MINI REVIEW
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Gallesia integrifolia: detailed analysis of its chemical compounds and biological effects

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Author contributions
Verly LB, Rangel Rosa AC, Marques CFPM, Perin ILB, dos Santos Medeiros G, Carvalho GA, Miranda GS, Caprini HOG, da Silva CR were responsible for formal analysis, investigation, methodology, writing, review, and editing. Santos MFC was responsible for conceptualization, funding acquisition, resources, supervision, and writing the original draft. All authors have read and agreed to the published version of the manuscript.

Competing interests
The authors declare no conflicts of interest.

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Abbreviations
GC-MS, gas chromatography-mass spectrometry; HPLC, high-performance liquid chromatography.

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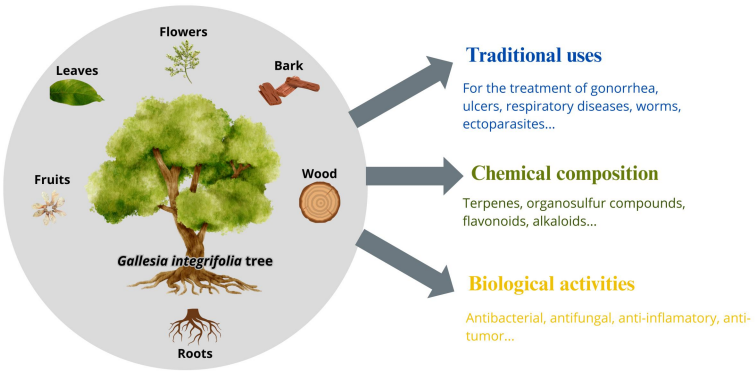
Abstract
The plant species *Gallesia integrifolia*, known in Brazil as Pau D'alho or Guararema, has great relevance in ethnopharmacology and is popularly used in the treatment of various health conditions, such as flu, cough, worms, ulcers and bacterial infections. Furthermore, several studies confirm its effectiveness in combating microorganisms of great clinical and economic importance, such as *Aspergillus* sp., *Penicillium* sp., *Trichoderma viride* and *Candida albicans*. However, there is still a lack of comprehensive phytochemical studies on this plant, which limits the understanding of its mechanisms of action and pharmacological potential. Therefore, this review was conducted through a narrative synthesis of the literature, gathering and analyzing available studies on the chemical composition and biological effects of *G. integrifolia*. The main findings indicate that the plant has antimicrobial activity and significant therapeutic potential, being effective against several pathogens of medical and economic relevance. Furthermore, the reviewed literature suggests that its bioactive compounds may have promising applications in the pharmaceutical and medical fields. The relevance of this study lies in expanding knowledge about the properties of *G. integrifolia*, highlighting its possible therapeutic applications and the need for further research to elucidate its mechanisms of action. The results reinforce the importance of more detailed phytochemical investigations to validate and expand the medicinal use of this species.

Keywords: ethnopharmacology; phytochemistry; pharmacognosy; *Gallesia integrifolia*; chemical composition; review



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Highlights

Gallesia integrifolia is rich in sulfur compounds linked to antimicrobial activity.
Demonstrates antifungal, antibacterial, and anti-inflammatory effects.
Widely used in traditional medicine for various diseases.
Further studies needed on compound isolation and mechanisms.

Medical history of objective

Gallesia integrifolia has been traditionally used in Brazilian medicine, with its first recorded mention found in Andrade and Vecchi's *Les bois indigènes de São Paulo* (1916), to treat respiratory, gastrointestinal, and inflammatory conditions. This review aims to consolidate current knowledge on its chemical composition and biological activities, highlighting its therapeutic potential and the need for further phytochemical and pharmacological investigations.

Background

Medicinal plants have long played a critical role in traditional health systems across the globe, particularly in biodiversity-rich regions such as South America. Ethnopharmacological knowledge continues to serve as a foundation for the discovery of novel bioactive compounds, many of which have been integrated into modern medicine. In this context, *Gallesia integrifolia* (Spreng.) Harms, a sulfur-rich, garlic-scented tree native to South America, stands out for its traditional use and pharmacological potential. Widely distributed across several Brazilian biomes, including the Amazon and the Cerrado, this monotypic species of the Phytolaccaceae family is traditionally used to treat respiratory, infectious, and inflammatory conditions. Its essential oil and other metabolites have drawn scientific attention due to demonstrated antimicrobial, antioxidant, and antitumor activities. Despite its recognized value in folk medicine, comprehensive phytochemical and pharmacological studies remain limited, highlighting the importance of further scientific investigation into this underexplored species.

Methods

Review

A comprehensive systematic review was conducted following rigorous methodological protocols to investigate the botanical, chemical, and pharmacological properties of *G. integrifolia*. The search strategy was implemented across five major scientific databases (SciELO (15), Scopus (30), Web of Science (25), PubMed (35), and JSTOR (15)) using a carefully designed combination of search terms, including: "*G. integrifolia*", "*Gallesia integrifolia*", "*Gallesia integrifolia* in medicine", "chemical *Gallesia*", "biological activity *Gallesia*", "constituents biology *Gallesia*", and "*Gallesia integrifolia* antifungal activity". These terms were selected to ensure comprehensive coverage of all relevant aspects of the species, from its basic botanical characterization to its potential medicinal applications.

The literature search encompassed all available publications between 1916 and 2024 without geographical restrictions, including English, Portuguese, and French articles. Various documents were considered, including peer-reviewed scientific articles, specialized academic works, and rigorously validated expedition reports, ensuring a comprehensive and robust approach to the subject matter.

The preliminary screening applied strict inclusion criteria, focusing on original research containing experimental data relevant to the chemical composition or biological activities of *G. integrifolia*. Studies that passed the initial screening underwent a full-text evaluation, where methodological quality was thoroughly assessed, including a review of sample preparation protocols and analytical methods. The final selection comprised 41 studies that met all quality criteria.

Data processing and statistical analysis

The extracted data were systematically organized and analyzed. Chemical information was categorized by compound class and structural characteristics, while biological activity data were evaluated based on assay type and experimental conditions.

The analyses were conducted using RStudio (version 2024.12.1 + 563). Descriptive statistical analyses were performed, including calculations of means, standard deviations, and confidence intervals. When applicable, inferential statistical tests, such as ANOVA and regression analysis, were employed to identify significant relationships between chemical constituents and biological activities.

Results and discussion

Chemical composition

The presence of sulphur compounds is a distinct chemotaxonomic characteristic of *G. integrifolia.* These sulfur compounds are present in all tissues, including leaves, flowers, fruits and bark, conferring the plant a pronounced garlic odor [1–3]. The volatile compounds found in the bark, leaves, flowers and fruit of *G. integrifolia* have a high content of sulfur compounds, justifying the strong garlic odor [2, 4, 5]. Considering the popularity of the plant and its ease of access, as it is capable of acclimatizing to different environments and regenerating easily, it is both abundant and accessible [6–9]. In addition to being quite common, as it is used medicinally and for material production, it requires greater attention, underscoring the need for rigorous studies to ensure the safety and efficacy of its popular use.

Neves (2012) employed chromatographic methods and one- and two-dimensional 1H and 13CNMR spectroscopy techniques to isolate and identify six chemical constituents of *G. integrifolia* [10]. Their chemical structures were characterized as two porphyrins: 7c-methoxypheophorbide A (GFDCC-15) C01 and 7c-methoxy-10-hydroxypheophorbide A (GFH12.6) C02; three triterpenes, including a binary mixture of α-amyrin (C03) and β-amyrin (C04) (GFD 4.1), as well as hexaprenol (GFH 2.5) C05, and a novel diterpene, 15-hydroxy-13-clerodene (GFH 3.9) C06. The high concentration of these compounds may justify the plant's traditional use in folk medicine, given the antimicrobial potential associated with these substances.

In the study carried out by Arunachalam (2017), 20 compounds were identified in the essential oil extracted from the stem of *G. integrifolia* through gas chromatography-mass spectrometry (GC-MS), which the most notable compounds was (−)-alpha-santalene (18.93%) C07, phytol (11.76%) C08, bis-disulfide-bis (9.86%) C09, methyl disulfide (6.94%) C10, beta-bisabolene (6.31%) C11, beta-sesquiphellandrene (4.53%) C12, (−)-zingiberene (2.80%) C13 and alpha-bergamotene (2.22%) C14 [11]. These compounds indicate a mixture of sesquiterpenes, suggesting possible biological activities such as antioxidant, antimicrobial, or anti-inflammatory properties [12, 13].

