Chemical composition and biological activities of essential oils from *Pectis* spp.

Pâmella Buenos Aires Domingues, Fabíola Galbiatti de Carvalho Carlo, Fábio Alessandro Pieri*

Institute of Life Sciences, Campus Governador Valadares, Federal University of Juiz de Fora, Rua São Paulo 745, 35010-180, Governador Valadares, Brazil
**Corresponding author: fabio.pieri@ufjf.br*

ABSTRACT

Natural products from the Brazilian flora have been presented as a vast source of bioactive compounds for the development of drugs. Among the native plants of the national flora, those of the genus *Pectis* can be found in various hot and dry habitats. The objective of this study was to conduct a review of the available scientific literature on the chemical composition and biological activities of *Pectis* spp. A search was performed on the Web of Science, Scopus and Pubmed databases using the descriptor "*Pectis*". Essential oils and natural compounds of the genus are rich in monoterpenes, citral, thymol, cumaldehyde, perillaldehyde, limonene and perillyl alcohol. These compounds confer to these oils biological activities corroborated by the literature as antibacterial, antifungal, nematicidal, larvicidal, analgesic, anti-inflammatory, and soothing, among others. It can be concluded that the extracts obtained from *Pectis* spp. have the potential to be used as an alternative to conventional treatments for infectious and inflammatory diseases, but clinical and toxicological (safety) studies need to be carried out.

Keywords: medicinal plants, essential oils, natural products, monoterpenes, perillyl alcohol

INTRODUCTION

Pectis is a botanical genus belonging to the Asteraceae family, which is the largest family of angiosperms, with about 1,600 genera and 25,000 species spread over tropical, subtropical and temperate regions (Silva et al. 2005; Oliveira et al. 2011; Marques et al. 2013). Species of *Pectis* are unique to the Americas, encompassing the Caribbean and Pacific Islands. These species can be found in a variety of hot and dry habitats, including deserts (Pereira et al. 2013). In Brazil, the genus is represented by approximately 180 species (Center for Environmental and Landscape Studies, 2020), with *Pectis brevipedunculata* Sch.Bip. distributed in several states of the country such as Pará, Bahia, Ceará, Maranhão, Pernambuco, Piauí, Tocantins, Distrito Federal, Goiás, Minas Gerais and Rio de Janeiro (Salgado and Gutiérrez).

Pectis spp. it has structures in its sheet that release aromatic substances. Some species are referred to as "lemongrass" due to their citrus aroma, similar to *Cymbopogon citratus* Stapf (Pereira et al. 2021). Depending on the species and the substances present in the oil, the aroma can vary from unpleasant to fruity or spicy (Marques and Kaplan 2013). Essential oils (EOs) are chemical substances with\ low molecular weight, some highly volatile, defined by an intense odor and capable of providing flavor and/or aroma. EOs include terpene hydrocarbons, simple alcohols, aldehydes, ketones, phenols, esters, ethers, organic acids and lactones. Of these compounds, terpenes have the ability to improve physicochemical properties and/or to increase bioavailability in controlled drug delivery (Damasceno et al. 2019).

The biological activities of *Pectis* spp. were described by Dawnum et al. (1989) as antibacterial and antifungal, corroborated shortly after by Prudent et al. (1995), Demo et al. (2005), da Silva et al. (2005), Marques et al. (2013), Jesus et al. (2020), and Zheng et al. (2021). Plants of this genus are used in several regions and communities due to their therapeutic actions, and ease of access and preparation. Despite its promising actions and all its benefits, *Pectis* is an underexplored genus, which justifies the need for further studies and

Received: July 02, 2022
Accepted after revision: March 21, 2023
Published on line: March 31, 2023
ISSN 1983-084X

investments regarding its composition and biological activities. The objective of this work was to conduct a review gathering information about the chemical composition and biological activities of essential oils from *Pectis* spp., available in the scientific literature.

RESEARCH METHOD

A review of scientific articles was carried out in June 2022 in the Web of Science, Scopus and Pubmed databases. The literature search was conducted using the descriptor "*Pectis*".

