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Chemical characterization of essential oil from three Myrtaceae species from the Restinga de Jurubatiba National Park

Caracterização química do óleo essencial de três espécies de Myrtaceae do Parque Nacional da Restinga de Jurubatiba

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Abstract

The Myrtaceae family is recognized for its ecological, economic, and chemical importance, being one of the most representative in the Atlantic Forest and Restinga ecosystems. Despite this relevance, the chemical diversity of Myrtaceae species in the Restinga de Jurubatiba National Park (northern Rio de Janeiro State, Brazil) remains poorly understood. In this study, we investigated the essential oil composition of *Myrcia amazonica* DC., *Myrciaria floribunda* (H. West ex Willd.). O. Berg, and *Eugenia sulcata* Spring ex Mart., three species that occur in this ecosystem and have diverse traditional uses. Essential oils extracted from the leaves were analyzed using gas chromatography-mass spectrometry (GC-MS), allowing the identification of their main constituents. The results revealed distinct chemical profiles within the family. The major compounds were γ-muurolene (13.63%), δ-cadinene (12.75%), and bicyclogermacrene (10.96%) in *M. amazonica*; (E)-nerolidol (20.03%), 1,8-cineole (17.50%), and β-selinene (6.73%) in *M. floribunda*; and β-caryophyllene (24.72%), α-pinene (11.14%), and trans-calamenene (9.07%) in *E. sulcata*. This is the first report on the chemical composition of the essential oil of *M. amazonica*, providing new information for the genus *Myrcia*. Moreover, the comparative analysis highlights the presence of distinct chemical markers and reinforces the use of essential oil composition as a tool for assessing the potential of Restinga plants. Thus, this study characterizes the chemical composition of three native Brazilian species belonging to the taxonomic group Myrtaceae, aiding in the identification of components with biotechnological potential.

Resumo

A família Myrtaceae é reconhecida por sua relevância ecológica, econômica e química, sendo uma das mais representativas nos ecossistemas de Mata Atlântica e Restinga. Apesar dessa importância, a diversidade química de muitas espécies da família presentes no Parque Nacional da Restinga de Jurubatiba (PNRJ), localizado no norte do estado do Rio de Janeiro, Brasil, ainda é pouco conhecida. Neste estudo, investigamos a composição do óleo essencial de Myrcia amazonica DC., Myrciaria floribunda (H. West ex Willd.) O. Berg e Eugenia sulcata Spring ex Mart., três espécies que ocorrem nesse ecossistema e possuem usos tradicionais diversos. Os óleos essenciais extraídos das folhas foram analisados por cromatografia gasosa acoplada à espectrometria de massas (CG-EM) e detecção de ionização em chama (CG-DIC), permitindo a identificação de seus principais constituintes. Os resultados demonstraram perfis químicos distintos dentro da família. Os compostos majoritários foram γ-muuroleno (13,63%), δ-cadineno (12,75%) e biciclogermacreno (10,96%) em M. amazonica; (E)-nerolidol (20,03%), 1,8-cineol (17,50%) e β-selineno (6,73%) em M. floribunda; e β-cariofileno (24,72%), a-pineno (11,14%) e trans-calameneno (9,07%) em E. sulcata. Este é o primeiro relato da composição química do óleo essencial de M. amazonica, contribuindo com novas informações para o gênero Myrcia. Além disso, a análise comparativa evidencia a presença de marcadores químicos distintos e reforça a utilização da composição de óleos essenciais como ferramenta para avaliar o potencial de plantas de Restinga. Assim, este estudo caracteriza a composição química de três espécies nativas brasileiras pertencentes ao grupo taxonômico Myrtaceae, auxiliando na identificação de componentes com potencial biotecnológico.

Introduction

The Myrtaceae family comprises about 1.5% of known Angiosperms. It includes approximately 5,650 species, organized into 130 to 150 genera, which occur primarily in the Southern Hemisphere, particularly in South America, Australia, and tropical Asia, with additional occurrences in Africa and Europe (Grattapaglia et al., 2012). In Brazil, it is distributed in vegetation such as the Amazon Forest, Cerrado (Silva et al., 2005), and the Atlantic Forest (Soares-Silva, 2000), with 1,034 known species distributed across 23 genera, making it one of the most species-rich plant families. The family belongs to the order Myrtales, with approximately 40% of the species present in this order, and stands out for its global ecological and economic significance (Silva; Mazzini, 2016).

In the northern region of Rio de Janeiro State, the southern flank of the Paraíba River flows into a delta on an extensive coastal plain (Figure 1a). To preserve this environment, the Restinga de Jurubatiba National Park (PNRJ) was established by Decree on 29 April 1998, covering the coastal municipalities of Macaé, Carapebus, and Quissamã (Figure 2) (Folharini et al., 2014). The PNRJ extends for 44 km of ocean coastline and is home to eighteen coastal lagoons. It comprises ecosystems with high biodiversity, covers 14,860 ha, is part of the Atlantic Forest domain, and is fully protected (Instituto Socioambiental, 2021). Since the 19th century, naturalists have recorded observations about Brazil's coastal landscapes. The various types of vegetation reported by them can still be found today on the Jurubatiba sandbank. However, many years passed without further publications. As a result, the chemical diversity present in this ecosystem remains poorly understood (Gonçalves-Esteves; Dias, 2001). Approximately 40 species from families such as Myrtaceae, Orchidaceae, Rubiaceae, and Verbenaceae are utilized by the local population for various purposes, with medicinal use being the most notable (Araújo, 2000).