Raimundo, et al. (2018) identified, through GC-MS, 34 compounds in the essential oil extracted from the fruits of *G. integrifolia*, among which the main compounds were dimethyl trisulfide (15.49%) C15, 2.8-dithianonane (52.63%) C16 and lentionin (14.69%) C17 [14]. Notably, 68% of the identified compounds belong to the organosulfur class. Additionally, Bortolucci, et al. (2020) investigated the main compounds present in the ethanolic extract of *G. integrifolia* flowers using GC-MS, identifying a total of 20 identified compounds, with the most prominent being vitamin E (20.9%) C18, linolenic acid methyl ester (14.0%) C19, bis (2-sulfhydryl ethyl) disulfide (11.9%) C20 and phytol (10.2%) C08 [15].

Bortolucci, et al. (2021) and Bortolucci, et al. (2022) investigated the alcoholic extract (98° GL ethyl alcohol) from the leaves, flowers and fruits of *G. integrifolia*, identifying sulfur compounds in flowers (21.7%), with disulfide, bis (2-ethyl sulfhydryl) (12.8%) C20 being the most prominent [15, 16]. In addition to sulfur compounds, other classes were identified, such as vitamin E (20.1%) C18 and phytol (11.0%) C08 in the flowers. Seventeen compounds were identified

through GC-MS in the hydroalcoholic extract from leaves of *G. integrifolia*, with the most concentrated compounds being phytol (30.9%) C08, linoleic acid ethyl ester (30.5%) C19 and methyl palmitate (10.9%) C21 [17].

Raimundo, et al. (2021) reported that essential oils obtained by hydrodistillation and identified by gas chromatography coupled with GC-MS consisted of 95.9% sulfur compounds in the flowers, with the main compounds being methyl p-tolyl sulfide (17.08%) C22, methionine ethyl ester (45.28%) C23, and n-ethyl-1,3-dithioisoindole (13.4%) C24 [18]. In another study, Raimundo et al. evaluated the chemical composition of volatile compounds from the leaves, flowers, and fruits of *G. integrifolia*, collected using the dynamic headspace technique, and revealed that flowers contained 44.4% of methanethiol C25 and 43.7% of dimethyl sulfide C26 [18].

Through the evaluation of essential oil obtained from the leaves, flowers and fruits of *G. integrifolia* by GC-MS, Souza, et al. (2022) identified the predominant compounds in each part of the plant as 3,5-dithiahexanol-5,5-dioxide C27 (leaves), methionine ethyl ester C23 (flowers), and 2,8-dithianonane (fruits) C16, highlighting the chemical diversity of this plant and possibly explaining its widespread use in medicine for various conditions [19]. Furthermore, diverse compounds with varying concentrations were found in two or more parts of the plant. For instance, 1,2,4-trithiolane C28 that was detected at concentrations of 1.04%, 1.81%, and 0.76% in leaves, flowers, and fruits respectively (Table 1). This variability may explain the diversity of extraction methods employed for different applications.

Studies on the chemical composition of *G. integrifolia* indicate that this plant contains a wide variety of identified compounds, which may explain its use for numerous conditions and diverse application methods. These compounds also account for sensory characteristics, such as the plant's distinctive odor. Despite the progress in identifying these bioactive compounds, further research is still needed to elucidate their mechanism of action and validate their therapeutic effects, ensuring their safe and effective use.

The analysis revealed the presence of various bioactive compounds, with a notable prevalence of sulfur-containing compounds, terpenoids, and phenolics. Sulfur-containing compounds, which were predominant in leaves and fruits, were associated with the antimicrobial properties of the species. Additionally, terpenoids such as α-amyrin and β-amyrin were identified in high concentrations, suggesting potential anti-inflammatory and antioxidant activities.

The relative distribution of compounds was statistically analyzed, showing significant variations among different plant parts ($P < 0.05$, ANOVA). Sulfur-containing compounds were found in higher concentrations in fruits (52.63%) compared to leaves (30.92%), suggesting a possible relationship with the species' ecological adaptation.

Biological activities

Gallesia integrifolia is widely used in traditional medicine to treat various conditions, including bronchitis, asthma, flu, cough, pneumonia, otitis, gonorrhea, worms, rheumatism, and prostate tumor. It is also indicated for its hypotensive properties, cholesterol-lowering effects, and ability to alleviate leg pain [20–24].

The tea prepared by infusing the leaves is used to treat ulcers, while the tea obtained by decocting the bark is applied to address intestinal parasites and respiratory and lymphatic diseases [22, 25–27]. Fresh, crushed leaves are used topically to treat abscesses, otitis and gonorrhea [22, 28]. In some Brazillian communities, the infusion of roots is indicated for rheumatism and ulcers, and the essential oil is employed in treating gonorrhea [29–32]. Despite its widespread use, these applications lack scientific validation, underscoring the need for rigorous studies to ensure the safety and efficacy of the plant's traditional use.

The hydroethanolic extract (HEGi) of the internal bark of the stem of *G. integrifolia* exhibits bacteriostatic effect, particularly gram-negative bacteria [33, 34]. This supports its widespread use in combating infectious bacterial diseases. The bioactivity may be attributed to phenolic compounds like gallic acid, rutin, and morin. Gallic acid's mechanism promotes the destabilization of bacterial cell membranes and acidification of the cytosol, while rutin and morin act by inhibiting nucleic acid synthesis and other essential cellular processes. These mechanisms may explain the antimicrobial effects of HEGi, although the bioactivity could also result from the synergistic action of multiple compounds present in the extract [33]. The essential oil of *G. integrifolia* demonstrates antifungal activity due to organosulfur compounds synthesized from sulfur-containing amino acids such as methionine and cysteine in plant tissue. The antifungal activity of these protective compounds is enhanced by sulfur, and disulfide bonds in these molecules are also associated with the antimicrobial potential of organosulfur compounds [35].

An ethnophamaceutical study by Jesus, et al. (2019) identified additional therapeutic applications of *G. integrifolia*, including treating back pain, bronchitis, rheumatism and constipation [21, 36]. Essential oils extracted from different plant parts have demonstrated *in vitro* antifungal activity against various pathogens [19, 21]. Souza, et al. investigated the antifungal activity of *G. integrifolia* against vulvovaginal candidiasis in pregnant women, examining the medicinal properties of its leaves, flowers, fruits and bark [19]. The results revealed that the essential oils from the flowers were the most effective against *Candida* spp. strains. The leaves and flowers exhibited efficacy similar to fluconazole against *C. albicans*.

In contrast, the flowers and fruit showed comparable activity to fluconazole against *C. tropicalis*, suggesting that different parts of the plant may contain compounds that act selectively against different fungal strains. The main compound found in leaves was 3,5-dithiahexanol-5,5-dioxide, while methionine ethyl ester was predominant in the flowers, and 2,8-dithianonane was the primary compound in the fruits. In addition to these compounds, the biological activity may also be attributed to phytol, a compound with well documented biological activity. However, it was not listed as one of the main compounds in this study [21].

The essential oil from the fruit of *G. integrifolia* exhibits anti-inflammatory activity [16]. In virtue of molecules that donate hydrogen sulfide (H_2S) also possess anti-inflammatory properties, the anti-inflammatory activity of the essential oil from the fruit of *G. integrifolia* may be associated with the presence of sulfur compounds. T-type CaV 3.2 channels are activated by hydrogen sulfide, which inhibits the voltage-dependent potassium channels and depolarizes peptidergic sensory neurons, releasing somatostatin. Additionally, hydrogen sulfide exerts an antiproliferative effect on T cells and induces the death of polymorphonuclear cells. Furthermore, the essential oil demonstrated moderate cytotoxic activity against human tumor cells lines while showing no effect on porcine non-tumor cells [16]. These results suggest that the sulfur compounds present in the essential oil of *G. integrifolia* may be responsible for its anti-inflammatory action and potential anticancer properties, opening new possibilities for its application in medicine [37].

The antifungal activity of this species can also be observed in the dichloromethane extract of the bark, which demonstrated a broad spectrum activity against fungal strains of various species, including *Cryptococcus neoformans*, *Microsporum gypseum*, *Penicillium purpurogenum*, *Saccharomyces cerevisiae*, *Trichophyton mentagrophytes*, *Neurospora crassa*, *Fusarium oxysporum var. pinaster*, and *Cladosporium cladosporioides* [14, 38–41] (Table 2). The diversity of fungi affected suggests that the compounds present in the plant may target multiple fungal mechanisms essential for survival. This antifungal potential could be harnessed for the development of new antifungal drugs. The chemical structure of the compounds found in the species are described in Table 3.

