

## Analysis of the volatile oils from three species of the gender *Syzygium*

Análise dos óleos voláteis de três espécies do gênero *Syzygium*

Análisis de los aceites volátiles de tres especies del género *Syzygium*

Received: 05/21/2021 | Reviewed: 05/29/2021 | Accept: 06/02/2021 | Published: 06/16/2021

**Amanda Silva Reis**

ORCID: <https://orcid.org/0000-0003-1070-2041>  
Universidade Federal de Goiás, Brazil  
E-mail: amanda\_s\_reis@hotmail.com

**Liliane de Sousa Silva**

ORCID: <https://orcid.org/0000-0001-9497-7573>  
Universidade Federal de Goiás, Brazil  
E-mail: ssliliane@gmail.com

**Christiane França Martins**

ORCID: <https://orcid.org/0000-0002-8177-0458>  
Universidade Federal de Goiás, Brazil  
E-mail: franh.chris@gmail.com

**José Realino de Paula**

ORCID: <https://orcid.org/0000-0002-4424-7692>  
Universidade Federal de Goiás, Brazil  
E-mail: pjrpaula@gmail.com

### Abstract

The species *Syzygium cumini*, *Syzygium malaccense* and *Syzygium jambos*, belong to the family Myrtaceae and are popularly known, respectively, by jambolan, red jambo and yellow jambo. These species are used in traditional medicine to treat diabetes mellitus, asthma, bronchitis, diuresis, gastrointestinal and respiratory infections, properties antipyretic, anti-inflammatory, antirheumatic and several other uses. The objective of this work is to identify and quantify the volatile compounds in the leaves of *S. cumini*, *S. malaccense* and *S. jambos*. The volatile oils were obtained by hydrodistillation using Clevenger apparatus and analyzed by Gas Chromatography Coupled to Mass Spectrometry (GC-MS). It was possible to identify 44 compounds present in the volatile oils of the leaves, being 20 compounds of *S. cumini*, 9 compounds of *S. malaccense* and 15 compounds of *S. jambos*. The major compounds present in the species *S. cumini* were  $\alpha$ -terpineol,  $\beta$ -caryophyllene and  $\alpha$ -humulene; for the species *S. malaccense* were aristolochene,  $\gamma$ -himachalene and  $\delta$ -amorphene; and for *S. jambos* species were  $\beta$ -cariofillene, (E,E)- $\alpha$ -farnesene and cariofillene alcohol. The species *S. cumini*, *S. malaccense* and *S. jambos* showed considerable differences in terms of volatile compounds, it is important to know their constituents in order to promote further studies focused on their medicinal potential.

**Keywords:** *Syzygium cumini*; *Syzygium malaccense*; *Syzygium jambos*; Essential oil; Chemiodiversity; Jambo.

### Resumo

As espécies *Syzygium cumini*, *Syzygium malaccense* e *Syzygium jambos*, pertencem à família Myrtaceae e são conhecidas popularmente, respectivamente, por jambolan, jambo vermelho e jambo amarelo. Essas espécies são utilizadas na medicina tradicional para tratamento de diabetes mellitus, asma, bronquite, diurese, infecções do trato gastrointestinal e respiratórias, possuem propriedades antipiréticas, anti-inflamatórias, antirreumáticas e também são utilizadas na indústria alimentícia devido aos seus frutos. O objetivo deste trabalho é identificar e quantificar os compostos voláteis nas folhas de *S. cumini*, *S. malaccense* e *S. jambos*. Os óleos voláteis foram obtidos por hidrodestilação utilizando aparelho de Clevenger e analisados por Cromatografia Gasosa Acoplada à Espectrometria de Massa (CG/EM). Foram identificados 44 compostos presentes nos óleos voláteis das folhas, sendo 20 compostos do *S. cumini*, 9 compostos do *S. malaccense* e 15 compostos do *S. jambos*. Os compostos majoritários presentes na espécie *S. cumini* foram,  $\alpha$ -terpineol,  $\beta$ -cariofileno e  $\alpha$ -humuleno; já para a espécie *S. malaccense* foram, aristolocheno,  $\gamma$ -himachaleno e  $\delta$ -amorfenol; para espécie *S. jambos* foram,  $\beta$ -cariofileno, (E,E)  $\alpha$ -farneseno e álcool cariofileno. As espécies *S. cumini*, *S. malaccense* e *S. jambos* apresentaram diferenças consideráveis quanto aos compostos voláteis, sendo importante conhecer os seus constituintes para impulsionar mais estudos voltados ao seu potencial medicinal.

**Palavras-chave:** *Syzygium cumini*; *Syzygium malaccense*; *Syzygium jambos*; Óleo volátil; Quimiodiversidade; Jambo.

### Resumen

Las especies *Syzygium cumini*, *Syzygium malaccense* e *Syzygium jambos*, pertenece a la familia Myrtaceae y normalmente son conocidas como jambolan, jambo rojo y jambo amarillo. Estas especies son utilizadas en la

medicina tradicional y son empleadas en varios tratamientos como en el de diabetes mellitus, del asma, bronquitis, diuresis, infecciones del tracto gastrointestinal y el respiratorio, además tienen propiedades antipiréticos, antiinflamatorios, antirreumáticos y otras muchas utilidades. El objetivo de esta pesquisa es identificar y cuantificar los compuestos volátiles en las hojas de *S. cumini*, *S. malaccense* y *S. jambos*. Estos aceites fueron extraídos a través de hidrodestilación utilizando el aparato de Clevenger y se hizo el análisis por Cromatografía Gaseosa acoplada a la Espectrometría de Masa (CG/EM) con ello se identificaron 44 compuestos presentes en los aceites volátiles de las hojas, siendo 20 compuestos de *S. cumini*, 9 compuestos de *S. malaccense* y 15 compuestos de *S. jambos*. Los compuestos mayoritarios presentes encontrados en la especie *S. cumini* fueron el  $\alpha$ -terpineol,  $\beta$ -caryophyllene y  $\alpha$ -humulene. Otros de los compuestos aristolocheno,  $\gamma$ -himachaleno y  $\delta$ -amorfeno fueron identificados en la especie *S. malaccense*. En la especie *S. Jambos* están presentes el  $\beta$ -caryophyllene, (E, E)  $\alpha$ -farneseno y alcohol cariofileno como compuestos mayoritarios. Las especies de *S. cumini*, *S. malaccense* y *S. jambos* presentan diferencias considerables cuanto a sus compuestos volátiles, cabe resaltar la importancia de conocer sus constituyentes para promover y desarrollar más estudios volcados a su potencial medicinal.