Among the species present in this ecosystem, *Myrcia amazonica* DC. (synonymy: *Aulomyrcia corymbosa* (DC.) O.Berg) is a non-endemic plant in Brazil distributed throughout the Amazon Rainforest, Atlantic Forest, and Cerrado (Santos et al., 2025). Popularly known as "camboim-mirim," *Myrcia amazonica* (Figure 1b) is poorly described, but there are reports of its traditional use in the treatment of diabetes and its antioxidant activity (Rocha et al., 2023; Cascaes et al., 2015). Antimicrobial, larvicidal, antiproliferative, antioxidant, anti-inflammatory, and antinociceptive biological activities have been described for this genus (Cascaes et al., 2015). From a botanical perspective, *Myrcia amazonica* is characterized by monopodial stem growth and the presence of simple trichomes. Its leaves are elliptic to ovate, with the midrib on the adaxial surface fully canaliculate to partially canaliculate and distally flattened toward the petiole; the abaxial surface is glabrous. Bracts or cataphylls subtending the leaves at the nodes are absent. Inflorescences occur axillarily, arising from rounded branchlets, with a pyramidal and alternate arrangement, and lanceolate bracteoles subtending the flowers. The flowers exhibit equal-theca anthers, a glabrous floral disc, and a glabrous hypanthium that is turbinate to obconical in shape; the sepals are completely free, with two locules, and the calyx opens without tearing. The fruits are globose, with calyx lobes that may persist (marcescent) or become caducous (Santos et al., 2025).

The *Myrciaria floribunda* (H. West ex Willd.) O. Berg (synonymy: *Eugenia floribunda* H. West ex Willd.), known as "Camboim" or "Cambuí", occurs in different biomes and ecosystems, including coastal sandbank areas (Figure 1c). Its fruits are among the most appreciated in the PNRJ, due to their sweet and slightly acidic taste. They are used in infusions to flavor "cachaça" or consumed fresh. Different flavonoids and triterpenes have already been isolated and identified (Rocha et al., 2023), and their insecticidal action against *Dysdercus peruvianus* and *Oncopeltus fasciatus* has been evaluated (Tietbohl et al., 2014). Regarding its botanical description, *M. floribunda* features a smooth-barked stem and glabrous leaves, which are lanceolate to ovate in shape, with an acuminate or acute apex, and a base that varies from acute to obtuse, characterized by conspicuous lateral venation. The leaves display translucent glands and may occasionally present a puberulent indumentum. Inflorescences are arranged in glomerules, with sessile flowers, glabrous calyx, and conate bracteoles that persist after anthesis. The fruits are globose and glabrous, containing one seed (Reflora, 2025).

Another noteworthy species is *Eugenia sulcata* Spring ex. Mart. (synonymy: *Stenocalyx sulcatus* (Spring ex Mart.) O. Berg) which is endemic to Brazil and occurs in the Atlantic Forest domain, found in rainforest and sandbank vegetation, and known by various popular names, such as "murta-preta" or "pitanguinha" (Figure 1d) (Santos et al., 2009). Found in the PNRJ, it has traditional use in the manufacture of jams because its fruits are edible (Santos et al., 2009; Rocha et al., 2023). In addition to demonstrating biological activity against *D. peruvianus* and *O. fasciatus, E. sulcata* caused mortality and delayed the development of *Rhodnius prolixus*. Its leaf essential oil has also been reported to inhibit the enzyme acetylcholinesterase (Rocha et al., 2023). In terms of its botanical description, *E. sulcata* presents elliptic to ovate leaves, with cuneate to obtuse bases and acute to acuminate apices. The leaf blades are chartaceous to coriaceous, with revolute margins and a sulcate midrib on the adaxial surface, in addition to a marginal vein. The inflorescences are arranged in auxotelic racemes, bearing persistent bracts. Flowers display caducous bracteoles, a costate and glabrous hypanthium, calyces open in the floral bud, four sepals and four petals. The fruits are globose, ribbed, and glabrous, with caducous bracteoles. Seeds are single, with fused cotyledons in the embryo (Reflora, 2025).