Despite the promising potential of this plant, there is a lack in the scientific literature regarding phytochemical isolation studies. Most research is focused on preliminary analyses or general biological activities without delving into the isolation and detailed structural identification of its compounds [33, 36, 37]. The absence of such specific isolation studies limits the understanding of the mechanisms of action of the bioactive compounds present in the species and

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Table 1 Chemical compounds present in different parts of the plant and described in literature

N°	%	Chemical compound	Extraction/identification	Part of plant	Author
C01	*	7c-methoxypheophorbide A	Methanolic extract/NMR	Leaf	Neves (2012)
C02	*	7c-methoxy-10-hydroxypheophorbide a	Methanolic extract/NMR	Leaf	Neves (2012)
C03	1.97	α-amyrin	Ethanolic extract/GC-MS	Fruit	Bortolucci et al (2020)
C03	*	α-amyrin	Methanolic extract/NMR	Leaf	Neves (2012)
C04	*	β-amyrin	Methanolic extract/NMR	Leaf	Neves (2012)
C05	*	Hexaprenol	Methanolic extract/NMR	Leaf	Neves (2012)
C06	*	15-hydroxy-13-clerodene	Methanolic extract/NMR	Leaf	Neves (2012)
C07	18.93	(−)-Alpha-santalene	Essential oil/GC-MS	Bark	Arunachalam et al (2017)
C08	30.92	Phytol	Ethanolic extract/GC-MS	Leaf	Bortolucci et al (2020)
C08	11.76	Phytol	Essential oil/GC-MS	Bark	Arunachalam et al (2017)
C08	10.24	Phytol	Ethanolic extract/GC-MS	Flower	Bortolucci et al (2020)
C08	6.5	Phytol	Ethanolic extract/GC-MS	Fruit	Bortolucci et al (2020)
C08	4	Phytol	Essential oil/GC-MS	Leaf	Souza et al (2022)
C08	3.04	Phytol	Essential oil/GC-MS	Flower	Souza et al (2022)
C08	3.9	Phytol	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C08	3.14	Phytol	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C09	9.86	Bis-dissulfide-bis	Essential oil/GC-MS	Bark	Arunachalam et al (2017)
C10	6.94	Methyl disulfide methyl	Essential oil/GC-MS	Bark	Arunachalam et al (2017)
C11	6.31	Beta-bisabolene	Essential oil/GC-MS	Bark	Arunachalam et al (2017)
C12	4.53	Beta-sesquiphellandrene	Essential oil/GC-MS	Bark	Arunachalam et al (2017)
C13	2.8	(−)-Zingiberene	Essential oil/GC-MS	Bark	Arunachalam et al (2017)
C14	2.22	Alpha-bergamotene	Essential oil/GC-MS	Bark	Arunachalam et al (2017)
C15	15.28	Dimethyl trisulfide	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C15	1.07	Dimethyl trisulfide	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C15	0.22	Dimethyl trisulfide	In natura/dynamic headspace	Fruit	Raimundo et al (2017)
C15	0.07	Dimethyl trisulfide	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C15	16.22	Dimethyl trisulfide	Essential oil/GC-MS	Fruit	Souza et al (2022)
C15	15.49	Dimethyl trisulfide	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C15	1.13	Dimethyl trisulfide	Essential oil/GC-MS	Leaf	Souza et al (2022)
C15	0.18	Dimethyl trisulfide	Essential oil/GC-MS	Bark	Arunachalam et al (2017)
C16	52.63	2,8-Dithianonane	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C16	0.12	2,8-Dithianonane	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C16	0.04	2,8-Dithianonane	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C16	54.01	2,8-Dithianonane	Essential oil/GC-MS	Fruit	Souza et al (2022)
C16	52.63	2,8-Dithianonane	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C17	14.69	Lenthionine	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C17	0.63	Lenthionine	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C17	0.15	Lenthionine	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C17	14.87	Lenthionine	Essential oil/GC-MS	Fruit	Souza et al (2022)
C17	14.69	Lenthionine	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C17	0.66	Lenthionine	Essential oil/GC-MS	Leaf	Souza et al (2022)

Table 1 Chemical compounds present in different parts of the plant and described in literature (*continued*)

N°	%	Chemical compound	Extraction/identification	Part of plant	Author
C17	0.56	Lenthionine	Essential oil/GC-MS	Flower	Souza et al (2022)
C18	20.86	Vitamin E	Ethanolic extract/GC-MS	Flower	Bortolucci et al (2020)
C18	18.04	Vitamin E	Ethanolic extract/GC-MS	Fruit	Bortolucci et al (2020)
C19	30.53	Methyl ester of linolenic acid	Ethanolic extract/GC-MS	Leaf	Bortolucci et al (2020)
C19	4.54	Methyl ester of linolenic acid	Ethanolic extract/GC-MS	Fruit	Bortolucci et al (2020)
C20	11.91	Bis (2-sulfanyl ethyl) disulfide	Ethanolic extract/GC-MS	Flower	Bortolucci et al (2020)
C20	0.14	Bis (2-sulfanyl ethyl) disulfide	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C21	10.91	Methyl palmitate	Ethanolic extract/GC-MS	Leaf	Bortolucci et al (2020)
C21	5.05	Methyl palmitate	Ethanolic extract/GC-MS	Fruit	Bortolucci et al (2020)
C21	4.69	Methyl palmitate	Ethanolic extract/GC-MS	Flower	Bortolucci et al (2020)
C22	17.08	Methyl p-tolyl sulfide	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C22	17.64	Methyl p-tolyl sulfide	Essential oil/GC-MS	Flower	Souza et al (2022)
C23	46.78	Methionine, ethyl ester	Essential oil/GC-MS	Flower	Souza et al (2022)
C23	5.29	Methionine, ethyl ester	Essential oil/GC-MS	Leaf	Souza et al (2022)
C23	45.28	Methionine, ethyl ester	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C23	5.32	Methionine, ethyl ester	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C23	0.1	Methionine, ethyl ester	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C23	0.1	Methionine, ethyl ester	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C24	13.4	N-ethyl-1,3-dithioisoindole	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C24	12.58	N-ethyl-1,3-dithioisoindole	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C24	3.69	N-ethyl-1,3-dithioisoindole	In natura/dynamic headspace	Flower	Raimundo et al (2017)
C24	1.05	N-ethyl-1,3-dithioisoindole	In natura/GC-MS	Fruit	Raimundo et al (2017)
C24	0.12	N-ethyl-1,3-dithioisoindole	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C24	13.24	N-ethyl-1,3-dithioisoindole	Essential oil/GC-MS	Flower	Souza et al (2022)
C24	13.03	N-ethyl-1,3-dithioisoindole	Essential oil/GC-MS	Leaf	Souza et al (2022)
C24	0.1	N-ethyl-1,3-dithioisoindole	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C25	44.91	Methanethiol	In natura/dynamic headspace	Flower	Raimundo et al (2017)
C25	16.26	Methanethiol	In natura/dynamic headspace	Fruit	Raimundo et al (2017)
C26	43.72	Dimethyl sulfide	In natura/dynamic headspace	Flower	Raimundo et al (2017)
C26	42.42	Dimethyl sulfide	In natura/dynamic headspace	Leaf	Raimundo et al (2017)
C26	1.42	Dimethyl sulfide	In natura/dynamic headspace	Fruit	Raimundo et al (2017)
C27	40.93	3,5-Dithiahexanol-5,5-dioxide	Essential oil/GC-MS	Leaf	Souza et al (2022)
C27	38.93	3,5-Dithiahexanol-5,5-dioxide	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C27	6.14	3,5-Dithiahexanol-5,5-dioxide	Essential oil/GC-MS	Flower	Souza et al (2022)
C27	5.94	3,5-Dithiahexanol-5,5-dioxide	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C27	0.1	3,5-Dithiahexanol-5,5-dioxide	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C27	0.1	3,5-Dithiahexanol-5,5-dioxide	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C28	1.76	1,2,4-Trithiolane	Ethanolic extract/GC-MS	Fruit	Bortolucci et al (2020)
C28	1.75	1,2,4-Trithiolane	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C28	1.08	1,2,4-Trithiolane	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C28	0.84	1,2,4-Trithiolane	Essential oil/GC-MS	Fruit	Raimundo et al (2021)

Table 1 Chemical compounds present in different parts of the plant and described in literature (*continued*)