**Palabras clave:** *Syzygium cumini*; *Syzygium malaccense*; *Syzygium jambos*; Aceite volátil; Quimiodiversidad; Jambo.

## 1. Introduction

Medicinal plants have global importance, in their fresh and processed form, in addition to being widely used in traditional medicine due to the bioactive molecules present in their composition (Hajimehdiipoor et al., 2014). These plants play a vital role in the prevention and treatment of diseases, being used by more than 80% of the world population to meet primary health needs (WHO, 2013). In addition, more than 50% of new drugs developed and approved for commercialization are derived from modified products of medicinal plants or their active constituents (Teng & Shen, 2015).

Active compounds can be classified as volatile and non-volatile, non-volatile include tannins, phenols, flavonoids, coumarins, chromones, xanthenes, lignans, neolignans, quinones, saponins, alkaloids, methylxanthines and volatile compounds, also called volatile oils, are defined as a product resulting from distillation by steam vapor and have as a starting point some part of the plant in question. They are generally pleasant in aroma, acid and spicy taste, generally colorless, lipophilic, oily-looking, volatile and soluble in an organic solvent. Its composition includes terpenic hydrocarbons, ethers, oxides, peroxides, ketones, phenols, simple and terpenic alcohols, aldehydes, organic acids, furans, lactones, coumarins, varying their concentrations (Simões et al., 2007).

Volatile oils have commercial and industrial importance, being used by the food, pharmaceutical, perfumery and cosmetic industries and are part of the healing action of medicinal plants (Trancoso, 2013). Volatile oils are not restricted to specific taxonomic groups, as they occur widely in the plant kingdom (Sangwan et al., 2001), so it is important to know and identify the chemical compounds present in these oils, as they confer pharmacological properties, requiring identification and quantification of these chemical compounds (Santos et al. 2021).

Among the species of plants producing volatile oils with greater prominence, is the family Myrtaceae, also known as family Myrtle, which has about 145 genera and more than 5,970 species (The plant list, 2021), being the genus *Syzygium* one of the genera that stand out for their phytochemical composition and various therapeutic properties, such as antimicrobial, antiseptic, antiviral, antidiabetic, anti-inflammatory action, in addition to its use for the treatment of respiratory disorders and stomach problems (Cock & Cheesman, 2018). *Syzygium cumini* (L.) is commonly known as black jambo, black plum, jambolana, among other popular names, originating in India and regions in southern Africa (Ayyanar & Subash-Babu, 2012) and is distributed in several regions of Brazil such as, North, Northeast and Southeast (Migliato et al., 2007). *S. cumini* has anti-cancer, hypoglycemic, antimicrobial properties, among others (Ruan, Zhang & Lin, 2008; Ahmed et al., 2019). *Syzygium malaccense* (LO), also known as red apple and mountain apple, is originally from Malaysia, but has spread to several tropical regions, such as Brazil (Augusta et al., 2010), has reports of hypoglycemic activities (Bairy, Sharma & Shalini, 2005) and antioxidants (Batista et al., 2017). *Syzygium jambos* (L.), also called yellow jambo, is originally from Southeast Asia, but is currently distributed in all tropics. It has antipyretic and anti-inflammatory properties is traditionally used to treat hemorrhages,

sypphilis, leprosy, wounds, ulcers and lung diseases (Kuiate et al., 2007; Nawwar et al., 2016).

The objective of the present work was to carry out the identification and quantification of the volatile compounds present in the species *S. cumini*, *S. malaccense* and *S. jambos* collected in the region of Rio Vermelho - Goiás (GO), Brazil.

## 2. Methodology

### 2.1 Collect botanical material and obtaining of volatile oil

The collect of botanical material (leaves) of *Syzygium malaccense* and *Syzygium cumini* were carried out in November 2020, in Itapuranga-Goiás, whereas the sample of *Syzygium jambos* was collected in October 2020 in Guaraíta-Goiás. All samples were collected in the morning before 10 AM. *Syzygium cumini* at the time of collection had ripe and green fruits, while *Syzygium malaccense* had flowers and *Syzygium jambos* had fruits.

### 2.2 Analysis of the chemical composition of volatile oil in leaves of the genus *Syzygium*

Experimental research was based on the technique described in the Farmacopeia Brasileira (2010), for the extraction of volatile oils, 110g of the dried leaves of *S. jambos*, 90g of the dried leaves of *S. cumini* and 117g of the dried leaves of *S. malaccense* were used. These leaves were crushed through an industrial blender and immediately subjected to hydrodistillation by steam dragging in a Clevenger type apparatus for 2 hours. The volatile oil was desiccated using anhydrous sodium sulfate ( $\text{Na}_2\text{SO}_4$ ) and subsequently stored in amber flasks, hermetically sealed, free of impurities and stored in a freezer for later use. The volatile oils obtained from the leaves of the three species of the *Syzygium* genus were subjected to gas phase chromatographic analysis coupled with mass spectrometry (GC-MS) on the QP2010A apparatus. A fused silica capillary column of the DB5 type was used, with a flow rate of 1 mL/min of helium, this being the gas used in the entrainment, the programmed temperature for heating was 60°C/2 min; 3°C min<sup>-1</sup>/240°C; 10°C min<sup>-1</sup>/280°C; 280°C/10min, the ionization energy was 70 eV. The injection volume of 1 µL was used in each sample diluted in hexane ( $\text{C}_6\text{H}_{14}$ ) in a proportion of 1mg: 20 ml. The identification of the chemical components was carried out by comparing the mass spectra and sample retention indices and with the findings in the literature according to Adams (2017) and in comparison, with the QP2010A device library, which uses the Nist reference (1999), for those not found through Adams (2017).