The identified studies were organized in a document and the titles and abstracts were read. The following inclusion criteria were used: chemical composition of the essential oil, discussion about the biological and medicinal activities of *Pectis* spp. In cases where it was not possible to verify the inclusion criteria from the abstract, the articles were obtained and read in full. The exclusion criteria were articles that did not report the composition of the EOs; articles that presented only a taxonomic description; articles that discussed photosynthesis pathways and drying methods. After reading the titles and abstracts of the articles found in the databases, the articles were selected for full reading according to the inclusion and exclusion criteria.

RESULTS

Based on the described criteria, 46 articles were selected and after applying the inclusion and exclusion criteria, 25 studies were included in the present study, comprising publications between 1949 and 2021.

Chemical composition of *Pectis* spp.

The main compounds found in the essential oil of *Pectis* spp. are presented in Table 1 and Figure 1. Most of the compounds found are classified as terpenes, the most common class to be found in essential oils and widely studied for their pharmacological properties (Matos et al. 2019) and potential as antimicrobial agents, insecticides, and weed control agents (Ninkuu et al. 2021). An analysis of fresh plants of the species *P. texana* Cory by Bradley et al. (1949) yielded 0.72% oil, of which 48% was thymol. Similar plants of *P. elongata* Kunth yielded 0.216% oil, of which 47% was cumaldehyde, an amount similar to that found in cumin oil, which is responsible for the spicy flavor of the plant.

Table 1. Chemical composition of *Pectis* spp. essential oils.

Species	Chemical Composition	(%)	Author (year)
P. texana Cory	Thymol	48.0	Bradley et al. (1949)
P. elongata Kunth	Citral	60.0	Bradley et al. (1949)
P. papposa Harv. & A.Gray	Cumaldehyde	47.0	Bradley et al. (1949)
	α-Pinene	2.0	
	β-Pinene	27.0	
	Carvone	12.0	
P. prostrata Sieber ex Less.	Perillaldehyde	70.74	Pino et al. (1996)
	Limonene	16.20	
	Perillyl alcohol	3.63	
P. floribunda A.Rich.	Perillaldehyde	44.5	Pino et al. (1999)
	Limonene	9.7	
P. apodocephala Baker	α-Pinene	10.7–11.4	Albuquerque et al. (2007)
		4.4–11.4	Albuquerque et al. (2003)
	Limonene	6.7–6.9	Albuquerque et al. (2007)
		5.8–6.7	Albuquerque et al. (2003)
	Neral	32.2–34.2	Albuquerque et al. (2007)
		28.1–34.2	Albuquerque et al. (2003)
	Geranial	42.9–44.5	Albuquerque et al. (2007)
		25.1–44.5	Albuquerque et al. (2003)

Table 1. continued

Species	Chemical Composition	(%)	Author (year)
P. oligocephala Sch.Bip.	α-Pinene	0.2	Albuquerque et al. (2007)
	Myrcene	0.7–1.7	Albuquerque et al. (2007)
		1.7	Albuquerque et al. (2003)
	α-Phellandrene	0.5–0.9	Albuquerque et al. (2007)
		0.9	Albuquerque et al. (2003)
	Limonene	1.2	Albuquerque et al. (2007)
	p-Cymene	50.3–70.9	Albuquerque et al. (2007)
		70.9	Albuquerque et al. (2003)
	Thymol	24.4–44.7	Albuquerque et al. (2007)
		24.4	Albuquerque et al. (2003)
P. brevipedunculata Sch.Bip.	α-Pinene	1.9	Marques e Kaplan, (2013)
		3.3	Pereira et al. (2013)
	Limonene	2.7	Marques e Kaplan, 2013
		4.5	Pereira et al. (2013)
	α-Terpineol	1.3	Marques e Kaplan, 2013
	Neral	35.8	Marques e Kaplan, 2013
		32.5	Pereira et al. (2013)
	Geranial	48.2	Marques e Kaplan, 2013
		49.2	Pereira et al. (2013)
P. substriata Rusby	Perillaldehyde	62.15	de Jesus et al. (2020)
	4-Undecanol	12.05	
	Limonene	6.46	
	α-Fenchene	2.89	
	Perillyl alcohol	2.51	
	cis-Piperitol acetate	2.49	
	9-Decenoic acid	1.40	

Among the 24 compounds identified in the oil from sheet of *P. prostrata* Sieber ex Less., the majority was perillaldehyde (70.74%), followed by limonene (16.20%) and perillyl alcohol (3.63%) (Pino et al. 1996). In another study Pino et al. (1999) described the chemical composition of the leaf oil of *P. floribunda* A.Rich. collected in Holguin, in eastern Cuba. Of a total of 31 compounds observed in the total ion chromatogram by GC-MS, 23 were identified. The oil was also rich in perillaldehyde, which accounted for 44.5% of the oil.

