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Research Article

Essential oil composition of *Clusia pachamamae* resin from Peru

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Abstract

Clusia pachamamae Zent.-Ruíz & A. Fuentes is a tree in the Clusiaceae family. The sesquiterpenoid-rich resin has been used traditionally by the native peoples for various rituals, ceremonies, and medicinal applications, however, the chemical profile of said resin has not been previously established. The current study establishes for the first time, to the best knowledge of the authors, the essential oil yield and composition of *C. pachamamae*. Among the identified 24 compounds, the resin contains a high amount of sesquiterpene hydrocarbons, specifically bicyclogermacrene (13.1%), δ-cadinene (12.8%), γ-muurolene (8.8%), α-cubebene (8.2%), and (*e*)-caryophyllene (7.5%). These results provide fundamental data for substantiation of ethnobotanical applications and future investigations on the secondary metabolites from this plant species.

1. Introduction

The genus *Clusia* is widely distributed across various habitats, ranging from near sea level to elevations of at least 3,500 meters in the Andes [1]. Traditionally, species within this genus have been utilized for numerous medicinal purposes, including treatments for colds, rheumatism, and antiseptics. They have also been used to prevent intestinal diseases, treat tetanus, consolidate bone fractures, act as hemostatic, and strengthen the immune system [2]. Despite the distribution and traditional medicinal use of *Clusia* species, some species, such as *Clusia pachamamae*, remain underexplored in terms of their chemical composition and bioactive potential.

Clusia pachamamae grows in montane forests at altitudes between 1700 and 2500 meters, particularly in Bolivia's high-rainfall regions [3]. The tree is typically found in distinctive environments such as mountain peaks and slopes exposed to humid trade winds. The species blooms from February to July and bears fruit from September to January [3]. Locally known as "incienso" and referred to as "miskki asnakk" in Quechua, "tarapu" in Aymara, and "churiri" in Kallawaya, *C. pachamamae* holds significant cultural importance and it is noted for producing a valuable resin [3]. This resin is a sticky, organic liquid that solidifies upon exposure to air, transforming into a solid, yellowish, shiny, and amorphous substance [4]. The high-value commercial resin is traditionally extracted by local communities in Bolivia through exudation triggered by cutting the bark or branches [4]. *Clusia pachamamae* is integrated into Andean traditions, particularly in rituals and ceremonies honoring Pachamama, the Andean deity representing Mother Earth. It is also used in incense burning and the "challa," a ritual to give thanks for material or spiritual gains [3].

Essential oil chemical compositions from different *Clusia* species have been reported, but their focus has been on flowers, fruits, or leaves, interestingly showing a high content of sesquiterpenes. To the authors' best knowledge, the essential oil profile from the resin of *C. pachamamae* has not been documented in the scientific literature, with reports focusing only on its use in Bolivia. Moreover, based on our research, there is no documented evidence of this species being previously reported or studied in Peru at any level. This study aims to determine the chemical composition of the essential oil extracted from the resin of *C. pachamamae* from Peru, providing new insights into its potential applications and furthering the understanding of its chemical properties.

2. Materials and methods

2.1 Plant material

Fresh *Clusia pachamamae* naturally exuded resin was collected in March 2024 from wildcrafting populations in Montecristo, Peru (8°21'03.8"S 76°43'51.7"W) (Fig. 1).

Figure 1. Resin exudation on *Clusia pachamamae* tree bark.

A representative voucher sample of the species is held at the Universidad Nacional de Cajamarca (Herbario Isidoro Sánchez Vega_UNC; herbarium code CPUN). The resin was under shade and at room temperature for 5 days. Distillation was carried out in a 12 L distillation chamber (Albrigi Luigi S.R.L., Italy). Distillation was carried out by steam distillation for 5 hours.

2.2 Extraction of the essential oil

The essential oil obtained was separated by a cooled condenser, collected, filtered, and stored in sealed amber vials at room temperature (25 °C) until analysis. The essential oil yield was calculated as the ratio of the essential oil volume (mL) to the plant material mass (kg) before the distillation process.