## 3. Results and Discussion

The yield of volatile oils from *S. cumini*, *S. malaccense* collected in Itapuranga-GO and *S. jambos* collected in Guaraíta-GO, were 0.76%, 0.05% and 0.24%, respectively.

Leaf yield of *S. cumini* was reported to be 0.56% in Cairo-Egypt (Mohamed, Ali & El-Baz 2013), 0.05% in Rio de Janeiro (Siani et al., 2013), in Maranhão (Brazil) 0.52% and in Pakistan 0.03% (Hanif et al., 2020). As for the leaves of *S. malaccense*, a yield of 0.15% was reported in Ifé in Nigeria (Karioti, Skaltsa & Gbolade 2007), 0.0297% in the city of Kuala Selagor (Malaysia) (Ismail, Ismail & Lajis et al., 2010) and 0.03% in Paraná (Brazil) (Feltrin et al., 2020). And for the leaves of *S. jambos*, information on their yield was not found in the literature. The variation in the yield values of these 3 species of *Syzygium* is due to the fact that volatile oils are intrinsically related to regional, biotic and abiotic factors. Atmospheric parameters such as climate, temperature and precipitation are related to the chemical diversity of volatile compounds, as well as seasonal aspects (Cruz et al., 2014; Verma, Padalia & Chauhan 2014).

Through the analysis of volatile oils of the 3 species of *Syzygium* by GC-MS it was possible to identify a total of 44 (100%) compounds (Table 1). In the volatile oil, of *S. cumini* 20 compounds were identified, of *S. malaccense* 9 compounds and *S. jambos*, 15 compounds (Figure 1).

**Table 1** - Constituents present in the essential oils of the leaves of three species of *Syzygium* extracted via hydrodistillation.

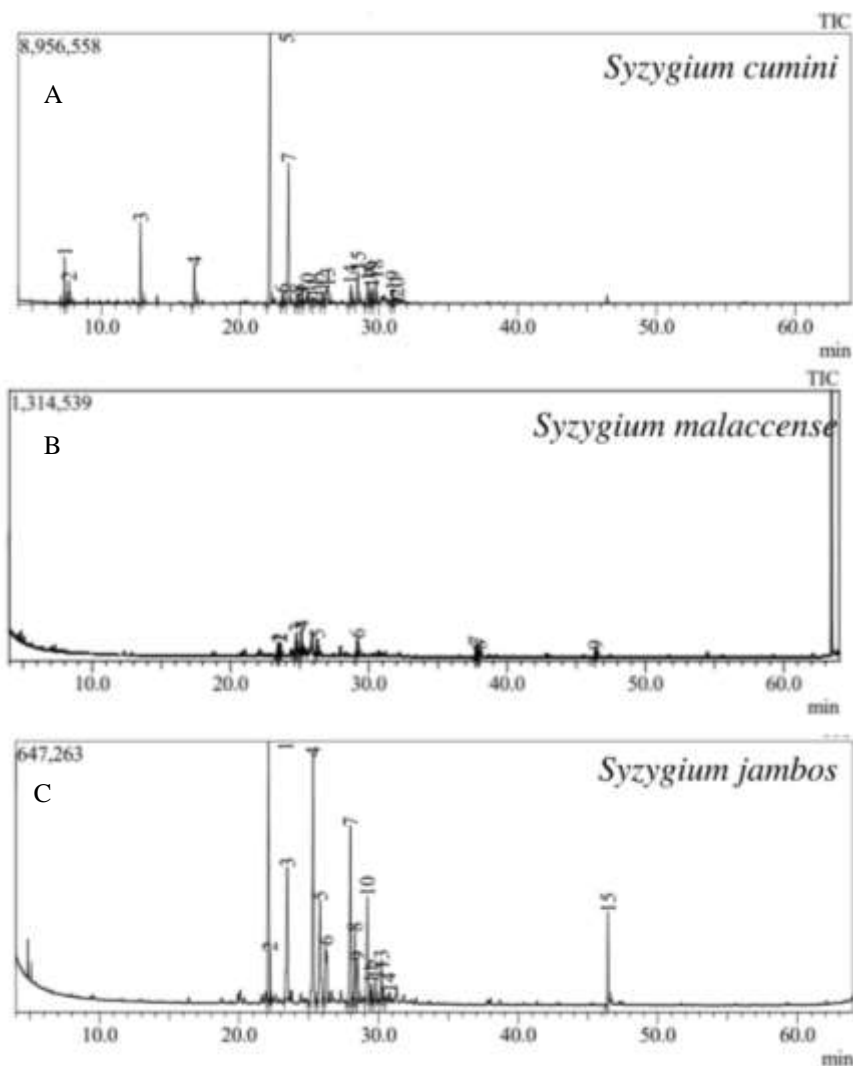
KLit	KIExp	Constituents	<i>S. cumini</i> (%)	<i>S. malaccense</i> (%)	<i>S. jambos</i> (%)
1032	1035	(Z)- $\beta$ -ocimene	2.77	-	-
1044	1045	(E)- $\beta$ -ocimene	1.29	-	-
1186	1187	$\alpha$ -terpineol	8.02	-	-
1283	1281	Isobornyl acetate	4.63	-	-
1415	1415	4,8- $\alpha$ -epoxy-Caryophyllane	-	-	1.28
1417	1414	$\beta$ -Caryophyllane	37.65	-	17.67
1433	1436	endo-Arbozol	0.92	-	-
1445	1446	Myltayl-4(12)-ene	-	11.43	-
1452	1447	$\alpha$ -humulene	18.37	-	10.66
1453	1449	Geranyl acetone	-	9.92	-
1471	1463	4,5-di-epi-aristolochene	1.10	-	-
1475	1471	$\gamma$ -gurjunene	0.89	-	-
1481	1479	$\gamma$ -himachalene	-	16.59	-
1487	1488	Aristolochene	-	20.06	-
1489	1481	$\beta$ -selinene	1.80	-	-
1495	1493	$\gamma$ -amorphene	0.95	-	-
1505	1505	$\beta$ -bisabolene	-	-	9.24
1505	1492	(E,E)- $\alpha$ -farnesene	-	-	16.10
1511	1517	$\delta$ -amorphene	-	11.79	-
1515	1508	10-epi-Italicene ether	1.34	-	-
1522	1518	$\delta$ -cadinene	3.39	-	-
1567	1562	palustrol	2.16	-	-
1570	1561	Caryophyllenyl alcohol	-	-	11.45
1571	1570	Caryolan-8-ol	-	-	4.94
1577	1575	trans-(IPP vc OH) Sesquisabinene hydrate	-	-	3.70
1582	1575	Caryophyllene oxide	4.38	-	-
1592	1593	Viridiflorol	3.04	10.67	6.40
1602	1593	Ledol	-	-	8.10
1608	1600	Humulene epoxide II	1.71	-	1.07
1618	1608	epi-cedrol	2.81	-	1.46
1640	1634	epi- $\alpha$ -muurolol	-	-	0.96
1651	1642	pogostol	1.55	-	-
1666	1650	14-hydroxy-(Z)-Caryophyllene	1.23	-	-
1846	1834	(2E,6E)-Farnesyl acetate	-	10.10	-
2100	2107	n-Heneicosane	-	-	4.88
-	1620	Isolongifolan-8-ol*	-	-	2.09
-	1841	2-pentadecanone*	-	4.63	-
-	2107	Phytol*	-	4.81	-
Total identification			100	100	100
		<b>Class</b>	<b><i>S. cumini</i> (%)</b>	<b><i>S. malaccense</i> (%)</b>	<b><i>S. jambos</i> (%)</b>
		Monoterpenes	8.69	0	0
		Oxygenated monoterpenes	8.02	0	0
		Sesquiterpenes	64.15	59.87	53.67
		Oxygenated sesquiterpenes	18.22	10.67	41.45
		Others (alcohol, alkane, ketone, ester)	0.92	29.46	4.88