The volatile constituents of the aerial parts of *P. apodocephala* Baker (lemon) and *P. oligocephala* Sch.Bip. collected in the municipality of Sobral, Ceará-Brazil, were analyzed by Albuquerque et al. (2003). The oils of both species were rich in monoterpenes, with *P. apodocephala* containing 79.7% monoterpenes, while *P. oligocephala* was rich in aromatic compounds (95.3%), including *p*-cymene, which was the most abundant at 70.9%, followed by thymol at 24.4%, and other non-aromatic compounds such as β-phellandrene, myrcene and α-phellandrene (Albuquerque et al. 2003). In another study of the same species, Albuquerque et al. (2007) reported that in the oil extracted from *P. oligocephala* the amount of geranial varied from 42.9 to 44.5% and neral varied from 32.2 to 34.2%, followed by α-pinene at around 10.7 to 11.4% and lastly, limonene at 6.7 to 6.9%. In contrast, the most abundant compounds found in *P. oligocephala* oils were *p*-cymene, ranging from 50.3 to 70.9%, and thymol, ranging from 24.4 to 44.7%.

Using high-speed counter-current chromatography (HSCCC) to separate essential oil components from *P. brevipedunculata*, Marques and Kaplan (2013) observed that the main component of the EO was citral at 84%, of which 35.8% was neral and 48.2% geranial, followed by 2.7% limonene and

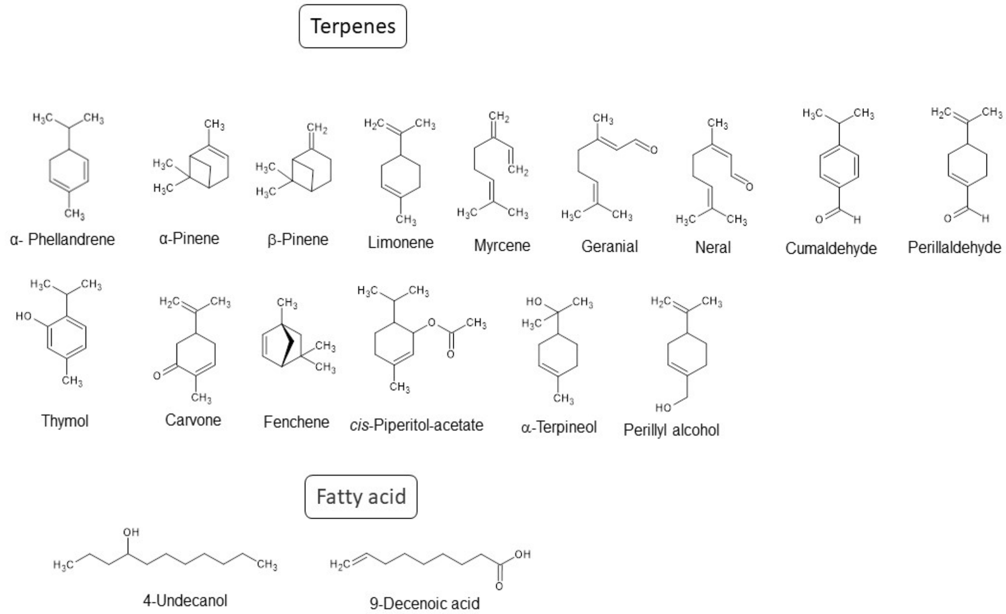

Figura 1. Structures of the main compounds detected in *Pectis* spp. from Brazil. Draw for ACD/ChemSketch version 2022

1.9% α-pinene. The specimens for their study were obtained from two climatic zones: the southeast (Rio de Janeiro and Espírito Santo) and northeast (Ceará) of Brazil. The components of the samples collected in Rio de Janeiro comprised 86.5% citral, of which 24.2% was neral and 62.3% was geranial. Samples from Espírito Santo contained 82.7% citral, of which 29.8% was neral and 52.9% geranial. The quantities were comparable with those in samples collected in Ceará in northeastern Brazil, which comprised 81.6% citral, of which 28.5% was neral and 53.1% geranial. α-pinene, limonene and the hydrocarbon tridecene were present in samples from all three states. Despite the different climatic zones, the citral content in the EO of the specimens was around 80.0% in each sample. Citral is component of volatile EO that is found in various aromatic plants such as lemon. The citral content in the EO of *P. brevipedunculata* ranged from 80% to 90%, being one of the components responsible for its citrus flavor.

