activity comparable to vancomycin (MIC, 6.25 μg/mL). Furthermore, all compounds showed inhibitory effect against *E. coli* NIHJK12 (MIC, 25 μg/mL) superimposable to those of vancomycin (MIC, > 25 μg/mL) and gentamycin (MIC, 25 μg/mL). This finding was further supported by Rukachaisirikul and co-workers who reported the anti-MRSA of garcinol (**45**), isogarcinol (**46**), and biphenyl derivative (**50**) purified from *G. bancana* with MIC values of 16, 32, and 64 μg/mL, respectively (Rukachaisirikul, Saelim, Karnsomchoke, & Phongpaichit, 2005a). The ethyl acetate (*G. fusca* and *G. gaudichaudii*), and methanol (*G. hopii* and *G. planchonii*) extracts of several *Garcinia* species showed inhibitory effects against four microorganisms. In terms of antibacterial activity, extract of *G. planchonii* displayed excellent (the classification bases are available in chapters 6–9 of Volume 106) MIC value of 75 μg/mL (against *E. coli* and *P. aeruginosa*), while *G. gaudichaudii* hampered the proliferation of *S. aureus* (MIC, 15.6 μg/mL) and *B. subtilis* (MIC, 25 μg/mL) (Nguyen et al., 2021).

p0335 The CH_2Cl_2/MeOH (1:1) extract from the stem bark of *G. polyantha* showed antimycobacterial activity against *Mycobacterium smegmatis* (MCC155) and a drug-susceptible strain of *M. tuberculosis* H37Rv (ATCC 27264) with MIC value of 78.12 μg/mL (each). Further screening of this extract for antibacterial application against 13 bacteria (both Gram-negative and positive) showed strong activity, MIC ≤ 78.12 μg/mL (Kuete et al., 2007b). 5-Hydroxyflavone (**51**), 1,5-dihydroxyxanthone (**52**), 1,4,8-trihydroxy-2-isoprenylxanthone (**53**), 1,3,5-trihydroxyxanthone (**54**), and 1,3,6,7-tretrahydroxyxanthone (**55**) isolated from this extract, were tested for their antimicrobial activity. Compound **55** showed the best activity on the two tested mycobacterial species with a recorded MIC of 4.88 μg/mL. The antibacterial efficacy of the tested compounds (**51** and **55**) ranged from 9.76 to 39.06 μg/mL. Equal MIC, 9.76 μg/mL was observed for compound **55** and gentamicin (reference antibiotic) against *P. aeruginosa*. The flowers of *G. dulcis* afforded rhamnazin (**56**) and xanthochymol (**47**). Rhamnazin displayed selective antibacterial activity on penicillin-sensitive strain, ATCC 25923 (MIC, 8 μg/mL), MRSA SK1 (MIC, 8 μg/mL), and *S. aureus* (MIC, 8 μg/mL), while xanthochymol (**47**) had weak (MIC > 128 μg/mL) antibacterial activities against the same bacteria (Deachathai et al., 2006). Moreover, these bacteria were less resistant to 2,4-dihydroxy-6-propylbenzoate benzyl (**57**) with a MIC value for each of 64 μg/mL (Deachathai, Phongpaichit, & Mahabusarakam, 2008).

p0340 Norathyriol (**58**), allanxanthone C (**59**), garcinone E (**60**) and bannanxanthone E (**61**) reported from the EtOAc extract of *G. mackeaniana* leaves showed potent antibacterial activities. The extract was active towards

B. subtilis (IC_{50}, 51.52 μg/mL), *L. fermentum* (IC_{50} > 256 μg/mL) and *S. aureus* (IC_{50}, 36.26 μg/mL). Selectivity was observed for norathyriol (**58**, IC_{50}, 88.0 μg/mL) against *S. aureus*. Allanxanthone C (**59**) and garcinone E (**60**) exhibited very good IC_{50} values of 5.41, and 4.29 μg/mL, respectively against *S. aureus*, combined with a good IC_{50} ranging from 10.80 to 11.50 μg/mL against *B. subtilis* and L. *fermentum* (Ha et al., 2020).