Subtitle: KILit = published Kovats retention index. KIExp = retention retention Kovats determined experimentally.

\* = Compounds identified by the QP2010A device library, Nist, 1999. Source: Authors.

Table 1 shows the analyses components of the essential oil of the 3 species of *Syzygium* with their respective retention times, retention index and percentage of normalized area. Of these, we have the majority and minority components, which are, respectively,  $\beta$ -Caryophyllane (37.65%), *S. cumini*; Aristolochene (20.06%), *S. malaccense*, and  $\beta$ -Caryophyllane (17.67%), *S. jambos*.

**Figure 1** - Chromatogram of volatile oils from three species of *Syzygium* analyzed by CG/MS. (A) *S. cumini*, (B) *S. malaccense* and (C) *S. jambos*.



Source: Authors.

The majority of the 3 species of *Syzygium* have sesquiterpene hydrocarbons, in which they showed a percentage of volatile oil composition among the species *S. cumini*, *S. malaccense* and *S. jambos*, respectively of 64.15%, 59.87% and 53.67%. The chromatograms results showed 20 peaks (A), 9 peaks (B) and 15 peaks (C), thus indicating the existence of 20 compounds, 9 compounds and 15 compounds, respectively (Figure 1).

In some published works, Dias et al. (2013), found monoterpene hydrocarbons (87.12%) and oxygenated monoterpenes (5.34%) as being the major class in the leaves of *S. cumini*. Mohamed, Ali & El-Baz (2013), found monoterpene hydrocarbons, oxygenated monoterpenes and oxygenated sesquiterpenes as the majority classes. Hanif et al. (2020) found monoterpene hydrocarbons (27%), oxygenated monoterpenes (26.27%), sesquiterpene hydrocarbons (20.95%) and oxygenated sesquiterpenes (18.13%).

In the literature, there are also reports of the classes of volatile compounds from *S. malaccense*, in which Karioti, Skaltsa & Gbolade (2007), found 41.6% of monoterpene hydrocarbons and 25.5% of sesquiterpene hydrocarbons, already Lawal et al. (2014), reported that monoterpene hydrocarbons, corresponded to 79.9% of the volatile oil composition of the leaves. Feltrin et al. (2020), found 68.76% of sesquiterpenes and 29.12% were oxygenated sesquiterpenes.

Regarding the classes that make up the volatile oil of *S. jambos*, there are few reports in the literature, but a study by Ghaareb et al. (2017), analyzed the leaves of this species and found that most of the compounds identified belonged to the class of sesquiterpene hydrocarbons, which corroborates with the compounds found in this work.

According to the literature cited above, the majority class common in the species of *S. cumini* and *S. malaccense* were mainly monoterpene hydrocarbons, which differs from the present study, in which the majority class common in all species (*S. cumini*, *S. malaccense* and *S. jambos*) were the sesquiterpene hydrocarbons and only the species *S. cumini* presented compounds belonging to the monoterpene class (8.69%).