The essential oil of *P. brevipedunculata* characterized by Pereira et al. (2013) comprised 81.7% citral (32.5% of which was neral and 49.2% geranial), followed by 4.5% limonene and 3.3% α-pinene. The percentage of citral in the *P. brevipedunculata* EO was consistent with the results of a previous study conducted by Marques and Kaplan (2013), indicating that Brazilian species can be considered a promising source of oil rich in citral. In the sample analysed by Oliveira et al. (2011), even though the percentage was lower than previously described, citral was still the most abundant component.

P. elongata sheet collected from three different regions of Martinique, a French Caribbean Island, at the same time of year but at different stages of maturity, showed significant differences in the yield of volatile aromatic compounds and oil composition. An increase in oil yield was observed when a higher percentage of linalool was present. The main components were neral, ranging from 15.65% to 27.47%, and geranial, ranging from 24.56% to 40.15%, these being the main components responsible for the aroma and, according to the authors, for the bactericidal and bacteriostatic activity (Prudent et al. 1995). Samples of *P. elongata* from the states of Pará (n = 2) and Amapá (n = 1) were evaluated in the study by Silva et al. (2005). For the isolation of volatile constituents, the first fresh sample was hydrodistilled for 4 h with Clevenger and the last two were dried at room temperature for 5 days before undergoing the hydrodistillation process. Using this approach, 28 volatile compounds were obtained. The main constituents were perillaldehyde (51.7%) and limonene (43.7%) in the first sample, with the same constituents in the second sample, but at lower percentages (64.6% and 33.7% respectively). The third sample collected in the state of Amapá contained 81.9% perillaldehyde, followed by its oxidation derivatives, 5.6% perillyl alcohol and 4% perillic acid. According to the authors, the high percentage of perillaldehyde in the dried samples (second and third) was due to the loss of limonene during the drying process.

An analysis of the aerial part of *P. substriata* using gas chromatography coupled with mass spectrometry (CG/MS) performed by de Jesus et al. (2020) identified 30 compounds, representing 98.91% of the total components of essential oil. The major compound in the sample was perillaldehyde at 62.15%, followed by 4-undecanol (12.05%), limonene (6.46%), α-fenchene (2.89%) and perillyl alcohol (2.51%).

Biological activities of *Pectis* spp.

The biological activities of the respective species covered in the reviewed articles are presented in Table 2.

An infusion of the aerial parts of *P. brevipedunculata* was mentioned by Oliveira et al. (2011) as being used in traditional medicine for soothing and mild anti-spasmodic purposes. Such actions have been attributed to citral, which, according to previous work (Lorenzi and Matos 2002; Marques and Kaplan 2013; Pereira et al. 2013; Zheng et al. 2021), is the main chemical component found in the plant. In Mato Grosso, *P. jangadensis* S. Moore tea is also used for the same purpose (Soares et al. 2009).

The plants used by the Izoceño-Guaraní community, a Guarani ethnic group (Bolivia), for medicinal purposes were described by Bourdy et al. (2004). One hundred and eighty-nine species were catalogued as having medicinal use, including *P. odorata* Griseb. The community uses the aerial part of the plant to prepare teas for kidney problems (pain and inflammation).

In Paraíba (Brazil), 119 species have medicinal indications. *P. elongata* and *P. oligophylla* Baker have the same indications, both being used in for hypotension and for stomach discomfort via infusion of the whole plant and for colds and flu using leaf teas (Agra et al. 2007).

A survey of plants used to treat acute respiratory infections (ARI) in children from a community in a municipality in Ceará, Brazil, was carried out by Lemos et al. (2016). Thirty-eight species were mentioned and *P. brevipedunculata* was mentioned as being used to treat ARI, more specifically using the sheet to prepare teas to combat cough, flu, bronchitis and sore throat.