N°	%	Chemical compound	Extraction/identification	Part of plant	Author
C28	1.1	1,2,4-Trithiolane	Ethanolic extract/GC-MS	Flower	Bortolucci et al (2020)
C28	1.81	1,2,4-Trithiolane	Essential oil/GC-MS	Flower	Souza et al (2022)
C28	1.04	1,2,4-Trithiolane	Essential oil/GC-MS	Leaf	Souza et al (2022)
C28	0.86	1,2,4-Trithiolane	Ethanolic extract/GC-MS	Leaf	Bortolucci et al (2020)
C28	0.76	1,2,4-Trithiolane	Essential oil/GC-MS	Fruit	Souza et al (2022)
C28	0.11	1,2,4-Trithiolane	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C29	40.43	3-Methylbutanal	In natura/dynamic headspace	Leaf	Raimundo et al (2017)
C29	0.68	3-Methylbutanal	In natura/dynamic headspace	Fruit	Raimundo et al (2017)
C30	35.29	2,3,5-Trithiahexane	In natura/CG-MS	Fruit	Raimundo et al (2017)
C30	1.62	2,3,5-Trithiahexane	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C30	0.22	2,3,5-Trithiahexane	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C30	0.1	2,3,5-Trithiahexane	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C30	0.28	2,3,5-Trithiahexane	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C30	6.17	2,3,5-Trithiahexane	Ethanolic extract/GC-MS	Flower	Bortolucci et al (2020)
C30	4.67	2,3,5-Trithiahexane	Etanólica/CG-MS	Fruit	Bortolucci et al (2020)
C30	3.79	2,3,5-Trithiahexane	Essential oil/GC-MS	Leaf	Souza et al (2022)
C30	2.29	2,3,5-Trithiahexane	Essential oil/GC-MS	Flower	Souza et al (2022)
C31	20.89	3,6-Dithiaoctan-1,8-diol	In natura/CG-MS	Fruit	Raimundo et al (2017)
C31	0.6	3,6-Dithiaoctan-1,8-diol	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C31	0.32	3,6-Dithiaoctan-1,8-diol	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C31	0.14	3,6-Dithiaoctan-1,8-diol	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C31	0.62	3,6-Dithiaoctan-1,8-diol	Essential oil/GC-MS	Flower	Souza et al (2022)
C32	10.6	Ethyl iso-allocholate	Ethanolic extract/GC-MS	Fruit	Bortolucci et al (2020)
C33	5.81	1,2,4,5-Tetrathiane	Essential oil/GC-MS	Fruit	Souza et al (2022)
C33	5.66	1,2,4,5-Tetrathiane	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C33	5.66	1,2,4,5-Tetrathiane	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C33	0.36	1,2,4,5-Tetrathiane	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C33	0.18	1,2,4,5-Tetrathiane	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C34	14.25	1,3,5-Trithiane	Essential oil/GC-MS	Leaf	Souza et al (2022)
C34	13.74	1,3,5-Trithiane	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C34	0.28	1,3,5-Trithiane	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C34	0.14	1,3,5-Trithiane	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C35	0.54	2,3,5,6-Tetrathiapentane	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C35	0.14	2,3,5,6-Tetrathiapentane	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C35	0.12	2,3,5,6-Tetrathiapentane	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C36	3.96	2,4-Dithiapentane	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C36	0.35	2,4-Dithiapentane	In natura/dynamic headspace	Fruit	Raimundo et al (2017)
C36	0.04	2,4-Dithiapentane	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C36	0.03	2,4-Dithiapentane	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C36	4.16	2,4-Dithiapentane	Essential oil/GC-MS	Leaf	Souza et al (2022)
C36	1.6	2,4-Dithiapentane	Ethanolic extract/GC-MS	Fruit	Bortolucci et al (2020)

Table 1 Chemical compounds present in different parts of the plant and described in literature (*continued*)

N°	%	Chemical compound	Extraction/identification	Part of plant	Author
C36	0.04	2,4-Dithiapentane	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C37	3.34	Dimethyl disulfide	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C37	1.06	Dimethyl disulfide	In natura/dynamic headspace	Fruit	Raimundo et al (2017)
C37	0.89	Dimethyl disulfide	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C37	0.27	Dimethyl disulfide	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C37	3.45	Dimethyl disulfide	Essential oil/GC-MS	Flower	Souza et al (2022)
C37	0.91	Dimethyl disulfide	Essential oil/GC-MS	Fruit	Souza et al (2022)
C37	0.06	Dimethyl disulfide	Essential oil/GC-MS	Bark	Arunachalam et al (2017)
C37	0.89	Dimethyl disulfide	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C38	14	Linoleic acid ethyl ester	Ethanolic extract/GC-MS	Flower	Bortolucci et al (2020)
C38	3.87	Linoleic acid ethyl ester	Ethanolic extract/GC-MS	Leaf	Bortolucci et al (2020)
C38	2.28	Linoleic acid ethyl ester	Ethanolic extract/GC-MS	Fruit	Bortolucci et al (2020)
C39	5.52	Ethanol, 2-(methylthio)	In natura/dynamic headspace	Leaf	Raimundo et al (2017)
C39	0.66	Ethanol, 2-(octylthio)	Essential oil/GC-MS	Leaf	Souza et al (2022)
C39	0.11	Ethanol, 2-(octylthio)	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C39	0.63	Ethanol, 2-(octylthio)	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C39	0.33	Ethanol, 2-(octylthio)	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C39	0.11	Ethanol, 2-(octylthio)	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C40	5.53	Hexathiepane	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C40	0.29	Hexathiepane	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C40	5.53	Hexathiepane	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C40	5.48	Hexathiepane	Essential oil/GC-MS	Fruit	Souza et al (2022)
C41	2.22	Methyl (methylsulfinyl) methyl sulfide (FAMSO)	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C41	1.99	Methyl (methylsulfinyl) methyl sulfide (FAMSO)	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C41	0.11	Methyl (methylsulfinyl) methyl sulfide (FAMSO)	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C42	0.33	Pentyl, 3-(methylthio) propanoate	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C42	0.1	Pentyl, 3-(methylthio) propanoate	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C42	0.09	Pentyl, 3-(methylthio) propanoate	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C43	3.1	S-phenyl-p-toluene-thiosulfonate	Essential oil/GC-MS	Flower	Souza et al (2022)
C43	3	S-phenyl-p-toluene-thiosulfonate	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C43	0.23	S-phenyl-p-toluene-thiosulfonate	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C43	0.18	S-phenyl-p-toluene-thiosulfonate	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C44	0.39	Trithiometoxymethane	In natura/CG-MS	Fruit	Raimundo et al (2017)
C44	0.35	Trithiometoxymethane	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C44	0.13	Trithiometoxymethane	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C44	0.08	Trithiometoxymethane	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C44	0.15	Trithiometoxymethane	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C45	0.89	(+)-Alpha santalol	Essential oil/GC-MS	Bark	Arunachalam et al (2017)
C46	0.34	(+)-Delta cadinene	Essential oil/GC-MS	Bark	Arunachalam et al (2017)
C47	0.24	1,3,6,9-Dodecatetraene-12-methylthio (Z,Z,Z)	Essential oil/GC-MS	Leaf	Raimundo et al (2021)

Table 1 Chemical compounds present in different parts of the plant and described in literature (*continued*)

N°	%	Chemical compound	Extraction/identification	Part of plant	Author
C48	1.82	1,3-Dimethyl-4-azaphenanthrene	In natura/CG-MS	Fruit	Raimundo et al (2017)
C48	0.2	1,3-Dimethyl-4-azaphenanthrene	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C49	0.23	11,13-Dihydroxy-tetradec5-ynoic acid, methyl ester	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C50	1.18	13,14-Epoxyoleanan-3-ol, acetate	Ethanolic extract/GC-MS	Flower	Bortolucci et al (2020)
C51	0.61	1-Oxa-4,7-dithinonane	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C52	5.22	2,3,5,6-Tetrathiaheptane	In natura/CG-MS	Fruit	Raimundo et al (2017)
C52	0.12	2,3,5,6-Tetrathiaheptane	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C53	0.15	2,7-Dithiaoctane	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C54	4.7	2-Butanamine	In natura/dynamic headspace	Flower	Raimundo et al (2017)
C55	0.45	2-Ethylfuran	In natura/dynamic headspace	Fruit	Raimundo et al (2017)
C56	0.09	2-Undecanone-6,10-dimethyl	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C56	0.05	2-Undecanone-6,10-dimethyl	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C57	0.73	3,4-Dimetoxy-dl-phenylalanine	In natura/dynamic headspace	Flower	Raimundo et al (2017)
C58	1.79	3,6-Dioxy-8-mercaptooctane-1-ol	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C58	0.08	3,6-Dioxy-8-mercaptooctane-1-ol	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C58	1.88	3,6-Dioxy-8-mercaptooctane-1-ol	Essential oil/GC-MS	Leaf	Souza et al (2022)
C59	0.54	3-(((Methylthio)methy)sulfonyl)-1-phenyl-1-propanone	Essential oil/GC-MS	Leaf	Souza et al (2022)
C59	0.81	3-(((Methylthio)methy)sulfonyl)-1-phenyl-1-propanone	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C59	0.18	3-(((Methylthio)methy]sulfonyl)-1-phenyl-1-propanone	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C60	0.13	3-Ethylthiophene	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C60	0.13	3-Ethylthiophene	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C61	1.68	3-O-acetyl-6-methoxy-cycloartenol	Ethanolic extract/GC-MS	Flower	Bortolucci et al (2020)
C61	0.77	3-O-acetyl-6-methoxy-cycloartenol	Ethanolic extract/GC-MS	Fruit	Bortolucci et al (2020)
C62	0.17	4-Methylthio-2-oxo-butanoic acid	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C62	0.06	4-Methylthio-2-oxo-butanoic acid	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C63	0.66	5,6-Dihydro-2,4,6-trimethyl-4H-1,3,5-di thiazine	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C64	0.56	5-Methyl-2-phenylindole	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C64	0.42	5-Methyl-2-phenylindole	In natura/CG-MS	Fruit	Raimundo et al (2017)
C64	0.08	5-Methyl-2-phenylindole	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C64	0.03	5-Methyl-2-phenylindole	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C64	0.58	5-Methyl-2-phenylindole	Essential oil/GC-MS	Fruit	Souza et al (2022)
C64	0.56	5-Methyl-2-phenylindole	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C65	0.08	7-Methyl-4-thioctane	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C66	1.11	Betulin	Ethanolic extract/GC-MS	Leaf	Bortolucci et al (2020)
C66	1.1	Betulin	Ethanolic extract/GC-MS	Fruit	Bortolucci et al (2020)
C67	0.13	Butanoic acid, 3-(acetylthio)	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C67	0.04	Butanoic acid, 3-(acetylthio)	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C68	5.23	Dimethyl tetrasulfide	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C68	0.48	Dimethyl tetrasulfide	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C69	1.57	Stigmasterol	Ethanolic extract/GC-MS	Leaf	Bortolucci et al (2020)