The evaluation of the chemical composition of essential oils, which are predominantly composed of terpenes and their derivatives, reveals distinct chemical profiles that influence their biological properties and potential technological applications. Furthermore, factors such as seasonality, soil conditions, and extraction techniques can influence the chemical composition of these oils, resulting in different chemical profiles and biological activities (Silveira et al., 2022). The species *Myrcia amazonica, Myrciaria floribunda,* and *Eugenia sulcata* display differentiated chemical profiles in their essential oils, as reported in the literature, highlighting their diversity. Previous studies indicate that *M. floribunda* has a sesquiterpene-rich composition, with major compounds including 1,8-cineole, (E)-nerolidol, and β-selinene (Machado et al., 2025). In contrast, *E. sulcata* is characterized by β-caryophyllene as the main component, followed by α-pinene and

trans-calamenene (Da Silva et al., 2024). Regarding *M. amazonica*, although the genus is one of the most representative within the family in Brazil, no records exist on the chemical composition of its essential oil. Therefore, this study is the first to investigate it. Nevertheless, other species within the genus *Myrcia* show a prominent presence of sesquiterpene hydrocarbons, such as β-caryophyllene, as recurrent constituents in their essential oils (Ferreira et al., 2020). From this perspective, this study characterized the chemical composition of three native Brazilian plants belonging to the taxonomic group Myrtaceae.



Figure 1. Species of the Restinga de Jurubatiba National Park; 2a - Aerial view of the vegetation (Source: Leandro Rocha, 2025); 2b - *Myrcia amazonica* (Source: Marcelo Santos, 2025); 2c - *Myrciaria floribunda* (Source: Francisco Machado, 2025); 2d - *Eugenia sulcata* (Source: Dianna da Silva, 2025).

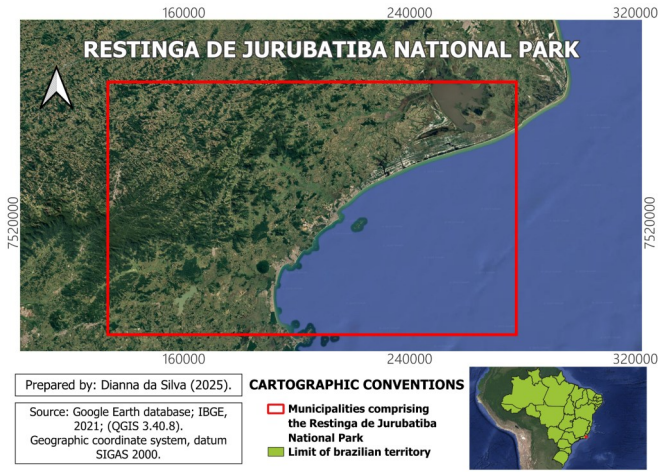


Figure 2. Maps of municipalities comprising the Restinga de Jurubatiba National Park (Source: Dianna da Silva, 2025).

Materials and methods

Collection of plant material

The leaves were collected during the summer in the Restinga de Jurubatiba National Park, Carapebus, Rio de Janeiro. Specimens of all species were identified by botanist Dr. Marcelo Guerra Santos and deposited in the herbarium of the State University of Rio de Janeiro (UERJ). The species *Myrcia amazonica* (RFFP: 19.802) was collected at coordinates 22º 13.0740' S 41º 35.1660 W and 22° 13.0460' S 41° 35.1530' W, *Myrciaria floribunda* (RFFP: 13.789) was collected at coordinates 22° 12.998' S 41° 35.018' W and 22° 12.986' S 41° 35.007' W, and *Eugenia sulcata* (RFFP: 13.788) was collected at coordinates 22° 12.984' S 41° 35.008' W and 22° 13.050'S 41° 35.121' W. The collection of plant material was authorized by SISGen (A8941F4) and SISBio/ICMBio (13659-21).

Essential oil extraction

Essential oils were extracted from fresh plant leaves by hydrodistillation using a modified Clevenger apparatus (5,000 mL capacity) for 3 hours. The obtained oils were dried over anhydrous sodium sulfate and stored in amber glass bottles under refrigeration at –20 °C. Fresh leaves of *Myrcia amazonica* (1,460 g), *Myrciaria floribunda* (400.1 g), and *Eugenia sulcata* (4,950 g) were used for extraction. For plant materials exceeding 400 g, successive extractions were performed to obtain the essential oil fractions.

Chemical characterization of essential oils

Chemical characterization was performed by gas chromatography-mass spectrometry (GC-MS) and flame ionization detector (GC-FID) under the following conditions: helium was used as carrier gas, with a flow rate of 1 mL/min in split injection mode at a ratio of 1:20. The oven heating program was started at 60 °C and increased at a rate of 3 °C/min until reaching 290 °C. The sample, previously diluted in dichloromethane at a concentration of 1 mg/mL, was injected with 1 µL (injector temperature: 260 ºC) into an RTX-5MS column (RESTEK, 0.25 mm inner diameter × 30 m length × 0.25 µm film thickness). Mass spectrometry was performed with electron impact ionization at 70 eV and a scan rate of 1 scan per second. The gas chromatograph used was a SHIMADZU GCMS-QP500 (Shimadzu Corporation, Kyoto, Japan), and the flame ionization detector was a GC-2014 (Shimadzu Corporation, Kyoto, Japan).