An investigation of the potential effects on the vascular system of the *P. brevipedunculata* EO and its main citral constituent in the thoracic aorta in rats was carried out by Pereira et al. (2013). They verified the potential of the plant for treatment of hypertension, with the EO causing vasodilation in the rats. In addition, the citral component reduced the influx of calcium by blocking voltage-gated type I Ca^{2+} channels.

In addition to the biological activities discussed above, it is worth mentioning the important activity of the genus *Pectis* against microorganisms, which was described in 8 of the 12 articles available (Table 1), as detailed below.

Antimicrobial activity of essential oils from *Pectis* spp.

In addition to determining the chemical composition of *P. elongata*, Prudent et al. (1995) evaluated the bacteriostatic and fungistatic activity of oil and solvent extracts against five bacterial strains and six fungal strains. *P. elongata* leaf oil showed a minimum inhibitory concentration (MIC) of 0.5 mg/ml against *Staphylococcus aureus*, *Escherichia coli* and *Micobacterium smegmatis* and 1 mg/ml against *Streptococcus faecalis* and *Pseudomonas aeruginosa*. The results were comparable with previous similar studies (Prudent et al. 1993 and Moleyar and Narasimhaum 1988) and the authors inferred that the bacteriostatic and fungistatic activities could be attributed to citral. Demo et al. (2005) also evaluated the antibacterial and antifungal properties of EO from the flora of different regions of Argentina. Among the oils tested, *P. odorata* collected in La Colera (Córdoba) only showed activity against Gram-positive bacteria, with an inhibition zone of 11.5 mm against *S. aureus* and 8 mm against *Staphylococcus epidermidis*. The diversity of activity of EO components for the investigated microorganisms can be attributed to the qualitative and quantitative differences in the constituents of oils. The oils varied according to climatic, environmental and local conditions and, as a consequence, different EO activities (Oliveira et al. 2011).

Marques et al. (2013) aimed to record the ethnobotanical values related to the traditional use of *P. brevipedunculata* and its chemical composition as well as to investigate the antimicrobial properties of the essential oil. Its effects on *Candida albicans*, *Cryptococcus neoformans*, *Trichophyton rubrum*, *Microsporum canis*, *Microsporum gypseum* and *S. aureus* MRSA, *Aspergillus niger*, *E. coli* and *S. epidermidis* were tested, using amphotericin B (1 mg/ml) as the control for fungi and vancomycin (1 mg/ml) for bacteria. The zone of inhibition of EO in the raw state varied from 5 to 15 mm at a concentration of 16.66 mg/ml, being 5 mm for *M. canis* and 15 mm for *T. rubrum*; at a concentration of 25 mg/ml, the halo ranged from 10 to 30 mm, 10 mm for *E. coli* and 30 mm for *E. niger*. It is noteworthy that at 25 mg/ml the zone of inhibition of EO was higher than that of the control in 4 of the 10 microorganisms tested. The activity of this dilution was only lower than the control for the fungus *C. neoformans*. There was a very strong toxic effect on *M. canis*, *M. gypseum* and *T. rubrum* at this concentration, completely preventing the growth of these microorganisms on the culture medium. Zheng et al. (2021) attributed the antifungal activity of *Pectis* spp. to the citral present in the plant.

Table 2. Biological activities of *Pectis* species described in the literature until 2020.