2.3 Essential oil analysis

Essential oil was analyzed, and volatile compounds were identified by GC/MS using an Agilent 7890BGC/5977B MSD (Agilent Technologies, Santa Clara, CA, USA) and Agilent J&W DB-5, 60 m × 0.25 mm, 0.25 μm film thickness, fused silica capillary column. Operating conditions: 0.2 μL of the sample, 25:1 split ratio, initial oven temperature of 60 °C with an initial hold time of 2 min, oven ramp rate of 4.0 °C per minute to 245 °C with a hold time of 5 min, helium carrier gas. The electron ionization energy was 70 eV, scan range 35–550 amu, scan rate 2.4 scans per second, source temperature 230 °C, and quadrupole temperature 150 °C. Volatile compounds were identified using the Adams volatile oil library [5] and Chemstation library search in conjunction with retention indices (MilliporeSigma, Sigma Aldrich, St. Louis, MO, USA). Volatile compounds were quantified and are reported as a relative area percent by GC/FID using an Agilent 7890B and Agilent J&WDB-5, 60 m × 0.25 mm, 0.25 μm film thickness, fused silica capillary column. Operating conditions: 0.1 μL of sample, 25:1 split injection, initial oven temperature at 40 °C with an initial hold time of 2 min, oven ramp rate of 3.0 °C per minute to 250 °C with a hold time of 3 min, helium carrier gas.

3. Results and discussion

The essential oil yield of *Clusia pachamamae* was 10.0 mL/kg. Since no prior studies report essential oil yield from Clusia sp. trunk resin, comparison is limited. However, these results establish a baseline for future investigations into the essential oil production from the resin of this genus.

The chemical profile is detailed in Table 1, revealing this essential oil is rich in sesquiterpene hydrocarbons

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Table 1. Chemical profile of *C. pachamamae* essential oil determined by GC/FID

KI	Compound Name	Area (%)
932	α-Pinene	0.2
1024	Limonene	0.2
1095	Linalool	0.1
1335*	Unknown compound #1	0.9
1348	α-Cubebene	1.0
1373	α-Ylangene	0.7
1374	α-Copaene	8.2
1389	β-Elemene	2.3
1417	(*E*)-Caryophyllene	7.5
1430	β-Copaene	2.0
1433*	Unknown compound #2	0.6
1439	Aromadendrene	2.2
1452	α-Humulene	6.7
1458	Allo-Aromadendrene	0.8
1478	γ-Muurolene	8.8
1480	Germacrene D	4.9
1482	Unknown compound #3	0.6
1483	α-Amorphene	1.7
1500	Bicyclogermacrene	13.1
1513	γ-Cadinene	5.7
1522	δ-Cadinene	12.8
1537	α-Cadinene	1.2
1577	Spathulenol	3.5
1582	Caryophyllene oxide	0.7
1585*	Unknown compound #4	0.8
1593*	Unknown compound #5	1.3
1606*	Unknown compound #6	1.2
1608	Humulene epoxide II	0.4
1633*	Unknown compound #7	0.7
1638	τ-Cadinol	1.6
1652	α-Cadinol	1.7
Compound classes		
Monoterpene hydrocarbons		0.4
Oxygenated monoterpenes		0.1
Sesquiterpene hydrocarbons		79.6
Oxygenated sesquiterpenes		7.9
Total identified compounds		***88.0***

Note: Essential oil sample was analyzed in triplicate to ensure repeatability (standard deviation < 1). Unidentified compounds of less than 0.5% are not included. KI is the Kovat's Index previously calculated by Robert Adams using a linear calculation on a DB-5 column [5]. *KI not previously calculated [5]. Manual calculation performed using alkane standards. Relative area percent was determined by GC/FID

(79.6%). Twenty-four compounds of *C. pachamamae* essential oil was identified. Bicyclogermacrene was the most abundant component in the essential oil (13.1%). Other notable sesquiterpene hydrocarbons include δ-Cadinene (12.8%), γ-Muurolene (8.8%), α-Cubebene (8.2%), and (*E*)-Caryophyllene (7.5%). The second most abundant group identified in the essential oil was oxygenated sesquiterpenes, including Spathulenol (3.5%), α-Cadinol (1.7%), τ-Cadinol (1.6%), Caryophyllene oxide (0.7%), and Humulene epoxide II (0.4%). The essential oil composition was determined after a 5-hour steam distillation. The results provide a comprehensive view of the volatile compounds present under these specific conditions, and future research may explore whether prolonged or different extraction methods could yield additional profiles. To the best of the authors' knowledge, no previous studies on essential oils specifically derived from the trunk resin of species from the genus *Clusia* have been reported.