In this work, most compounds were considered those with a content  $\geq 5\%$ . In the species of *S. cumini* were,  $\beta$ -Caryophyllene (37.65%),  $\alpha$ -terpineol (8.02%), and  $\alpha$ -humulene (18.37%). For the species of *S. malaccense*, the major compounds were aristolochene (20.06%),  $\gamma$ -himachalene (16.59%),  $\delta$ -amorphone (11.79%), miltail-4(12)-eno (11.43%), viridiflorol (10.67%), (2E, 6E)-farnesyl acetate (10.10%) and geranyl acetone (9.92%). Finally, for the *S. jambos* species, the major compounds were  $\beta$ -caryophyllene (17.67%), (E,E)- $\alpha$ -farnesene (16.10%), caryophyllene alcohol (11.45%),  $\alpha$ -humulene (10.66%),  $\beta$ -bisabolene (9.24%), ledol (8.10%) and viridiflorol (6.40%). In the 3 species of *Syzygium* under study, we can observe the variety of chemical compounds, the only compound present in the three species being viridiflorol.

In the literature, there are some reports of the identification of volatile compounds from these three species in different regions. The volatile compounds from *S. cumini* leaves collected in Cairo-Egypt, were  $\alpha$ -pinene (32.32%),  $\beta$ -pinene (12.44%), trans-Caryophyllene (11.19%), 1,3,6 -octatriene (8.41%) and  $\Delta$ -3-careno (5.55%) (Mohamed, Ali & El-Baz, 2013). In samples collected in São Luís, Maranhão-Brazil, the majorities were  $\alpha$ -pinene (31.85%), (Z)- $\beta$ -ocimene (28.98%), (E)- $\beta$ -ocimene (11.71%),  $\beta$ -pinene (5.57%) and (E) - $\beta$ -Caryophyllene (5.02%) (Dias et al., 2013). In the samples collected in Rio de Janeiro-Brazil, the major compounds identified were  $\alpha$ -pinene (22.2%), limonene (7.30%), cis- $\beta$ -ocimene (10.2%), trans- $\beta$ -ocimene (5.88%),  $\alpha$ -terpineol (7%),  $\beta$ -Caryophyllene (9.45%) and  $\alpha$ -humulene (5.50%) (Siani et al., 2013). One of the main common compounds among the literature records for *S. cumini* is  $\alpha$ -pinene, but this compound was not found in the present work. However, the samples collected in the Rio Vermelho region shared common compounds with the samples collected in Rio de Janeiro and São Luís, the compounds (Z)- $\beta$ -ocinene and  $\beta$ -karyophyllene, and the compounds trans- $\beta$ -ocimene,  $\alpha$  -terpineol and  $\alpha$ -humulene in samples from Rio de Janeiro.

In relation to *S. malaccense*, the volatile oil from its leaves collected in Ifé, Nigeria, is mainly composed of, p-cymene (13.5%), (-)- $\beta$ -Caryophyllene (9.0%), (-)- $\beta$ -pinene (8.0%),  $\alpha$ -terpineol (7.5%), (+)- $\alpha$ -pinene (7.3%), terpene-4-ol (5.5%) and  $\gamma$ -terpinene (5.0%) (Karioti, Skaltsa & Gbolade, 2007). In samples, of the volatile oil from the leaves of *S. malaccense* collected in Kuala Selagor (Selagor), the major compounds were hexanoic acid (12.16%), methyl salicylate (8.27%), 3-hexen-1-ol (7.81%), 1-octen-3-ol (5.89%) and n-hexadecanoic acid (5.07%) (Ismail, Ismail & Lajis, 2010). Feltrin et al. (2020), identified the major compounds being,  $\alpha$ -cubebene (5.78%),  $\beta$ -Caryophyllene (6.56%),  $\beta$ -copaene (5.51),  $\Delta$ -cadinene (5.27%),  $\alpha$  -bulnesene (5.98%), trans-sesquisabinene (7%), sphaulenol (10.25%) in samples collected in Paraná-Brazil. It is observed that none of the major compounds reported by the literature are present in this work for *S. malaccense*, not even in a minor form, and a common compound among the studies reported in the literature was  $\beta$ -Caryophyllene.

In samples of *S. jambos* fruits collected in Marseille-France, linalool (23%), (E) cinnamyl alcohol (21%), geraniol (7.30%) and 3-phenylpropanol (6) were identified as major compounds, 80% (Vernin et al., 1991). In two samples collected in

the city of Rio Verde and Nova América, in the State of Goiás - Brazil, the major compounds were  $\beta$ -Caryophyllene (9.46-10.86%),  $\alpha$ -humulene (5.57-7.07%),  $\alpha$ -zingibirene (5.02-17.73), butylated hydroxytoluene (5.79-32.82%), Caryophyllene alcohol (5.28-17.14%), cariolan-8-ol (6.29 % -10.75%), Caryophyllene oxide (5.05%), tujopsan-2- $\alpha$ -ol (5.48-12.19%) and n-heneicosane (5.51-22.56%) (Rezende et al., 2013). In samples of leaves of *S. jambos* collected in Giza-Egypt, have the major presence of  $\delta$ -cadinene (10.85%), cumaldehyde (10.75%),  $\beta$ -hymachalene (6.40%), isocariophyllene (6,39%), naphthalene (5.64%),  $\beta$ -cadinene (5.63%), alloaromadendrene (5.41%) and  $\gamma$ -gurjunene (5.27%) (Ghareeb et al. 2017). It is observed that the main compounds present in both France and Egypt are different and are not part of the compounds found in the samples of this work, but in the nine main compounds identified by Rezende et al. (2013), in Goiás-Brazil, three are present in the samples collected, these being the compounds  $\beta$ -caryophyllene,  $\alpha$ -humulene and caryophyllene alcohol.

The variability of the chemical composition of the volatile oils of the different *Syzygium* species, as well as others, are linked to regional, genetic, physiological aspects such as periods of fruiting, flowering and reproductive rest, water stress and ecological factors such as the herbivore, biome, type of soil and available nutrients, in addition to the difference in temperature, solar irradiation, climate and rainfall (Cruz et al., 2014, Domingos et al., 2020).