Biological activity	Description of activity	Species	Anatomical part of the plant	Geographic region	Author (year)
Soothing	Laboratory test	*P. brevipedunculata* Sch.Bip.	Aerial parts	Rio de Janeiro - Brazil	Oliveira et al. (2011)
Antibacterial Antifungal	Laboratory test	*P. canescens* Kunth, *P. filipes* Harv. & A.Gray, *P. imberbis* A.Gray, *P. linifolia* L., *P. longipes* A.Gray, *P. luckoviae* D.J.Keil, *P. multiflosculosa* (DC.) Sch.Bip., *P. multiseta* Benth., *P. papposa* Harv. & A.Gray, *P. prostrata* Cav., *P. purpurea* Brandegee, *P. schaffneri* Sch.Bip. ex A.Gray	Not described	North America semiarid	Dawnum et al. (1989)
Antibacterial Antifungal	Laboratory test	*P. elongata* Kunth	Sheet	Martinique - North America	Prudent et al. (1995)
Intestinal spasm Colored urine Kidney disease Illness in general	Traditional use	*P. odorata* Griseb.	Aerial parts	Chaco - Bolívia	Bourdy et al. (2004)
Antibacterial Antifungal	Laboratory test	*P. odorata* Griseb.	Aerial parts	Córdoba- Argentina	Demo et al. (2005)
Bacteriostatic Fungistatic	Laboratory test	*P. elongata* Kunth	Not described	Pará and Amapá - Brazil	da Silva et al. (2005)
Nematicide Larvicide	Laboratory test	*P. oligocephala* Sch.Bip. *P. apodocephala* Baker	Aerial parts	Ceará - Brazil	Albuquerque et al. (2007)
Stomach Hypotension Influenza Cold	Traditional use	*P. elongata* Kunth *P. oligophylla* Baker	Sheets	Paraíba - Brazil	Agra et al. (2007)
Analgesic Anti-inflammatory	Laboratory test	*P. jangadensis* S. Moore	Whole plant	Cuiabá - Brazil	Soares et al. (2009)
Vasodilator	Laboratory test	*P. brevipedunculata* Sch.Bip.	Aerial parts fresh	Not described	Pereira et al. (2013)
Antibacterial Antifungal	Laboratory test	*P. brevipedunculata* Sch.Bip.	Aerial parts	Rio de Janeiro- Brazil	Marques et al. (2013)
Cough Influenza Bronchitis Sore throat	Traditional use	*P. brevipedunculata* Sch.Bip.	Sheets	Crato - Ceará - Brazil	Lemos et al. (2016)
Antibacterial	Laboratory test	*P. substriata* Rusby	Aerial parts	Mato Grosso do Sul- Brazil	De Jesus et al. (2020)
Antifungal	Laboratory test	*Pectis* sp.			Zheng et al. (2021)

When tested against *T. rubrum*, geranial showed better results in terms of zone of inhibition and cell membrane damage when compared to neral.

Pectis substriata oil was tested against *S. aureus*, *S. intermedius* and *Staphylococcus warneri*, both standard strains and clinical isolates. In addition to being tested alone, the oil was tested in combination with conventional antimicrobials such as ampicillin, tetracycline and kanamycin to assess the possibility of synergistic action between them. The best result for *P. substriata* oil alone was against *S. warneri*, with a MIC of 62.5 µg/ml followed by a MIC of 250 µg/ml against clinical *S. intermedius*. When ampicillin was added, the MIC against *S. warneri* decreased to 0.049 µg/ml, and to 25 µg/ml with the addition of tetracycline, respectively. The same MIC value was obtained for the oil associated with kanamycin against *S. intermedius* (de Jesus et al. 2020).

In addition to reporting the essential oils obtained from the aerial parts of *P. apodocephala* and *P. oligocephala* Sch.Bip., Albuquerque et al. (2007) also evaluated their nematicidal and larvicidal activities against *Meloidogyne incognita* and *Aedes aegypti*. Despite having different chemical compositions, the oils of the two plants studied showed satisfactory activity. Nematicidal activity against *M. incognita* was evaluated in a 50-µl aliquot of water containing approximately 100 juveniles and 1 mg of the oil to be tested. The number of inactive nematodes was counted at three different times: *P. apodocephala* oil resulted in an average larval mortality of 85.5% in 24 h, 91% in 48 h and 93% in 72 h, *P. oligocephala* showed even better results, with 94% larval mortality in 24 h, 98.5% in 48 h and 99% in 72 h. After 24 h no larvae recovered mobility. Larvicidal activity against *Aedes aegypti* was tested at concentrations of EO of 5 to 500 µg/ml. *P. oligocephala* oil showed 100% mortality at 100 µg/ml, while *P. apodocephala* oil at the same concentration showed 22% mortality. The best result for *P. apodocephala* oil was 96% at the maximum tested concentration of 500 µg/ml. Essential oils thus exhibited relevant activity and can be considered promising natural nematicides and larvicidal agents against the vector of several important arboviruses such as Dengue, Chikungunya and Zika.

The genus *Pectis* has an oil rich in components such as terpenes, aldehydes and hydrocarbons. The composition of the oil may vary according to the species, region of cultivation, harvest time, anatomical part analyzed, and extraction method. These compounds are responsible for important microbiological and medicinal activities. According to previous studies, cited in this work, the most common class of terpenes found in the essential oil of *Pectis* spp. have pharmacological properties that have been the subject of many studies. However, further studies are needed to reinforce the use of *Pectis* and to correlate its activities with its composition.