Due to the lack of literature on essential oils derived from *Clusia* trunk resins, direct comparisons are limited. However, studies on other *Clusia* species such as *Clusia hilariana*, which has aromatic flowers and reported to have a high content of sesquiterpenes, with (*E*)-caryophyllene being the major compound (37.1% to 49.7%) [6]. Essential oil from fruits of *Clusia nemorosa* was characterized by the abundance of sesquiterpenes, with (*E*)-caryophyllene as the predominant compound (37.3% to 48.6%) [7]. Essential oil from leaves of *Clusia lanceolata* showed only sesquiterpene compounds, with (*E*)-Caryophyllene as its major compound (43.2% to 56.4%) [8]. Similarly, the essential oil of *Clusia pachamamae* in the present study is also rich in sesquiterpenes, which suggests that a high sesquiterpene content may be characteristic of essential oils in the *Clusia* genus, regardless of the plant part.

The bioactivities of essential oils are typically determined by their most abundant chemical constituents [9,10]. In our study, the major compounds are bicyclogermacrene and δ-cadinene. Bicyclogermacrene has been documented to exhibit antimicrobial, antitumor, antiprotozoal, and anticancer activities [11,12], as well as demonstrating a high capacity for free radical scavenging [13]. On the other hand, δ-cadinene has been reported to induce dose- and time-dependent inhibitory effects on the growth of the OVACR-3 cell line. This cell line is

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associated with one of the leading causes of cancer mortality in women and is the primary cause of mortality from gynecological malignancies [14]. Although the resin of *Clusia pachamamae* is traditionally used in rituals and ceremonies, the presence of these bioactive volatile compounds in its essential oil suggests potential therapeutic applications.

Utilizing the available mass spectral libraries (NIST 2020; Adam's library) for this study, we successfully identified 88.0% of the essential oil components in the resin of *C. pachamamae*. However, limitations in the analytical methods may have impeded the identification of certain compounds. Employing advanced techniques such as two-dimensional gas chromatography with time-of-flight mass spectrometry (GC×GCTOFMS), nuclear magnetic resonance spectroscopy (NMR), and high-resolution mass spectrometry (HRMS) could enhance compound identification [15].

4. Conclusions

This study provides, for the first time, the chemical composition of the essential oil from the trunk resin of *Clusia pachamamae*. Twenty-four compounds were identified, the major constituents being Bicyclogermacrene (13.1%) and δ-Cadinene (12.8%). According to the authors' knowledge, while previous studies on other species of the *Clusia* genus have focused on essential oils derived from flowers, fruits, and leaves, this research marks the first report on the essential oil composition from trunk resin of any *Clusia* species, offering a unique contribution to the understanding of the genus. The sesquiterpene-rich profile observed in *C. pachamamae* is consistent with findings from other *Clusia* species, suggesting that high sesquiterpene content may be characteristic of essential oils from different plant parts in this genus. The presence of bioactive compounds, such as Bicyclogermacrene and δ-Cadinene, suggests possible therapeutic properties, although no direct studies have confirmed these activities for the resin-derived essential oil of *C. pachamamae*. Further research is recommended to explore its potential biological activities, such as antimicrobial testing or cytotoxicity assays and its applications in the pharmaceutical and cosmetic industries. Future studies should use advanced analytical methods and the creation of comprehensive reference standard databases. Such approaches will improve the identification of unknown compounds and support a deeper understanding of the essential oil's properties and possible uses.

Authors' contributions

Conceptualization, C.P.; Methodology, C.P., A.A.; Software, C.P., A.A; Validation, C.P.; Formal analysis (GC/MS, GC/FID), C.P., A.A., T.M.W.; Investigation, C.P., A.A.; Resources, C.P., E.C.; Data curation, C.P., A.A.; Writing – original draft, C.P., A.A.; Writing – review & editing, C.P., A.A., T.M.W., E.C.

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Availability of data and materials

All data will be made available on request according to the journal policy.

Conflicts of interest

The authors declare no conflict of interest. The funding entity had no role in the design of the study, in the collection, analysis, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results.

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