Chemical identification was achieved by comparing the obtained mass spectra and calculated Arithmetic Index (AI) values with those reported in the literature (Adams, 2007). The fragmentation profiles were also cross-referenced with the mass spectral database of the National Institute of Standards and Technology (NIST, Gaithersburg, MD, USA). The AI was determined by interpolating the retention times of a standard mixture of n-alkanes (C7–C40) with those of the analyzed compounds under identical chromatographic conditions. Relative abundance was assessed using GC-FID under the same analytical conditions as GC-MS, applying the peak area normalization method.

Results and Discussion

Analysis of the Yield and Chemical Composition of Essential Oils

The yield of the essential oil of *Myrcia amazonica* in the present study was 0.42 % (w/w) and exhibited a slightly yellowish coloration. Twenty-eight substances were found in the essential oil, of which a total of 74.88% were identified (Table 1). The main substances were γ-muurolene (13.63%), δ-cadinene (12.75%), and bicyclogermacrene (10.96%) (Figure 3a). The only identified compounds in the chemical analysis were sesquiterpene hydrocarbons, which were also observed in *Myrcia tomentosa*, with the major substances being germacrene D (17.62%), (E)-caryophyllene (15.05%), and δ-cadinene (6.42%) (Oliveira et al., 2023). For *Myrcia sylvatica*, in addition to hydrocarbon sesquiterpenes, oxygenated sesquiterpenes were found, with the major constituents being (Z)-α-trans-bergamotene (24.57%), α-sinensal (13.44%), and (Z)-α-bisabolene (8.33%) (de Moraes et al., 2022a).

The γ-muurolene is a cyclic sesquiterpene hydrocarbon also found in small amounts in the species *M. multiflora* (0.12%) (Ferreira et al., 2021) and *M. paivae* (0.26%) (de Moraes et al., 2022b). No studies describing the action of the isolated compound were found; however, for essential oils rich in γ-muurolene, such as *Piper anonifolium*, toxic effects on practical insects have been described (Mendonça et al., 2024). For *Spiranthera odoratissima*, moderate microbial activity has been found (Chaibub et al., 2013). δ-cadinene is also a hydrocarbon sesquiterpene present not only in other *Myrcia* species such as *M. paivae* (1.03%) (de Moraes et al., 2022b), *M. loranthifolia* (3.80%) (dos Santos et al., 2023) and *M. tomentosa* (6.42%) (Oliveira et al., 2023) but also in other species of the Myrtaceae family such as *Myrciaria floribunda* (1.17%) and *Eugenia sulcata* (1.65%) present here in this study. The antimicrobial activity of δ-cadinene against *Listeria monocytogenes* and its potential to inhibit biofilm formation (Qin et al., 2024) and as an acetylcholinesterase (AChE) inhibitor (Salihu et al., 2024) have been reported in the literature. Bicyclogermacrene is a hydrocarbon sesquiterpene also recurrent in other *Myrcia* species such as *Myrcia sylvatica* (3.34%) (Oliveira et al., 2023) and *M. loranthifolia* (9.62%) (dos Santos et al., 2023). This terpene has already demonstrated larvicidal activity (Govindarajan; Benelli, 2016) and, for an essential oil rich in this substance, has shown anti-inflammatory activity (Soares et al., 2022).

The essential oil obtained from the fresh leaves of *Myrciaria floribunda* yielded 0.71% (w/w). It showed a translucent, slightly yellowish appearance. Chemical analysis identified 85.50% of the total composition, distributed as 8.95% monoterpene hydrocarbons, 19.84% oxygenated monoterpenoids, 36.68% sesquiterpene hydrocarbons, and 20.03% oxygenated sesquiterpenoids. Among the identified constituents, the major ones were (E)-nerolidol (20.03%), 1,8-cineole (17.50%), and β-selinene (6.73%) (Figure 3b). These compounds were described by Machado et al. (2025) as the three main components of *M. floribunda*, with a predominance of 1,8-cineole (13.03%), followed

Table 1. Chemical characterization of *Myrcia amazonica* volatile oil performed by GC-MS and GC-FID. a- Retention time; b-Arithmetic Index reported; c- Arithmetic Index from the literature; NI - Not identified.

	Retetion time[a]	Arithmetic index $_{Rep}$ [b]	Arithmetic index $_{Lit}$ [c]	Substance	Relative abundance (%)
1	22.697	1333	NI	NI	0.66
2	23.338	1348	NI	NI	0.62
3	24.586	1377	1374	α-copaene	4.86
4	25.146	1390	1389	β-elemene	4.24
5	25.941	1409	1409	α-gurjenene	2.75
6	26.446	1422	1417	(E)-caryophyllene	6.82
7	27.650	1451	NI	NI	0.68
8	27.732	1453	1454	(E)-β-farnesene	1.08
9	27.918	1457	NI	NI	0.63
10	28.125	1462	1458	allo -aromadendrene	5.08
11	28.598	1474	NI	NI	2.84
12	28.712	1477	NI	NI	0.82
13	28.978	1483	1478	γ-muurolene	13.63
14	29.301	1491	NI	NI	0.60
15	29.410	1493	1496	Viridiflorene	7.57
16	29.584	1498	1500	Bicyclogermacrene	10.96
17	29.685	1500	1500	α-muurolene	2.00
18	30.480	1520	1522	δ-cadinene	12.75
19	30.657	1525	1528	Zonarene	3.14
20	31.027	1534	NI	NI	1.11
21	32.516	1572	NI	NI	0.85
22	33.135	1588	NI	NI	4.07
23	33.466	1596	NI	NI	2.37
24	33.553	1598	NI	NI	2.22
25	33.876	1607	NI	NI	1.90
26	34.737	1630	NI	NI	1.90
27	35.323	1646	NI	NI	2.22
28	35.757	1657	NI	NI	1.62
	TOTAL IDENTIFIED				74.88
	Sesquiterpene hydrocarbons	74.88			