Pectis is a botanical genus that is widespread in different regions and climates, and its species have relevant amounts of EOs. Thus, as they present promising biological activities, are easy to obtain and are socially accessible in different parts of Brazil and Latin America, EOs from *Pectis* spp. are potential alternatives to conventional medicines that need further study to verify their effect against infectious and inflammatory diseases.

ACKNOWLEDGMENTS

The authors would like to thank the Research Support Foundation of the State of Minas Gerais (FAPEMIG) (identifier number 13744) for supporting this work via a research grant.

AUTHORS' CONTRIBUTION

All authors contributed to the study. Conceptualization, P.B.A.D., F.G.C.C. and F.A.P.; investigation, P.B.A.D.; methodology, P.B.A.D.; project administration, F.A.P.; supervision, F.G.C.C. and F.A.P.; validation, P.B.A.D., F.G.C.C. and F.A.P.; visualization, P.B.A.D., F.G.C.C. and F.A.P.; writing - original draft, P.B.A.D.; writing - review & editing, P.B.A.D., F.G.C.C. and F.A.P. All authors read and approved the final manuscript.

DECLARATION OF CONFLICT OF INTERESTS

The authors have no conflicts of interest to declare.

REFERENCES

Agra MF, Baracho GS, Nurit K, Basílio IJLD, Coelho VPM (2007) Medicinal and poisonous diversity of the flora of "Cariri Paraibano", Brazil. J Ethnopharmacol 111:383-395. https://doi.org/10.1016/j.jep.2006.12.007

Albuquerque MRJR, Costa SMO, Bandeira PN, Santiago GMP, Andrade-Neto M, Silveira ER, Pessoa ODL (2007) Nematicidal and larvicidal activities of the essential oils from aerial parts of *Pectis oligocephala* and *Pectis apodocephala* Baker. An Acad Bras Cienc 79:209-213. https://doi.org/10.1590/S0001-37652007000200003

Albuquerque MRJR, Souza EB, Mesquita EF, Nunes EP, Cunha NA, Silveira ER (2003) Volatile constituents of the aerial parts of *Pectis apodocephala* and *Pectis oligocephala*. J Essent Oil Res 15:372-373. https://doi.org/10.1080/10412905.2003.9698613

Bourdy G, Michel LRC, Roca-Coulthard A (2004) Pharmacopoeia in a shamanistic society: the Izoceño-Guaraní (Bolivian Chaco). J Ethnopharmacol 91:189-

208. https://doi.org/10.1016/j.jep.2003.09.013

Bradley CE, Haagen-Smit AJ (1949) The essential oil of *Pectis papposa*. Econ Bot 3:407-412. https://doi.org/10.1007/bf02859170

Damasceno CSB, Higaki NTF, Dias JFG, Miguel MD, Miguel OG (2019) Chemical composition and biological activities of essential oils in the family Lauraceae: A systematic review of the Literature. Planta Med 85:1054-1072. https://doi.org/ 10.1055/a-0943-1908

Demo M, Oliva MM, López ML, Zunino MP, Zygadlo JA (2005) Antimicrobial activity of essential oils obtained from aromatic plants of Argentina. Pharm Biol 43:129-134. https://doi.org/10.1080/13880200590919438

Downum KR, Villegas S, Rodriguez E, Keil D (1989) Plant photosensitizers: A survey of their occurrence in arid and semiarid plants from North America. J Chem Ecol 15:345-355. https://doi.org/10.1007/BF02027795

Jesus GS, Micheletti AC, Takahashi KM, Matayoshi T, Pott A, Yoshida NC (2020) Antimicrobial potential of *Pectis substriata* essential oil (Asteraceae) against drug-resistant *Staphylococcus strains*. An Acad Bras Ciênc 92:e20200456. https://doi.org/10.1590/0001-3765202020200456

Lemos ICS, Delmondes GA, Santos ADF, Santos ES, Oliveira DR, Figueiredo PRL, Alves DA, Barbosa R, Menezes IRA, Coutinho HDM, Kerntopf MR, Fernandes GP (2016) Ethnobiological survey of plants and animals used for the treatment of acute respiratory infections in children of a traditional community in the municipality of barbalha, Ceará, Brazil. Afr J Tradit Complement Altern Med 13:166-175. https://doi.org/10.21010/ajtcam.v13i4.22

Lorenzi H, Matos FJA (2002) Plantas Medicinais no Brazil: Nativas e Exóticas. 1.ed. São Paulo: Instituto Plantarum. 512p.