p0345 The antibacterial guided fractionation of the leaves extract of *G. livingstonei* afforded amentoflavone (**62**) and 4′-methoxyamentoflavone (**63**), with exceptional antibacterial activity against *E. coli*, *P. aeruginosa S. aureus*, *E. faecalis* **62** (MIC, 40, > 100, 40, and 60 μg/mL, respectively) and **63** (MIC, 8, 60, 40, and 8 μg/mL, respectively), with the extract exhibiting substantially low activity (MIC ≥ 500 μg/mL) against the various nosocomial pathogens tested (Kaikabo, Samuel, & Eloff, 2009). In addition to their antibacterial capacity, these compounds (**62** and **63**) had anti-mycobacterial properties against *M. smegmatis* ATCC 1441 with MIC values of 0.6 and 1.4 mg/mL, respectively in comparison to isoniazid (MIC, 1.3 mg/mL) (Kaikabo & Eloff, 2011). Likewise, amentoflavone (**62**) had a different level of activity against Gram-positive (*E. faecium* ATCC 19434 (MIC, 8 μg/mL), *S. aureus* ATCC 25923 (MIC, 4 μg/mL), *S. mutans* ATCC 3065 (MIC, 32 μg/mL)) and Gram-negative (*E. coli* O-157 ATCC 25922 (MIC, 8 μg/mL), *E. coli* ATCC 43895 (MIC, 16 μg/mL), *P. aeruginosa* ATCC 27853 (MIC, 8 μg/mL)) bacteria (Hwang, Choi, Woo, & Lee, 2013). Average activity against MRSA was also reported for C-4 geranylated xanthones, cheffouxanthone (**64**, MIC, 64 μg/mL), and bangangxanthone A (**65**, MIC, 32 μg/mL). In addition to this, *S. aureus* was sensitive to bangangxanthone A (**65**, MIC, 16 μg/mL) and the methanolic extract (*G. hombroniana*) was less active against MRSA (MIC, 200 μg/mL), and *S. aureus* (MIC, 128 μg/mL) (Klaiklay, Sukpondma, Rukachaisirikul, & Phongpaichit, 2013).

p0350 Extract and ten pure isolates (smeathxanthone A (**13**), isoxanthochymol (**48**), 1,5-dihydroxyxanthone (**52**), 1,3,5-trihydroxyxanthone (**54**), cheffouxanthone (**64**), bangangxathone A (**65**) smeathxanthone B (**66**), friedelin (**67**), triacontanyl caffeate (**68**), guttiferone I (**69**)) from the stem bark of *G. smeathmannii* were active against 19 pathogenic bacteria (both Gram-negative and -positive). The methanolic extract inhibited the growth of bacteria with MIC, values in the interval of 78.12–156.25 μg/mL. Purified metabolites showed a broad spectrum of activities with MIC values ranging from 0.61 to 19.53 μg/mL. Cheffouxanthone (**64**) and fridelin (**67**) performed the best against 10/19 and 9/19 bacteria tested, respectively. Their

MIC values were recorded from 9.76 μg/mL (24.65 μM) to 19.53 μg/mL (49.3 μM) for cheffouxanthone (**64**) and from 1.22 μg/mL (2.03 μM) to 4.88 μg/mL (8.12 μM) for fridelin (**67**) (Kuete et al., 2007a). Other benzophenones like 7-epiclusianone (**70**, MIC, 1.2 and 0.6 μg/mL) and guttiferone-A (**71**, MIC, 2.4 and 2.4 μg/mL) exhibited outstanding to excellent antibacterial activities against *S. aureus* and *B. cereus*, respectively (Naldoni et al., 2009).

p0355 Apart from this, Mahamodo et al. reported the antimicrobial activity of three polyketides, goudotianones 1 (**72**) and 2 (**73**) and 1,3,7-trihydroxy-2-isoprenylxanthone (**74**) isolated from *G. goudotiana* leaves (Mahamodo et al., 2014). Phloroglucinols derivatives (**72** and **73**) had MIC values of 39 μg/mL (each) against *E. faecalis* C159–6 and *S. lugdunensis* T26A3, respectively. The acetonic extract and xanthone (**74**) arrested the growth of two strains in addition to *M. smegmatis* 5003 with MIC≤ 78 μg/mL.

p0360 Simple xanthone: 1,5,6-trihydroxyxanthone (**75**) reported from *G. succifolia* showed a MIC value of 64 μg/mL against *S. aureus* ATCC25923 and *B. subtilis* ATCC 6633, while 1,6,7-trihydroxyxanthone (**76**) presented MIC values of 64 and 128 μg/mL, respectively. Interestingly, both compounds were equipotent against *S. aureus* MRSA (MIC, 64 μg/mL). However, none of the xanthones tested was active against vancomycin-resistant *E. faecalis* (Duangsrisai et al., 2014). Two xanthones (cowaxanthone (**77**) and isojacareubin (**78**)) and biflavonoid (fukugiside (**79**)) isolated from Thailand medicinal plant, *G. fusca* displayed inhibitory effects against *H. pylori* ATCC 43504, *H. pylori* DMST20165 and *H. pylori* HP40 (Nontakham, Charoenram, Upamai, Taweechotipatr, & Suksamrarn, 2014). *H. pylori* DMST20165 reference strain was more sensitive to compounds **77** (MIC, 4.6 μM) and **79** (MIC, 10.8 μM) than the positive control, metronidazole (MIC, 11.1 μM). Isojacareubin (**78**: MIC, 23.9 μM) displayed the most potent activity against *H. pylori* strains.