by β-selinene (12.13%) and (E)-nerolidol (13.48%). In other studies, carried out in sandbank areas in the same environment as the present study, 1,8-cineole (10.7%), β-selinene (13.3%), (E)-nerolidol (15.4%), and zonarene (7.7%) were identified as the main constituents (Machado et al., 2023), 1,8-cineole (38.4%), γ-himachalene (7.0%), α-selinene (7.4%), β-selinene (8.4%) and (E)-nerolidol (5.5%) (Tietbohl et al., 2020).

Studies with *M. floribunda* have demonstrated a range of biological activities. In vitro studies have shown that the ethyl acetate extract of *M. floribunda* exhibits antiproliferative activity against several cancer cell lines and demonstrates antioxidant activity associated with a wide variety of phenolic and flavonoid compounds (Tietbohl et al., 2017). Furthermore, the bark extract of *M. floribunda* has been shown to exhibit anti-inflammatory effects and reduce abdominal pain in mice (Santos et al., 2020). The work of Tietbohl et al. (2014) demonstrated its effect against agricultural pests, such as *Oncopeltus fasciatus* and *Dysdercus peruvianus*, with LC50 values of 112.44 and 309.64 µg/insect, respectively, after one day of treatment. The essential oil and leaf extract showed a potent larvicidal effect against *Aedes aegypti*, with an LC_{50} of 201.73 ppm for the essential oil and 15.85% for the aqueous extract (Santos et al., 2025). This effect against *Aedes aegypti* was also observed in the work of Machado et al. (2025). In this study, the larvicidal effect was enhanced by the use of essential oil encapsulated in nanoemulsions with LC_{50} values of 233.65 (199.9–272.5) µg/mL after 48 h of exposure. Additionally, nanoemulsions of *M. floribunda* essential oil revealed molluscicidal potential LC_{50} of 48.11 µg/mL, 29.66 µg/mL, and 47.02 µg/mL in embryos, juveniles and adult mollusks of *Biomphalaria glabrata* after 48 h, respectively, and LC_{50} of 83.88 µg/mL for cercariae of *Schistosoma mansoni* after 2 h (Machado et al. 2023).

The major components identified in the essential oil of *M. floribunda* are cited with diverse potentialities and biological effects. (E)-nerolidol has been associated with potential anti-inflammatory, antioxidant, antimicrobial, antibiofilm, antioxidant, and antiparasitic effects and plays a very active role in the defense system of some plants (Chan et al., 2016). The 1,8-cineole is frequently associated with mucolytic, antimicrobial, and anti-inflammatory activities (Pries et al., 2023). It is mentioned as an alternative to conventional fungicides against different *Penicillium* spp., as it does not cause the development of resistance (Tahiri et al., 2022). Other studies also indicate that the essential oil from *Lippia alba* leaves, rich in 1,8-cineole (70.01%), induces mortality by ingestion in *Nasutitermes corniger* with LC_{50} of 18.25 and 8.4 µL/g for workers and soldiers, respectively, and for *Sitophilus zeamais*, with LC_{50} of 0.297 µL/g (Lima et al., 2021). The β-selinene, although with fewer studies on its isolated action, is cited as a component of several essential oils, such as *Callicarpa macrophylla*, which presents antioxidant action (Chandra

Table 2. Chemical characterization of *Myrciaria floribunda* volatile oil performed by GC-MS and GC-FID. a- Retention time; b- Arithmetic Index reported.; c- Arithmetic Index from the literature; NI - Not identified.