The volatile constituents found in this study corroborate the constituents that are commonly found in several plants of the Myrtaceae family and belonging to the *Syzygium* genus, such as *Syzygium aromaticum* (Raina et al., 2001), Guinea-Bissau (Noudogbessi et al., 2008), *Syzygium densiflorum* (Saranya et al., 2012), *Syzygium calophyllifolium* (Vignesh et al., 2013) and *Syzygium benthamianum* (Deepika et al., 2013).

The compounds present in these species have pharmacological relationships already reported in the literature, such as  $\alpha$ -terpineol that has anticancer activity (Haassan et al., 2010), gastroprotective (Souza et al., 2011), antimicrobial (Park et al., 2012) and antidiarrheal (Negreiros et al., 2019).  $\beta$ -Caryophyllene has properties registered as a local anesthetic (Ghelardini et al., 2001), anti-inflammatory (Dahham et al., 2015), anticonvulsant (De Oliveira et al., 2016) and antibacterial (Moo et al. 2020). Viridiflorol, a common compound among the species studied, is registered as having anti-inflammatory, antioxidant and antimycobacterial properties (Trevizan et al., 2016). The compound  $\alpha$ -humulene, has biological properties registered as antitumor (Legault et al., 2003), anti-inflammatory (Fernandes et al., 2007) and antimicrobial against *Bacteroides fragilis* (Jang, Rhee & Eom, 2020). We can relate the biological activities of these compounds with those mentioned by popular use and preliminary pharmacological studies of extracts, oils and fractions of the species *S. cumini*, *S. malaccense* and *S. jambos*, which justifies some medicinal properties of the studied species.

#### 4. Conclusion

The present study promoted the complete identification of the volatile compounds of the studied species and identified their major compounds, which allows future studies of the biological and pharmacological activities of these components. It can be concluded that the three species of jambo (*S. cumini*, *S. malaccense* and *S. jambos*) present significant differences regarding the chemical constitution of volatile compounds and their major components. It was observed that viridiflorol is the only component that appears in the three species studied. It is important to know the chemical composition of the plants to demonstrate that there is a foundation in the use of these plants in traditional and popular medicine, since their chemical components are what give these plants the various medicinal properties and so that they can be used in the production of pharmaceutical inputs.

It is possible, therefore, in future studies to assess whether inferences in the rainfall regime can influence the concentration of some components and not others. If the variations observed in the results obtained for each sample are indicative that a complex network of environmental factors and/or conditions, such as temperature, humidity, duration and

intensity of solar irradiations, interactions with pollinators and predators, are influencing the composition of the oil and not just the rain regime.

## Acknowledgments

The authors are grateful this work was financially supported by the following Brazilian research funding agencies: Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Financiadora de Estudos e Projetos (FINEP), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Fundação de Apoio à Pesquisa da Universidade Federal de Goiás (FUNAPE), and Fundação de Amparo à Pesquisa do Estado de Goiás (FAPEG).

## References

- Adams, R. P. (2017). *Identification of essential oil components by gas chromatography/mass spectrometry* (ed. 4.1). Carol Stream, IL: Allured publishing corporation.
- Ahmed, R., Tariq, M., Ahmad, I. S., Fouly, H., Hasan, A., & Kushad, M. (2019). Poly (lactic-co-glycolic acid) nanoparticles loaded with *Callistemon citrinus* phenolics exhibited anticancer properties against three breast cancer cell lines. *Journal of Food Quality*.
- Augusta, I. M., Resende, J. M., Borges, S. V., Maia, M. C. A., & Couto, M. A. P. G. (2010). Physical and chemical characterization of malay red-apple (*Syzygium malaccensis*, (L.) Merryl & Perry) Skin and pulp. *Food Science and Technology*, 30(4), 928-932.
- Ayyanar, M., & Subash-Babu, P. (2012). *Syzygium cumini* (L.) Skeels: A review of its phytochemical constituents and traditional uses. *Asian Pacific journal of tropical biomedicine*, 2(3), 240-246.
- Bairy, K. L., Sharma, A., & Shalini, A. (2005). Evaluation of the hypoglycemic, hypolipidemic and hepatic glycogen raising effects of *Syzygium malaccense* upon streptozotocin induced diabetic rats. *Journal of Natural remedies*, 5(1), 46-51.
- Batista, Â. G., da Silva, J. K., Cazarin, C. B. B., Biasoto, A. C. T., Sawaya, A. C. H. F., Prado, M. A., & Júnior, M. R. M. (2017). Red-jambo (*Syzygium malaccense*): Bioactive compounds in fruits and leaves. *LWT-Food science and technology*, 76, 284-291.
- Cock, I. E., & Cheesman, M. A. T. T. H. E. W. (2018). Plants of the genus *Syzygium* (Myrtaceae): A review on ethnobotany, medicinal properties and phytochemistry. *Bioactive Compounds of Medicinal Plants: Properties and Potential for Human Health; Goyal, MR, Ayeleso, AO, Eds*, 35-84.
- Cruz, E. M. D. O., Pinto, J. A. O., Fontes, S. S., Arrigoni-Blank, M. D. F., Bacci, L., Jesus, H. C. R. D., ... & Blank, A. F. (2014). Water deficit and seasonality study on essential oil constituents of *Lippia gracilis* Schauer germplasm. *The Scientific World Journal*, 2014.
- Dahham, S. S., Tabana, Y. M., Ahamed, M. B. K., & Majid, A. M. A. (2015). In vivo anti-inflammatory activity of  $\beta$ -caryophyllene, evaluated by molecular imaging. *Molecules & Medicinal Chemistry*, 1.
- De Oliveira, C. C., de Oliveira, C. V., Grigoletto, J., Ribeiro, L. R., Funck, V. R., Grauncke, A. C. B., ... & Oliveira, M. S. (2016). Anticonvulsant activity of  $\beta$ -caryophyllene against pentylenetetrazol-induced seizures. *Epilepsy & Behavior*, 56, 26-31
- Deepika, N., Eganathan, P., Sujanal, P., & Parida, A. (2013). Chemical composition of *Syzygium benthamianum* (Wt. ex Duthie) Gamble essential oil-an endemic and vulnerable tree species. *Journal of Essential Oil Bearing Plants*, 16(2), 289-293.
- Dias, C. N., Rodrigues, K. A., Carvalho, F. A., Carneiro, S. M., Maia, J. G., Andrade, E. H., & Moraes, D. F. (2013). Molluscicidal and leishmanicidal activity of the leaf essential oil of *Syzygium cumini* (L.) SKEELS from Brazil. *Chemistry & biodiversity*, 10(6), 1133-1141.
- Domingos, A. L. R. Da S.; Marco, C. A.; Machado, M. I. R.; Feitosa, A. J. S.; Palmeira, I. A.; Silva, J. H. da. (2020) Content and chemical identification of essential basil oil (*Ocimum basilicum*, var. cinamon) l submitted to water stress in different environments. *Research, Society and Development*, [S. l.], v. 9, n. 8, p. e919985247.
- Feltrin, F. M., Gibbert, L., da Silva Santos, N. C., de Assis Marques, F., Miguel, M. D., Zanin, S. M. W., ... & Dias, J. D. F. G. (2020). Extraction and identification of essential oil components from the leaves of *Syzygium malaccense* (L.) Merr. & Lm Perry, Myrtaceae. *Ciência e Natura*, 42, 6.
- Fernandes, E. S., Passos, G. F., Medeiros, R., da Cunha, F. M., Ferreira, J., Campos, M. M., ... & Calixto, J. B. (2007). Anti-inflammatory effects of compounds alpha-humulene and (-)-trans-caryophyllene isolated from the essential oil of *Cordia verbenacea*. *European journal of pharmacology*, 569(3), 228-236.
- Ghareeb, M. A., Hamed, M. M., Abdel-Aleem, A. A. H., Saad, A. M., Abdel-Aziz, M. S., & Hadad, A. H. (2017). Extraction, isolation, and characterization of bioactive compounds and essential oil from *Syzygium jambos*. *Extraction*, 10(8).
- Ghelardini, C., Galeotti, N., Mannelli, L. D. C., Mazzanti, G., & Bartolini, A. (2001). Local anaesthetic activity of  $\beta$ -caryophyllene. *Il Farmaco*, 56(5-7), 387-389.
- Hajimehdipoor, H., Gohari, A. R., Ajani, Y., & Saeidnia, S. (2014). Comparative study of the total phenol content and antioxidant activity of some medicinal herbal extracts.