Table 1 Chemical compounds present in different parts of the plant and described in literature (*continued*)

N°	%	Chemical compound	Extraction/identification	Part of plant	Author
C69	7.38	Stigmasterol	Ethanolic extract/GC-MS	Fruit	Bortolucci et al (2020)
C70	0.15	Limonene	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C70	0.05	Limonene	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C71	0.33	Linalool	In natura/CG-MS	Fruit	Raimundo et al (2017)
C71	0.06	Linalool	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C72	0.11	Methyl-phenethyl sulfide	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C72	0.1	Methyl-phenethyl sulfide	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C73	2.11	Ethyl palmitate	Ethanolic extract/GC-MS	Fruit	Bortolucci et al (2020)
C73	1.43	Ethyl palmitate	Ethanolic extract/GC-MS	Leaf	Bortolucci et al (2020)
C74	2.6	Propyl-undecenoate	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C74	0.11	Propyl-undecenoate	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C75	5.59	Dimethyl tetrasulfide	Essential oil/GC-MS	Leaf	Souza et al (2022)
C75	0.14	Dimethyl tetrasulfide	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C76	3.49	Dimethyl thiosulphonate	In natura/dynamic headspace	Fruit	Raimundo et al (2017)
C76	0.13	Dimethyl thiosulphonate	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C76	2.23	Propyl undecenoate	Essential oil/GC-MS	Leaf	Souza et al (2022)
C76	0.53	Propyl undecenoate	Essential oil/GC-MS	Flower	Souza et al (2022)
C77	0.15	Trans-β-ionone	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C77	0.13	Trans-β-ionone	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C78	5.59	β-sitosterol	Ethanolic extract/GC-MS	Fruit	Bortolucci et al (2020)
C78	0.64	β-sitosterol	Ethanolic extract/GC-MS	Leaf	Bortolucci et al (2020)
C79	2.61	γ-sitosterol	Ethanolic extract/GC-MS	Leaf	Bortolucci et al (2020)
C79	2.14	γ-sitosterol	Ethanolic extract/GC-MS	Fruit	Bortolucci et al (2020)
C80	2.25	γ-terpinene	In natura/dynamic headspace	Flower	Raimundo et al (2017)
C81	0.73	γ-tocopherol	Ethanolic extract/GC-MS	Leaf	Bortolucci et al (2020)
C82	0.56	β-tocopherol	Ethanolic extract/GC-MS	Leaf	Bortolucci et al (2020)
C83	0.17	β-pinene	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C84	0.05	α-thujene	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C85	8.63	α-terpinolene	In natura/dynamic headspace	Leaf	Raimundo et al (2017)
C86	0.09	α-terpinene	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C87	2.61	α-monoolein	Ethanolic extract/GC-MS	Fruit	Bortolucci et al (2020)
C88	0.01	α-fenchone	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C89	0.08	Trimethylsilyl methanesulfonate	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C90	0.09	Trans-α-ionone	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C91	0.35	Thiophene,2-((methylthio)ethynyl)	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C92	2	Rutin	Ethanolic extract/high-performance liquid chromatography (HPLC)	Bark	Arunachalam et al (2016)
C93	0.91	R-limonene	Ethanolic extract/GC-MS	Flower	Bortolucci et al (2020)
C94	0.18	Propane,1,1-thiobis(3- (methylthio))	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C95	0.33	Pentylfuran	In natura/CG-MS	Fruit	Raimundo et al (2017)
C96	0.88	Morin	Ethanolic extract/HPLC	Bark	Arunachalam et al (2016)
C97	6.84	Lupeol	Ethanolic extract/GC-MS	Fruit	Bortolucci et al (2020)

Table 1 Chemical compounds present in different parts of the plant and described in literature (*continued*)

N°	%	Chemical compound	Extraction/identification	Part of plant	Author
C98	4.88	Cycloartenol acetate	Ethanolic extract/GC-MS	Fruit	Bortolucci et al (2020)
C98	0.99	Cycloartenol acetate	Ethanolic extract/GC-MS	Flower	Bortolucci et al (2020)
C99	6.07	10,13-Octadecadienoic acid, methyl ester	Ethanolic extract/GC-MS	Flower	Bortolucci et al (2020)
C99	5.04	10,13-Octadecadienoic acid, methyl ester	Ethanolic extract/GC-MS	Fruit	Bortolucci et al (2020)
C100	5.57	n-hexadecanoic acid	Ethanolic extract/GC-MS	Flower	Bortolucci et al (2020)
C100	1.04	n-hexadecanoic acid	Ethanolic extract/GC-MS	Fruit	Bortolucci et al (2020)
C101	1.57	Palmitoleic acid, methyl ester	Ethanolic extract/GC-MS	Leaf	Bortolucci et al (2020)
C102	0.5	Borneol acetate	Essential oil/GC-MS	Bark	Arunachalam et al (2017)
C103	0.81	Citronellol acetate	Essential oil/GC-MS	Bark	Arunachalam et al (2017)
C104	2.6	Lupeol acetate	Ethanolic extract/GC-MS	Fruit	Bortolucci et al (2020)
C105	1.05	Stearic acid	Ethanolic extract/GC-MS	Leaf	Bortolucci et al (2020)
C106	1.2	Gallic acid	Ethanolic extract/HPLC	Bark	Arunachalam et al (2016)
C107	5.99	Linoleic acid	Ethanolic extract/GC-MS	Leaf	Bortolucci et al (2020)
C108	0.97	Alpha-pinene	Essential oil/GC-MS	Bark	Arunachalam et al (2017)
C109	0.19	Allyl phenyl sulfide	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C110	3.53	Barringtogenol C	Ethanolic extract/GC-MS	Flower	Bortolucci et al (2020)
C111	1.21	Beta-farnesene	Essential oil/GC-MS	Bark	Arunachalam et al (2017)
C83	0.09	β-pinene	Essential oil/GC-MS	Bark	Arunachalam et al (2017)
C112	1.43	Beta-santalene	Essential oil/GC-MS	Bark	Arunachalam et al (2017)
C113	0.1	Butane,1,4-bis (methylthio)	Essential oil/GC-MS	Fruit	Raimundo et al (2018)
C114	0.02	Camphene	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C115	0.93	Cedr-8-en-13-ol	Ethanolic extract/GC-MS	Flower	Bortolucci et al (2020)
C116	9.08	Dimethyl sulfone	In natura/dynamic headspace	Fruit	Raimundo et al (2017)
C117	0.36	Dimethyl sulfoxide	In natura/dynamic headspace	Fruit	Raimundo et al (2017)
C118	0.08	D-limonene	Essential oil/GC-MS	Bark	Arunachalam et al (2017)
C119	0.2	Eicosane	Essential oil/GC-MS	Flower	Raimundo et al (2021)
C120	2.63	Inotodiol	Ethanolic extract/GC-MS	Flower	Bortolucci et al (2020)
C121	0.23	Hexanal	In natura/dynamic headspace	Fruit	Raimundo et al (2017)
C122	0.64	Isobornyl acetate	In natura/CG-MS	Fruit	Raimundo et al (2017)
C123	4.95	Isohumulone	Ethanolic extract/GC-MS	Leaf	Bortolucci et al (2020)
C124	5.17	Methyl linoleate	Ethanolic extract/GC-MS	Flower	Bortolucci et al (2020)
C125	0.55	Ethyl Octadecanoate	Ethanolic extract/GC-MS	Flower	Bortolucci et al (2020)
C126	0.37	caryophyllene oxide	Essential oil/GC-MS	Bark	Arunachalam et al (2017)
C127	0.06	δ-2-carene	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C128	0.66	3,6-Dithiaoctan-1-ol	Essential oil/GC-MS	Fruit	Raimundo et al (2021)
C128	0.14	3,6-Dithiaoctan-1-ol	Essential oil/GC-MS	Leaf	Raimundo et al (2021)
C128	0.63	3,6-Dithiaoctan-1-ol	Essential oil/GC-MS	Fruit	Souza et al (2022)