	Retetion time[a]	Arithmetic index $_{Rep}$ [b]	Arithmetic index $_{Lit}$ [c]	Substance	Relative abundance (%)
1	8.352	988.30	988	Myrcene	0.55
2	9.393	1017.87	1014	α-cerpinene	0.78
3	9.662	1024.83	1020	p-cymene	0.66
4	9.851	1029.73	1029	Limonene	1.95
5	9.973	1032.88	1026	1,8-cineole	17.50
6	10.947	1058.10	1054	γ-terpinene	5.01
7	12.052	1086.72	NI	NI	0.70
8	12.542	1099.40	NI	NI	0.94
9	16.689	1195.91	1199	γ-terpineol	2.34
10	24.581	1377.33	1374	α-copaene	2.41
11	26.442	1421.51	1417	(E)-caryophyllene	1.78
12	27.917	1457.27	1452	α-humulene	0.81
13	28.652	1475.10	1476	β-chamigrene	1.06
14	29.215	1488.75	1492	σ-selinene	2.24
15	29.297	1490.74	1489	β-selinene	6.73
16	29.440	1494.20	1496	Viridiflorene	1.22
17	29.589	1497.82	1498	α-selinene	4.23
18	29.869	1504.83	NI	NI	3.91
19	30.470	1520.10	1522	δ-cadinene	1.17
20	30.538	1521.83	1528	Zonarene	2.66
21	30.748	1527.17	NI	NI	0.76
22	31.053	1534.92	NI	NI	2.99
23	31.216	1539.06	1537	α-cadinene	6.18
24	31.414	1544.09	1545	Selina-3,7(11)-diene	6.19
25	32.080	1561.02	1561	(E)-nerolidol	20.03
26	32.198	1564.02	NI	NI	2.46
27	33.134	1587.80	NI	NI	0.98
28	35.868	1660.25	NI	NI	1.76
	TOTAL IDENTIFIED				85.50
	Monoterpene hydrocarbons	8.95			
	Oxygenated monoterpene	19.84			
	Sesquiterpene hydrocarbons	36.68			
	Oxygenated sesquiterpene	20.03			

et al., 2017). β-selinene is one of the three major sesquiterpenes in *Bocageopsis multiflora* essential oil, demonstrating potent larvicidal activity against *Aedes aegypti* with LC_{50} values of 40.8 and 39.4 µg/mL in 24 and 48 h, respectively, as well as adulticidal activity with efficacy with an LC_{50} of 12.5 µg/mL (Silva et al., 2024).

The *Eugenia sulcata* essential oil exhibited a clear, yellowish appearance and yielded 1%. According to the chemical characterization, 30 substances were identified (Table 3), representing a total of 96.17% of the substances found. The major substances were β-caryophyllene (24.72%), α-pinene (11.14%), and trans-calamenene (9.07%) (Figure 3c). Previous studies have described the composition of the essential oil in leaves as formed of sesqui- and monoterpenoids, with many similarities among them, but also some differences. The first description of the chemical composition of *E. sulcata* essential oil was published in 2004, based on a specimen collected at Jureia Beach, São Paulo, southern Brazil. In this work, the yield was 0.1%, which is too low compared to the present work. The monoterpene α-pinene (34.2%) was observed as the major constituent, followed by sesquiterpenoids β-caryophyllene (15.0%) and globulol (11.8%) (Apel et al., 2004). In 2010, Ramos et al. provided the first description of a specimen collected in Rio de Janeiro, at Restinga de Jurubatiba National Park, the same location as the present work and the subsequent ones, with a yield of 1.5%. Monoterpenes still remain the majority class, this time represented by 1,8-cineole (19.6%). A high abundance of α-pinene (16.9%) and β -pinene (14.5%) was also observed (Ramos et al., 2010). Those works only related oil's phytochemical properties, without evaluating possible biological applications.

Bringing it into a biotechnological context, in 2012, beyond the chemical characterization, anticholinesterasic activity was also analyzed. Sesquiterpenes were the major compounds (55.1%), highlighting β-caryophyllene (24.6%), in addition to the previously

Table 3. Chemical characterization of *Eugenia sulcata* volatile oil performed by GC-MS and GC-FID. a- Retention time; b- Arithmetic Index reported.; c- Arithmetic Index from the literature; NI - Not identified.

	Retention time	Arithmetic index	Arithmetic index $_{Lit}$ [c]	Substance	Relative abundance (%)
1	6.726	934.12	932	α-pinene	11.14
2	8.099	979.87	974	β-pinene	7.24
3	9.666	1024.94	1022	o-cymene	0.47
4	9.856	1029.85	1025	Sylvestrene	1.87
5	9.977	1032.99	1026	1,8-cineol	6.2
6	16.695	1196.05	NI	NI	0.90
7	23.343	1348.52	1348	α-cubebene	1.12
8	24.317	1371.19	1373	α-ylangene	0.38
9	24.588	1377.5	1374	α-copaene	3.86
10	25.149	1390.55	1389	β-elemene	0.80
11	25.942	1409.38	1409	α-gurjunene	0.39
12	26.462	1421.99	1417	β-caryophyllene	24.72
13	26.923	1433.17	1431	β-gurjunene	1.98
14	27.925	1457.47	1452	α-humulene	6.48
15	28.123	1462.27	1464	9-epi-(E)-caryophyllene	1.00
16	28.713	1476.58	1478	γ-muurolene	2.50
17	29.298	1490.76	1488	β-selinene	2.25
18	29.424	1493.82	NI	NI	0.79
19	29.592	1497.89	1498	α-selinene	2.74
20	29.686	1500.18	1500	α-muurolene	1.06
21	30.013	1508.49	1508	Germacrene A	0.66
22	30.264	1514.87	1513	γ-cadinene	1.65
23	30.475	1520.23	1522	α-cadinene	4.22
24	30.589	1523.13	1521	trans-calamenene	9.07
25	31.029	1534.31	1528	cis-calamenene	1.74
26	31.365	1542.85	1544	α-calacorene	0.35
27	32.991	1584.17	1582	Caryophyllene oxide	2.28
28	33.776	1604.33	NI	NI	1.00
29	34.059	1611.9	NI	NI	0.38
30	35.770	1657.63	NI	NI	0.76
	TOTAL IDENTIFIED				96.17
	Monoterpene hydrocarbons	20.72			
	Oxygenated monoterpene	6.20			
	Sesquiterpene hydrocarbons	66.97			
	Oxygenated sesquiterpene	2.28			