- Hanif, M. U., Hussain, A. I., Aslam, N., Kamal, G. M., Chatha, S. A. S., Shahida, S., ... & Hussain, R. (2020). Chemical Composition and Bioactivities of Essential Oil from Leaves of *Syzygium cumini* (L.) Skeels Native to Punjab, Pakistan. *Chemistry & biodiversity*, 17(8), e1900733.
- Hassan, S. B., Gali-Muhtasib, H., Göransson, H., & Larsson, R. (2010). Alpha terpineol: a potential anticancer agent which acts through suppressing NF- $\kappa$ B signalling. *Anticancer Research*, 30(6), 1911-1919.
- Ismail, I. S., Ismail, N., & Lajis, N. (2010). Ichthyotoxic properties and essential oils of *Syzygium malaccense* (Myrtaceae). *Pertanika Journal of Science & Technology*, 18(1), 1-6.
- Jang, H. I., Rhee, K. J., & Eom, Y. B. (2020). Antibacterial and antibiofilm effects of  $\alpha$ -humulene against *Bacteroides fragilis*. *Canadian journal of microbiology*, 66(6), 389-399.
- Karioti, A., Skaltsa, H., & Gbolade, A. A. (2007). Analysis of the leaf oil of *Syzygium malaccense* Merr. et Perry from Nigeria. *Journal of Essential Oil Research*, 19(4), 313-315.
- Kuiate, J. R., Mouokeu, S., Wabo, H. K., & Tane, P. (2007). Antidermatophytic triterpenoids from *Syzygium jambos* (L.) Alston (Myrtaceae). *Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives*, 21(2), 149-152.
- Legault, J., Dahl, W., Debiton, E., Pichette, A., & Madelmont, J. C. (2003). Antitumor activity of balsam fir oil: Production of reactive oxygen species induced by  $\alpha$ -humulene as possible mechanism of action. *Planta medica*, 69(05), 402-407.
- Migliato, K. F., Moreira, R. R., Mello, J. C., Sacramento, L. V., Corrêa, M. A., & Salgado, H. (2007). Quality control of *Syzygium cumini* (L.) Skeels fruits. *Revista Brasileira de Farmacognosia*, 17(1), 94-101.
- Mohamed, A. A., Ali, S. I., & El-Baz, F. K. (2013). Antioxidant and antibacterial activities of crude extracts and essential oils of *Syzygium cumini* leaves. *Plos one*, 8(4), e60269.
- Moo, C. L., Yang, S. K., Osman, M. A., Yuswan, M. H., Loh, J. Y., Lim, W. M., ... & Lai, K. S. (2020). Antibacterial Activity and Mode of Action of  $\beta$ -caryophyllene on *Bacillus cereus*. *Polish journal of microbiology*, 69(1), 49.
- Nawwar, M. A., Hashem, A. N., Hussein, S. A., Swilam, N. F., Becker, A., Haertel, B., ... & Linscheid, M. W. (2016). Phenolic profiling of an extract from *Eugenia jambos* L. (Alston)-the structure of three flavonoid glycosides-antioxidant and cytotoxic activities. *Die Pharmazie-An International Journal of Pharmaceutical Sciences*, 71(3), 162-168.
- Negreiros, P. S. da Costa, D. S., da Silva, V. G., de Carvalho Lima, I. B., Nunes, D. B., de Melo Sousa, F. B., ... & Oliveira, R. D. C. M. (2019). Antidiarrheal activity of  $\alpha$ -terpineol in mice. *Biomedicine & Pharmacotherapy*, 110, 631-640.
- Nist (National Institute of Standards and Technology), 1999. PC version 1.7 of the NIST/EPA/NIH Mass Spectral Library Norwalk. Perkin-Elmer Corp., CT, USA
- Noudogbessi, J. P., Yédomonhan, P., Sohounhoulou, D. C., Chalchat, J. C., & Figuérédo, G. (2008). Chemical composition of essential oil of *Syzygium guineense* (Willd.) DC. var. *guineense* (Myrtaceae) from Benin. *Records of natural products*, 2(2).
- Park, S. N., Lim, Y. K., Freire, M. O., Cho, E., Jin, D., & Kook, J. K. (2012). Antimicrobial effect of linalool and  $\alpha$ -terpineol against periodontopathic and cariogenic bacteria. *Anaerobe*, 18(3), 369-372.
- Raina, V. K., Srivastava, S. K., Aggarwal, K. K., Syamasundar, K. V., & Kumar, S. (2001). Essential oil composition of *Syzygium aromaticum* leaf from Little Andaman, India. *Flavour and fragrance journal*, 16(5), 334-336.
- Rezende, W. P., Borges, L. L., Alves, N. M., Ferri, P. H., & Paula, J. R. (2013). Chemical variability in the essential oils from leaves of *Syzygium jambos*. *Revista Brasileira de Farmacognosia*, 23(3), 433-440.
- Ruan, Z. P., Zhang, L. L., & Lin, Y. M. (2008). Evaluation of the antioxidant activity of *Syzygium cumini* leaves. *Molecules*, 13(10), 2545-2556.
- Sangwan, N. S., Farooqi, A. H. A., Shabih, F., & Sangwan, R. S. (2001). Regulation of essential oil production in plants. *Plant growth regulation*, 34(1), 3-21.
- Santos, C. V. Dos.; Mallmann, A. P.; Toledo, A. G.; Bandeira, D. M.; Costa, W. F. Da.; Marins, D. M. Ávila.; Corrêa, J. M.; Pinto, F. G. Da S. (2021). Chemical composition, antimicrobial and antioxidant activity of leaves essential oil the *Myrcia palustris* DC. (Myrtaceae). *Research, Society and Development*, [S. l.], v. 10, n. 3, p. e20510313303.
- Saranya, J., Eganathan, P., Sujanal, P., & Parida, A. (2012). Chemical composition of leaf essential oil of *Syzygium densiflorum* wall. ex wt. & arn.-a vulnerable tree species. *Journal of Essential Oil Bearing Plants*, 15(2), 283-287.
- Siani, A. C., Souza, M. C., Henriques, M. G., & Ramos, M. F. (2013). Anti-inflammatory activity of essential oils from *Syzygium cumini* and *Psidium guajava*. *Pharmaceutical biology*, 51(7), 881-887.
- Simões, C. M. O., Schenkel, E. P., Gosmann, G., Mello, J. C. P., Mentz, L. A., & Petrovick, P. R. (2007). Farmacognosia: da planta ao medicamento. 1002 pg. *Porto Alegre/Florianópolis: Editora da UFSC/Editora da UFRGS*.
- Souza, R. H. L., Cardoso, M. S. P., Menezes, C. T., Silva, J. P., De Sousa, D. P., & Batista, J. S. (2011). Gastroprotective activity of  $\alpha$ -terpineol in two experimental models of gastric ulcer in rats. *Daru: journal of Faculty of Pharmacy, Tehran University of Medical Sciences*, 19(4), 277.
- Teng, Z. Q., & Shen, Y. (2015). Research progress of genetic engineering on medicinal plants. *China journal of Chinese materia medica*, 40(4), 594-601
- The plant list. (sf). *Syzygium*. <http://www.theplantlist.org/tpl1.1/search?q=Syzygium>
- Trancoso, M. D. (2013). Projeto Óleos voláteis: extração, importância e aplicações no cotidiano. *Revista Práxis*, 5(9).