Table 2 Biological activities of *G. integrifolia* related in the literature

Type of extraction	Use	Part of plant	Author
Infusion	Treatment of ulcers	Leaves	(Grandtne e Chevrette, 2013)
Infusion	Antiparasitic, treatment of respiratory and lymphatic diseases	Bark	(Balbach, 1993)
Fresh leaves	Treatment of abscesses, otitis, and gonorrhea	Leaves	(Balbach, 1993)
Infusion	Treatment of rheumatism and ulcers	Roots	(Barbosa et al., 1999; Munoz et al., 2000; Bieski et al., 2012).
Essential oil	Treatment of gonorrhea	Leaves	(Barbosa et al., 1999; Munoz et al., 2000; Bieski et al., 2012).
Hydroethanolic extract	Bacteriostatic effect against gram-negative bacteria	Internal bark of stem	(Arunachalam et al., 2016).
Essential oil	Antifungal activity	Leaves	(Raimundo et al., 2018).
Essential oil	Antifungal activity against strains of *Candida* spp.	Flowers	(Bortolucci et al., 2022).
Essential oil	Antifungal activity against strains of *C. albicans*	Leaves and flowers	(Bortolucci et al., 2022).
Essential oil	Antifungal activity against strains of *C. tropicalis*	Flowers and fruit	(Bortolucci et al., 2022).
Essential oil	Moderate citotoxic activity against strains of human tumor cells	Fruit	(Bortolucci et al., 2022).
Essential oil	Anti-inflammatory activity	Fruit	(Bortolucci et al., 2022).
Dichloromethane extract	Antifungal activity	Bark	(Freixa et al., 1998)

Source: authors' production, 2024.

Table 3 Chemical structure of the compounds

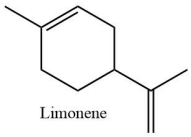
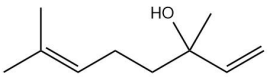
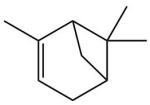
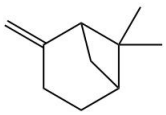
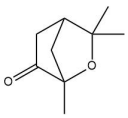
Class	Code of compound	Structure
Terpenes	C70	 Limonene
	C71	 Linalool
	C108	 Alpha-pinene
	C83	 Beta-pinene
	C88	 Alpha-fenchone

Table 3 Chemical structure of the compounds (*continued*)

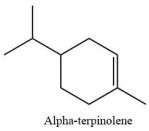
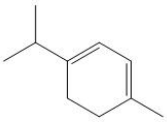
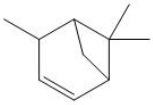
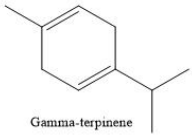
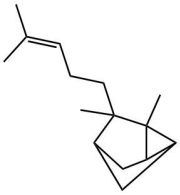
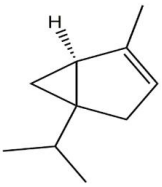
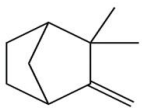
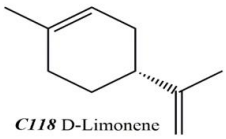
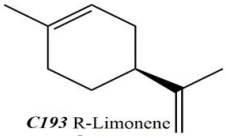
Class	Code of compound	Structure
Terpenes	C85	 Alpha-terpinolene
	C86	 Alpha-terpinene
	C127	 Delta-2-carene
	C80	 Gamma-terpinene
	C07	 alpha-Santalene
	C84	 ***C84*** alpha-Tujene
	C114	 ***C114*** Camphene
	C118	 ***C118*** D-Limonene
	C193	 ***C193*** R-Limonene

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Table 3 Chemical structure of the compounds (*continued*)

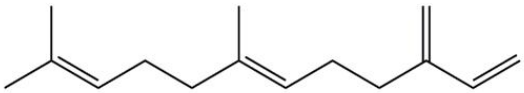
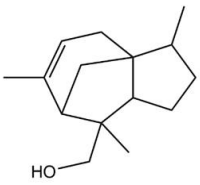
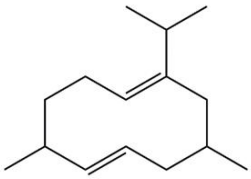
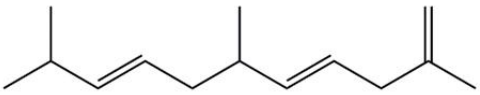
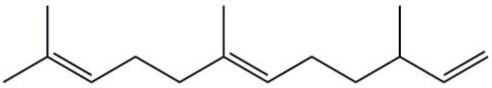
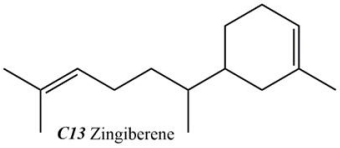
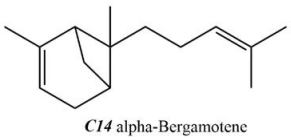
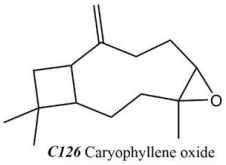
Class	Code of compound	Structure
Terpenes	C111	 ***C111*** beta-Farnesene
	C115	 ***C115*** Cedr-8-en-13-ol
	C112	 ***C112*** beta-Santalene
	C11	 ***C11*** beta-Bisabolene
	C12	 ***C12*** beta-Sesquiphellandrene
	C13	 ***C13*** Zingiberene
	C14	 ***C14*** alpha-Bergamotene
	C126	 ***C126*** Caryophyllene oxide

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Table 3 Chemical structure of the compounds (*continued*)

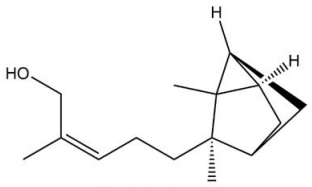
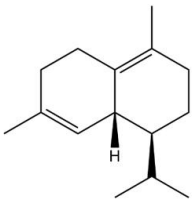
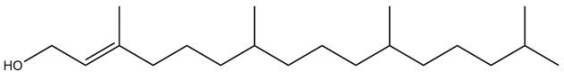
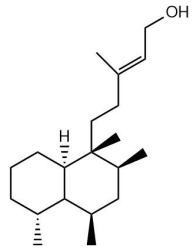
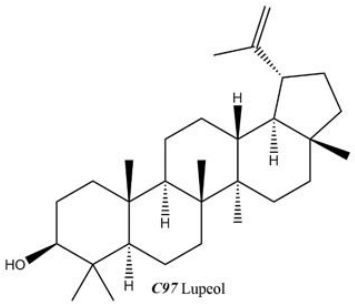
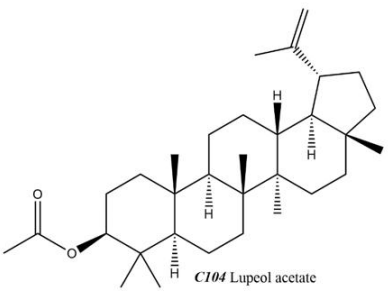
Class	Code of compound	Structure
Terpenes	C45	 ***C45*** alpha-Santalol
	C46	 ***C46*** delta-Cadinene
	C08	 ***C08*** Phytol
	C06	 ***C06*** 15-hydroxy-13-clerodene
	C97	 ***C97*** Lupeol
	C104	 ***C104*** Lupeol acetate

Table 3 Chemical structure of the compounds (*continued*)