mentioned monoterpenes α- and β-pinene (17.2 and 10.9%). Furthermore, the essential oil was able to inhibit acetylcholinesterase, exhibiting an IC_{50} of 4.66 ± 0.48 μg/mL, higher than other species from *Eugenia* genus (Lima et al., 2012). This suggests a possible insecticidal mechanism, since cholinergic overstimulation can lead to paralysis and subsequent death in insects. (Rattan et al., 2010), action which was evaluated *in vivo* on *Dysdercus peruvianus* and *Oncopeltus fasciatus*, two species of agricultural pest insects (Gonzalez et al., 2014), and *Rhodnius prolixus,* Chagas disease vector, and *Rhipicephalus* (*Boophilus*) *microplus,* a parasitic mite that feeds on the blood of cattle, which represents serious public health and livestock economy problems (Feder et al., 2019). Other studies succeeded in approaching biological activities from oil and its derived products, such as a valuation of hemodynamic parameters and cardiovascular effects in rats (Santos et al., 2013; 2014), anti-inflammatory (receptor P2X7R) (Magalhães et al., 2022), and fungal inhibitory against *Aspergillus sp.* (Da Silva et al., 2024). All these works resume the presence of β-caryophyllene (18.65-34.4%) as the main metabolite, with variations of the following compounds, from α-pinene (6.75-17.3%), and β-pinene (4.00-10.2%) (Santos et al., 2013; 2014; González et al., 2014; Feder et al., 2019; Da Silva et al., 2024), to δ-cadinene (10.02%) (Magalhães et al., 2022).

β-Caryophyllene is a natural hydrocarbon sesquiterpene found in many plants as a specialized metabolic product. It's an important constituent of several essential oils, including cannabis, peppermint, and cloves. Notably, various interesting biological activities have been described in the literature (e.g., anti-inflammatory, neuroprotective, antioxidant, antimicrobial, and antidepressant effects) (Janadri et al., 2025). This type of sesquiterpene, due to its unique configuration, serves as a versatile base for various molecule types, including substances with significant biotechnological potential (Gyrdymova; Rubtsova, 2022). On the other hand, monoterpenes α- and β-pinene are bicyclic hydrocarbons isomers exhibited in many plants, highlighting coniferous trees. The α-pinenes are considered an essential intermediate in the synthesis of other monoterpenoids, such as limonene and menthol, in the flavor and fragrance industry (Bahare et al., 2019). Their biological actions are extensively reported to be antimicrobial, antitumor, gastroprotective, insecticidal, antimalarial, and other important effects (Allenspach; Steuer, 2021). In the case of trans-calamenene, first time described as composing *E. sulcata* essential oil in Da Silva