Trevizan, L. N. F., do Nascimento, K. F., Santos, J. A., Kassuya, C. A. L., Cardoso, C. A. L., do Carmo Vieira, M., ... & Formagio, A. S. N. (2016). Anti-inflammatory, antioxidant and anti-*Mycobacterium tuberculosis* activity of viridiflorol: The major constituent of *Allophylus edulis* (A. St.-Hil., A. Juss. & Cambess.) Radlk. *Journal of ethnopharmacology*, 192, 510-515.

Verma, R. S., Padalia, R. C., & Chauhan, A. (2014). Essential oil composition of *Aegle marmelos* (L.) Correa: chemotypic and seasonal variations. *Journal of the Science of Food and Agriculture*, 94(9), 1904-1913.

Vernin, G., Vernin, G., Metzger, J., Roque, C., & Pieribattesti, J. C. (1991). Volatile constituents of the Jamrosa aroma *Syzygium jambos* L. Aston from Reunion Island. *Journal of Essential Oil Research*, 3(2), 83-97.

Vignesh, R., Puhazhselvan, P., Sangeethkumar, M., Saranya, J., Eganathan, P., & Sujanalpal, P. (2013). GC-MS analysis, antimicrobial, scavenging ability and cytotoxic activity of leaves of *Syzygium calophyllifolium* Walp. *Journal of Biologically Active Products from Nature*, 3(2), 121-129.

World Health Organization. (2013). *Sustaining the drive to overcome the global impact of neglected tropical diseases: second WHO report on neglected diseases* (No. WHO/HTM/NTD/2013.1). World Health Organization.