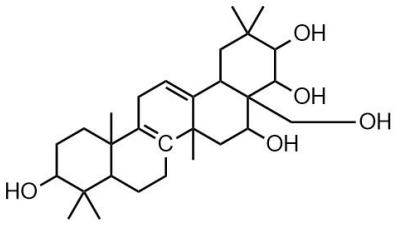
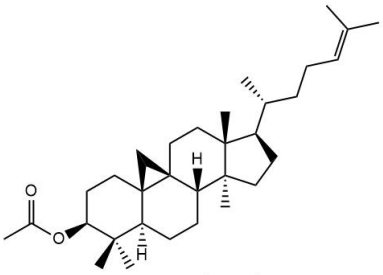
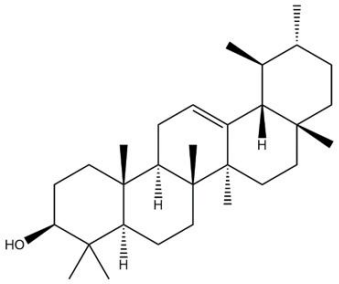
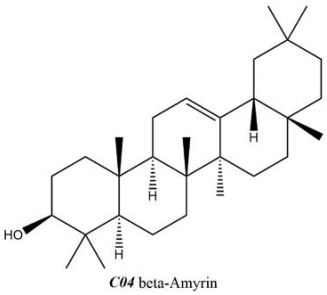
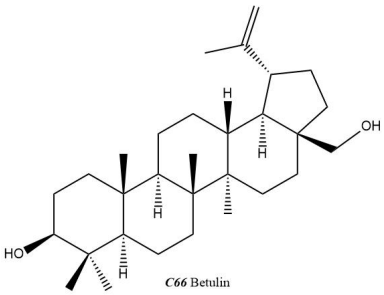
Class	Code of compound	Structure
	C110	 ***C110*** Barringtogenol C
	C110	 ***C110*** Cycloartenol acetate
Terpenes	C03	 ***C03*** alpha-Amyrin
	C04	 ***C04*** beta-Amyrin
	C66	 ***C66*** Betulin

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Table 3 Chemical structure of the compounds (*continued*)

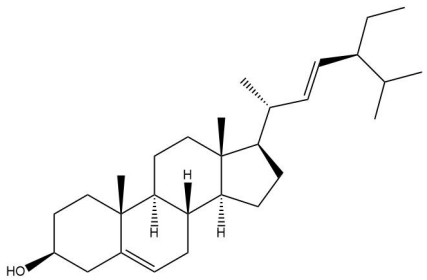
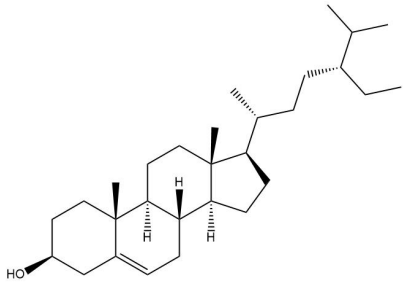
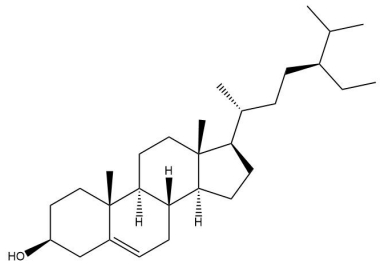
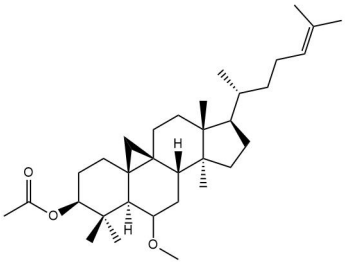
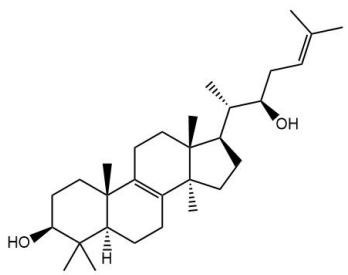
Class	Code of compound	Structure
Terpenes	C69	 ***C69*** Betulin
	C78	 ***C78*** beta-Sitosterol
	C79	 ***C79*** gamma-Sitosterol
	C61	 ***C61*** 3-O-acetyl-6-methoxy-cycloartenol
	C120	 ***C120*** Inotodiol

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Table 3 Chemical structure of the compounds (*continued*)

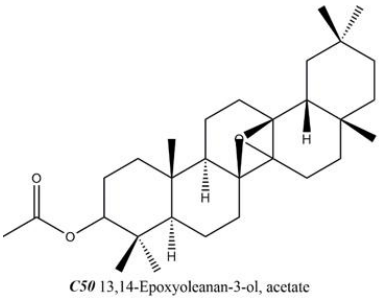
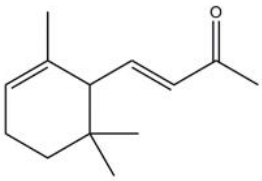
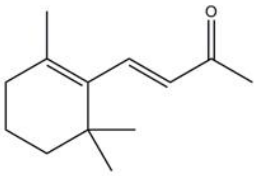
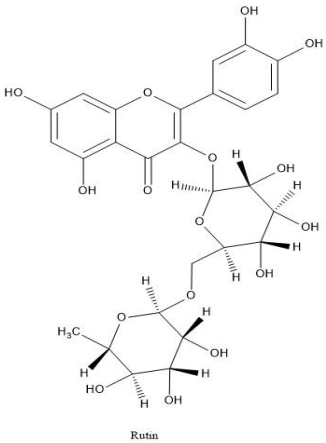
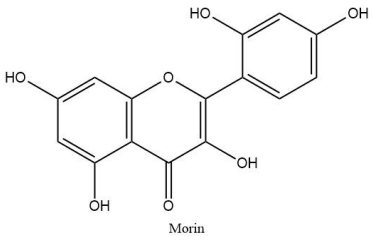
Class	Code of compound	Structure
Terpenes	C50	 ***C50*** 13,14-Epoxyoleanan-3-ol, acetate
	C90	 ***C90*** Trans-a-Ionone
	C77	 ***C77*** Trans-b-Ionone
Flavonoids	C92	 Rutin
	C96	 Morin

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Table 3 Chemical structure of the compounds (*continued*)

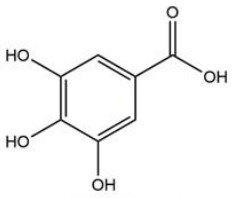
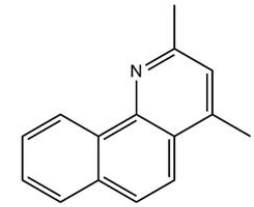
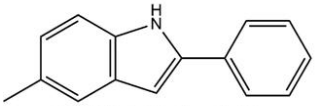
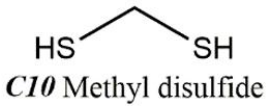
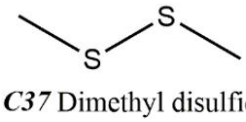
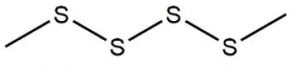
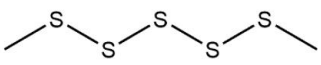
Class	Code of compound	Structure
Phenolic compounds	C106	 *C106* Gallic acid
	C48	 *C48* 1,3-Dimethyl-4-azaphenanthrene
Alkaloids		
	C64	 *C64* 5-Methyl-2-phenylindole
	C10	 *C10* Methyl disulfide
	C37	 *C37* Dimethyl disulfide
Sulphur compounds		
	C15	 *C15* Dimethyl trisulfide
	C68	 *C68* Dimethyl tetrasulfide

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Table 3 Chemical structure of the compounds (*continued*)

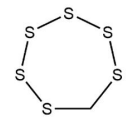
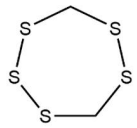
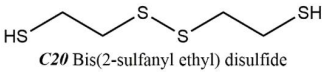
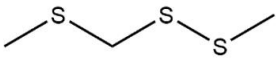
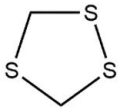
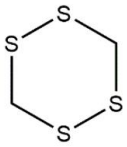
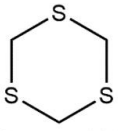
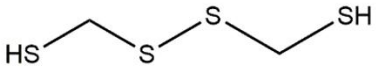
Class	Code of compound	Structure
Sulphur compounds	C40	 ***C40*** Hexathiepane
	C17	 ***C17*** Lenthionine
	C16	 ***C16*** 2,8-Dithianonane
	C25	 ***C25*** Methanethiol
	C20	 ***C20*** Bis(2-sulfanyl ethyl) disulfide
	C36	 ***C36*** 2,4-Dithiapentane
	C30	 ***C30*** 2,3,5-Trithiahexane
	C28	 ***C28*** 1,2,4-Trithiolane
	C33	 ***C33*** 1,2,4,5-Tetrathiane
	C34	 ***C34*** 1,3,5-Trithiane
	C35	 ***C35*** 2,3,5,6-Tetrathiapentane

Table 3 Chemical structure of the compounds (*continued*)