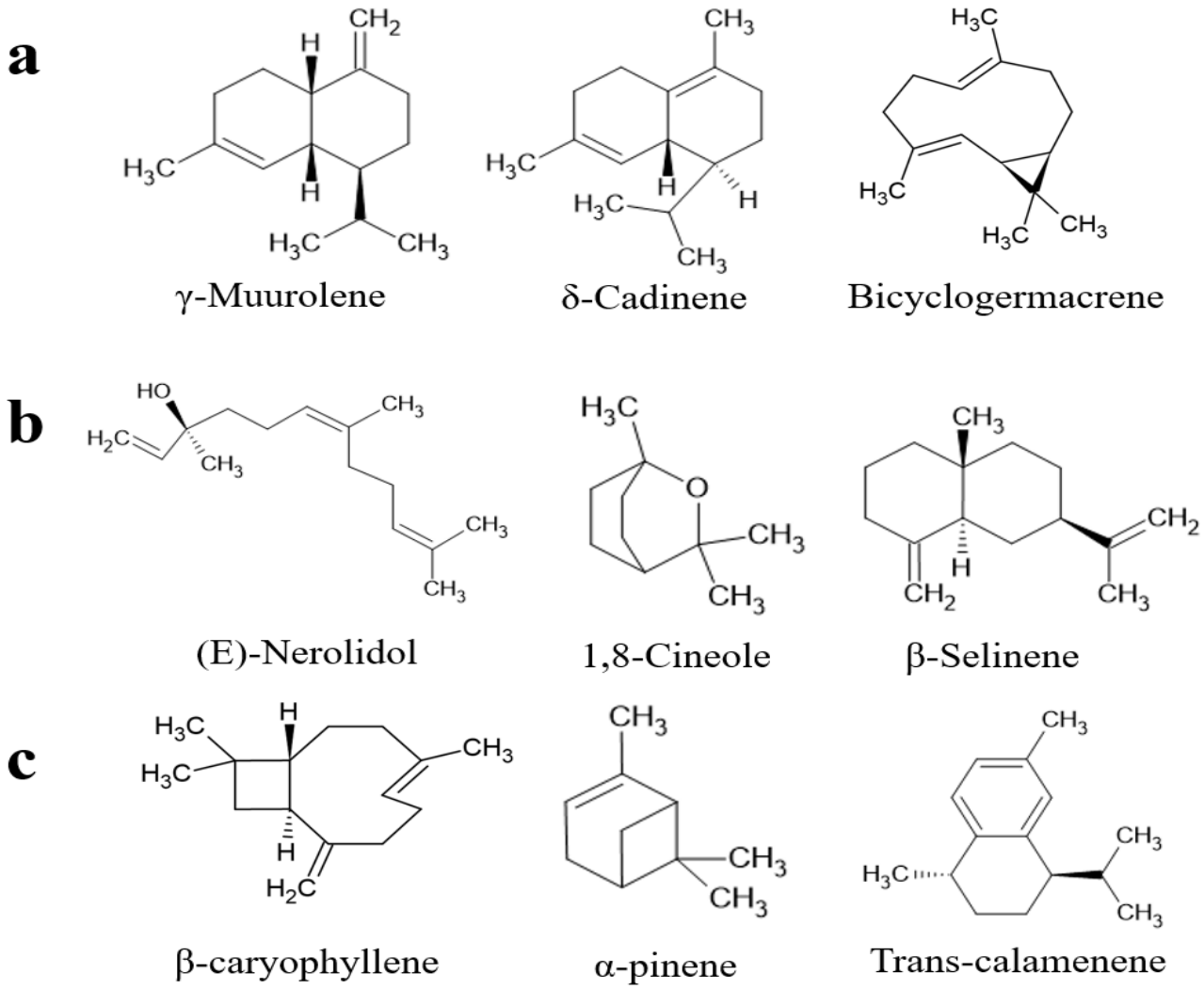


Figure 3: Chemical structures of the main compounds of the essential oil of (a) *Myrcia amazonica*, (b) *Myrciaria floribunda*, and *(c) Eugenia sulcata* (Alícia Carvalho, 2025

et al. (2024), and which is also present in this study, few works describe the biological efficacy of this isolated sesquiterpene. However, its cadinane-type skeleton demonstrates potential antifungal (Shi et al., 2019) and anti-inflammatory effects (Qin et al., 2024), making it an interesting substance to study in more depth.

The differences in the chemical profile of a plant species are associated with several factors associated with the expression of multiple metabolic pathways, whose modulation depends on environmental factors such as soil nutrients, temperature, water availability, seasonality, circadian rhythm, ultraviolet radiation, air pollution, altitude, and interactions with other organisms, including pathogens and predators (Gobbo-Neto et al., 2007; Qian et al., 2024). In this context, 'restingas' stand out for constituting unique ecosystems, strongly influenced by specific external conditions, such as wind, salinity, temperature, and other environmental factors, which can potentially accentuate these chemical variations in the plant species in these environments (Machado et al., 2025).

Conclusion

The chemical characterization of the essential oils of *Eugenia sulcata*, *Myrcia amazonica*, and *Myrciaria floribunda* revealed distinct phytochemical profiles that reflect the biochemical diversity within the Myrtaceae. While *E. sulcata* and *M. amazonica* were composed primarily of sesquiterpene hydrocarbons, *M. floribunda* presented monoterpenes and sesquiterpenes, with a focus on oxygenated compounds. These findings represent the first report on the chemical composition of *M. amazonica* and contribute to the knowledge of Restinga de Jurubatiba National Park species. Overall, the study provides valuable information for identifying of bioactive constituents with biotechnological potential, supporting future research in pharmacology, agriculture, and natural product development.

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Author Contributions

Conceptualization: ASC, DSS, LAP. Data curation: ASC, DSS, FPM, MGS, LR. Formal analysis: ASC, DSS, FPM, DF. Funding acquisition: FPM, LR. Investigation: ASC, DSS, RICF, FPM. Methodology: ASC, DSS, FPM. Project administration: ASC, DSS, LAP, FPM. Resources: FPM, LR. Software: ASC, DSS, FPM. Supervision: LAP, FPM, LR. Validation: FPM, VCRV, MGS, LR. Visualization: MGS, LR. Writing – original draft: ASC, DSS, RICF, LAP, VCRV. Writing – review and editing: ASC, DSS, RICF, FPM, LR.

Conflict of Interest

The authors declare there are no conflicts of interest to disclose.

Data Availability

There are no additional data disponible by the authors.

Ethical Compliance

Not applicable.

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