p0365 Nigrolineaxanthone F (**80**), latisxanthone D (**81**), and brasilixanthone (**82**), isolated from *G. nigrolineata* showed anti-MRSA activity, with an equal MIC value of 2 μg/mL (Rukachaisirikul, Tadpetch, Watthanaphanit, Saengsanae, & Phongpaichit, 2005b). Rukachaisirikul and co-authors further reported the anti-MRSA activity of nigrolineaxanthone N (**83**), 8-desoxygartanin (**84**), and ananixanthone (**38**) with minimum inhibitory concentration (MIC) values of 4, 16, and 32 μg/mL, respectively in comparison to the standard drug, vancomycin (MIC, 2 μg/mL) (Rukachaisirikul et al., 2003).

p0370 Doitunggarcinone B (**85**), dulxanthone B (**86**), 10-*O*-methylmacluraxanthone (**87**), and macluraxanthone (**20**) from the twigs of *G. propinqua* displayed antibacterial potencies on a panel of sensitive and MDR strains: *E. coli* TISTR 780, *S. typhimurium* TISTR 292, *S. aureus* TISTR 1466 and methicillin-resistant *S. aureus* (MRSA) SK1 with MIC value as low as 2 μg/mL (against *S. aureus* TISTR 1466). Outstanding activities (MIC ≤ 4 μg/mL) were observed for macluraxanthone (**20**) and 10-*O*-methylmacluraxanthone (**87**) against Gram-positive bacteria (MRSA-SK1 and *S. aureus* TISTR 1466) (Tantapakul et al., 2012). Caged-tetraprenylated xanthones, scortechinones B (**88**) and I (**89**), and W (**90**) purified from *G. Scortechinii* were active against MRSA with MICs of 3.38, 12.8, and 52.8 μM, respectively. These activities were at least 2-fold less potent than vancomycin (MIC, 1.38 μM) (Sukpondma et al., 2005). The antibacterial activity of secondary metabolites is summarized in Table 3 and their chemical structures in Fig. 1.

7. Antibacterial modes of action of *Garcinia species*

p0375 Mangosteen (*G. mangostana*) produced high amounts of bioactive biprenylated xanthones, such as α, β, and γ-mangostins. Due to their potent antibacterial effects against both Gram-positive and Gram-negative bacteria, several authors have underlined their synergism and potentiation effects in presence of some antibiotics (Phitaktim et al., 2016; Sakagami, Iinuma, Piyasena, & Dharmaratne, 2005; Seesom et al., 2013; Sivaranjani et al., 2019). In parallel to this, α-mangostin is a multitarget inhibitor of a facultatively anaerobic bacteria, mutans streptococci. α-Mangostin acts as an inhibitor of acid production by *S. mutans* UA159. Other targets for inhibition by α-mangostin include malolactic fermentation and NADH oxidase, the major respiratory enzyme for *S. mutans* (Nguyen & Marquis, 2011).

8. Patents with the genus *Garcinia*

p0380 (−)-Hydroxycitric acid, a derivative of citric acid found in fruit rinds of some *Garcinia* species, especially *G. indica*, *G. atroviridis* and *G. cambogia* is widely used in pharmaceutical to improve exercise performance and weight loss (Braswell, Ahmed, & Ray, 1999; Hastings & Barnes, 1997; Murthy et al., 2020). Hasegawa et al., have also patented some tricyclic xanthones from *G. mangostana* as a potential inhibitor of *Helicobacter pylori* (Hasegawa, Sasaki, Almi, Takayama, & Koyano, 1996). In the same line, extract from *G. mangostana* combined with *Panax quinquefolius* reduce neuronal cell death, therefore increasing neurite length (Hsieh, Huang, & Chen, 2018).

9. Conclusion

p0385 This review presents a comprehensive summary of ethnobotanical, phytochemical constituents, and antibacterial activities of the genus *Garcinia*. Several species of this genus are used in folkloric medicines to treat various disorders the world over. A literature survey revealed that xanthones, benzophenones, and flavonoids are the major secondary metabolites reported from *Garcinia* species. Other miscellaneous phytochemicals such as terpenoids, biphenyls, phenolic acids, organic acids, and alkaloids have also been reported. Solvent extracts from *G. kola*, *G. lucida*, *G. nobilis,* and other *Garcinia* species have been shown to possess remarkable antibacterial activities against several bacterial strains including MDR phenotypes. Among the isolated compounds, α-mangostin, a prenylated xanthone from *G. mangostana* was found to display the most significant antibacterial effects against a panel of both Gram-positive and Gram-negative bacteria and thus a potential antibacterial agent. Moreover, (-)-hydroxycitric acid from some *Garcinia* fruits is an important anti-obesity agent in the pharmaceutical industry.

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