Marques AM, Lima CHP, Alviano CS, Esteves RL, Kaplan MAC (2013) Traditional use, chemical composition and antimicrobial activity of *Pectis brevipedunculata* essential oil: A correlated lemongrass species in Brazil. Emir J Food Agric 25:798-808. https://doi.org/10.9755/ejfa.v25i10.16408

Marques AM, Kaplan MAC (2013) Preparative isolation and characterization of monoterpene isomers present in the citral-rich essential oil of *Pectis brevipedunculata*. J Essent Oil Res 25:210-215. https://doi.org/10.1080/10412905.2013.767756

Matos SP, Teixeira HF, Lima AAN, Veiga-Junior VF, Koester LS (2019) Essential oils and isolated terpenes in nanosystems designed for topical administration: A review. Biomolecules 9(4):138. https://doi.org/10.3390/biom9040138

Moleyar V, Narasimhaum P (1988) Fungitoxicity of binary mixtures of citral, cinnanic aldehyde, menthol and lemongrass oil against *Aspergillus niger* and *Rhizopus stolonifer*. Lebensm.-Wiss. Technol 21: 100-102. http://ir.cftri.res.in/id/eprint/2288

Ninkuu V, Zhang L, Yan J, Fu Z, Yang T, Zeng H (2021) Biochemistry of terpenes and recent advances in plant protection. Int J Mol Sci 22(11):5710. https://doi.org/10.3390/ijms22115710

Oliveira MTR, Berbert PA, Martinazzo AP, Berbert-Molina MA (2011) Drying kinetics of lemon-scented grass. Trans ASABE 54:1837-1846. https://doi.org/10.13031/2013.39823

Pereira SL, Marques AM, Sudo RT, Kaplan MAC, Zapata-Sudo G (2013) Vasodilator activity of the essential oil from aerial parts of *Pectis brevipedunculata* and its main constituent citral in rat aorta. Molecules 18:3072-3085. https://doi.org/10.3390/molecules18033072

Pereira SF, Barroso A, Mourão RHV, Fernandes CP (2021) A low energy approach for the preparation of nano-emulsions with a high citral-content essential oil. Molecules 26: 3666. https://doi.org/10.3390/molecules26123666

Pino JA, Rosado A, Fuentes V (1996) Chemical composition of the leaf oil of *Pectis prostrata* Cav. from Cuba. J Essent Oil Res 8:579-580. https://doi.org/10.1080/10412905.1996.9700697

Pino JA, Rosado A, Fuentes V (1999) Composition of the essential oil of *Pectis floribunda* A. Rich. J. Essent. Oil Res. 11: 31-32. https://doi.org/10.1080/10412905.1999.9701062

Prudent D, Perineau F, Bessieri JM, Michel G (1995) Analysis of the essential oil of *Pectis elongata* Kunth. from Martinique. Evaluation of its bacteriostatic and fungistatic properties. J Essent Oil Res 7:63-68. https://doi.org/10.1080/10412905.1995.9698464

Prudent D, Perineau F, Bessieri JM, Michel G, Bravo R (1993) Chemical analysis, bacteriostatic and fungistatic properties of the essential oil of the Atoumau from Martinique (*Alpinia speciosa* K. Schum.). J Essent Oil Res 5:255-264. https://doi.org/10.1080/10412905.1993.9698218

Salgado VG, Gutiérrez DG. *Pectis in* Flora e Funga do Brasil. Jardim Botânico do Rio de Janeiro. Available in: <https://floradobrasil.jbrj.gov.br/FB16235>

Silva MHL, Andrade EHA, Maia JGS (2005) The essential oil of *Pectis elongata* Kunth occuring in North Brazil. Flavour Fragrance J 20:462-464. https://doi.org/10.1002/ffj.1546

Zheng Y, Shang Y, Li M, Li Y, Ouyang W (2021) Antifungal activities of *cis-trans* citral isomers against *Trichophyton rubrum* with ERG6 as a potential target. Molecules 26:4263. https://doi.org/10.3390/molecules26144263