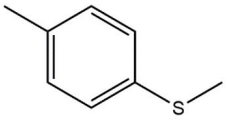
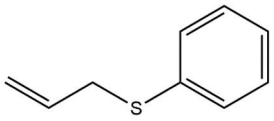
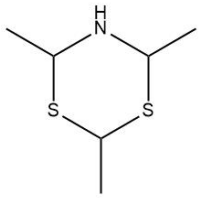
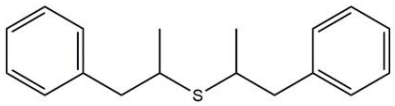
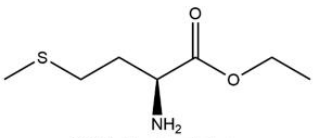
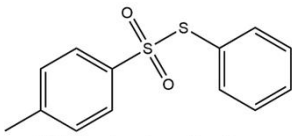
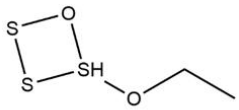
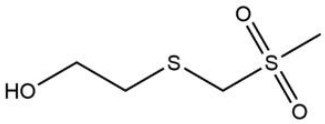
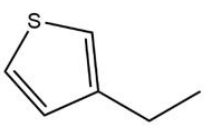
Class	Code of compound	Structure
	C22	 ***C22*** Methyl p-tolyl sulfide
	C109	 ***C109*** Allyl phenyl sulfide
	C63	 ***C63*** 5,6-Dihydro-2,4,6-trimethyl-4H-1,3,5-dithiazine
	C72	 ***C72*** Methyl-phenethyl sulfide
	C26	 ***C26*** Dimethyl sulfide
Sulphur compounds	C23	 ***C23*** Methionine ethyl ester
	C43	 ***C43*** S-Phenyl-p-toluene-thiosulfonate
	C44	 ***C44*** Trithiometoxymethane
	C27	 ***C27*** 3,5-Dithiahexanol-5,5-dioxide
	C60	 ***C60*** 3-Ethylthiophene

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Table 3 Chemical structure of the compounds (*continued*)

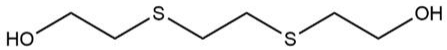
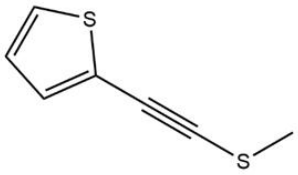
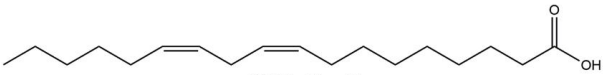
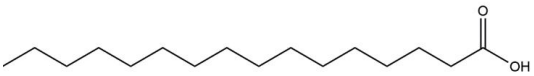
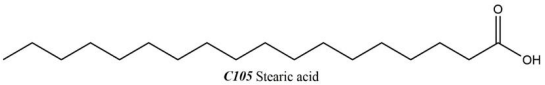
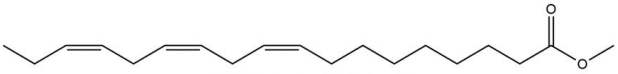
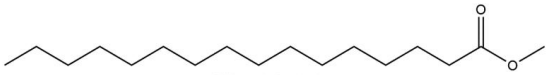
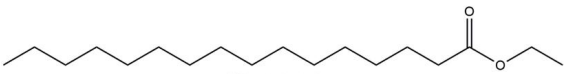
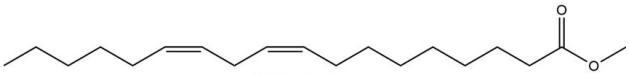
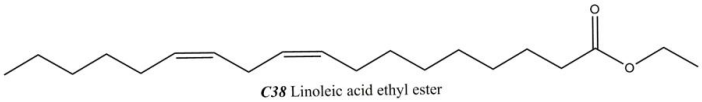
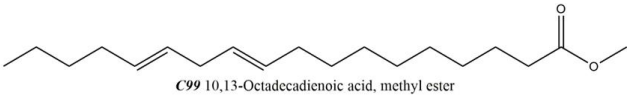
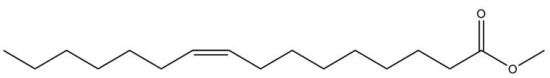
Class	Code of compound	Structure
	C31	 ***C31*** 3,6-Dithiaoctan-1,8-diol
Sulphur compounds	C91	 ***C91*** Thiophene,2-[(methylthio)ethynyl]
	C107	 ***C107*** Linoleic acid
	C100	 ***C100*** n-Hexadecanoic acid
	C105	 ***C105*** Stearic acid
	C19	 ***C19*** Methyl ester of linolenic acid
	C21	 ***C21*** Methyl palmitate
Fatty acids and derivatives	C73	 ***C73*** Ethyl palmitate
	C124	 ***C124*** Methyl linoleate
	C38	 ***C38*** Linoleic acid ethyl ester
	C99	 ***C99*** 10,13-Octadecadienoic acid, methyl ester
	C101	 ***C101*** Palmitoleic acid, methyl ester

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Table 3 Chemical structure of the compounds (*continued*)

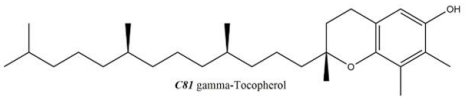
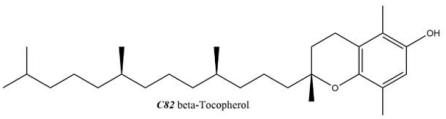
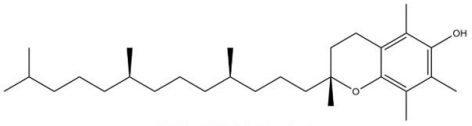
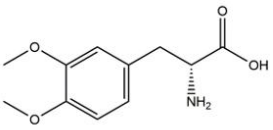
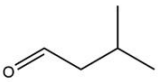
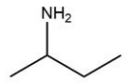
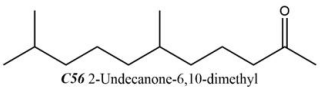
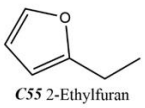
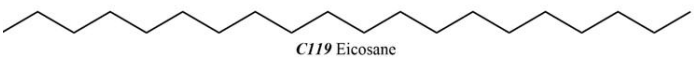
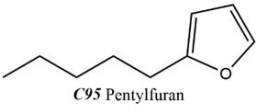
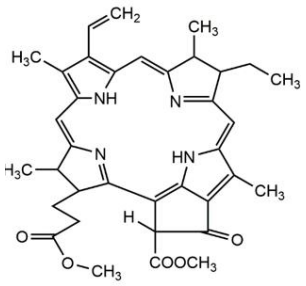
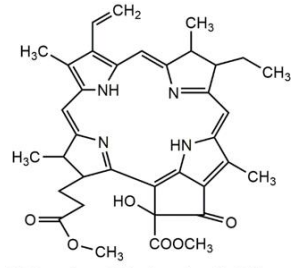
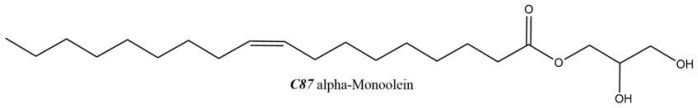
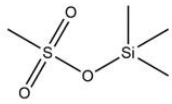
Class	Code of compound	Structure
Tocopherols	C81	 *C81* gamma-Tocopherol
	C82	 *C82* beta-Tocopherol
	C18	 *C18* Vitamin E (alpha-Tocopherol)
Aromatic and heterocyclic compounds	C57	 *C57* 3,4-Dimethoxy-D-phenylalanine
	C121	 *C121* Hexanal
	C29	 *C29* 3-Methylbutanal
	C54	 *C54* 2-Butanamine
Other compounds	C56	 *C56* 2-Undecanone-6,10-dimethyl
	C55	 *C55* 2-Ethylfuran
	C119	 *C119* Eicosane
	C95	 *C95* Pentylfuran

Table 3 Chemical structure of the compounds (*continued*)

Class	Code of compound	Structure
Other compounds	C1	 *C1* 7c-methoxypheophorbide a
	C2	 *C2* 7c-methoxy-10-hydroxypheophorbide a
	C87	 *C87* alpha-Monoolein
	C89	 *C89* Trimethylsilyl methanesulfonate

restricts its medicinal potential. Furthermore, the lack of these studies results in a lack of standardization regarding safe usage levels of the plant. These studies would not only enhance existing ethnopharmacological knowledge but also open new avenues for this species' medicinal and biotechnological application.

The reviewed data indicated that *G. integrifolia* exhibits significant antifungal, antibacterial, and antioxidant activity. Ethanolic extracts from the leaves demonstrated inhibition of *Candida albicans* and *Aspergillus* sp. at concentrations of 100 µg/mL ($P < 0.01$, Tukey test).

Regression analysis showed a positive correlation between sulfur-containing compounds and antifungal activity ($R^2 = 0.89$), reinforcing the hypothesis that these metabolites play a fundamental role in the plant's chemical defense.

Conclusion

G.integrifolia turns out to be a highly relevant species for Brazilian biodiversity and ethnopharmacology. Its botanical attributes and the richness of bioactive compounds in the vegetal material give it a broad range of traditional medicinal applications, as evidenced by the studies reviewed. Given the wide geographical distribution of *G. integrifolia* and its traditional use in several communities to treat various diseases, the need to carry out more detailed studies that isolate and characterize the bioactive compounds present in the plant became evident. These studies will validate the preexistent ethnopharmacological knowledge and open new possibilities for this species's medicinal and biotechnological application.

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