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# Chemical Analysis of Solid Tree Resins of Protium Heptaphyllum and Protium Icicariba

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## Abstract

Solid tree resins of *Protium heptaphyllum* and *Protium icicariba* were studied and analyzed volatile compounds compared. The absence of sabinene in the resin of the tree *Protium icicariba* is the main distinguishing feature.

**Keywords**: *Protium heptaphyllum*; *Protium icicariba*; Resin; Volatile compound; Terpenes; GC/MS

## Introduction

*Protium icicariba*, commonly known as "Almescar" or "Icica," is a tropical tree native to South America, particularly found in the Amazon Rainforest. It is renowned for its resin, which has been traditionally used by indigenous communities for its medicinal properties and as an incense ingredient.

*Protium heptaphyllum*, often referred to as "Breu Branco", "Mel Branco", "Almesca" or "Almécega," is another tree species found in the Amazon Rainforest, and the Atlantic rainforest. It is well-known for producing a fragrant resin called "Breu" or "White Breu," which is used in traditional healing practices and as incense in spiritual rituals.

Both *Protium icicariba* and *Protium heptaphyllum* play significant roles in the cultural and traditional practices of indigenous peoples in their respective regions. Their resins have a long history of use for spiritual and medicinal purposes and continue to be valued for their aromatic and therapeutic qualities.

Almescar, also known as Breu Branco, is a fascinating resin (Figure 1) extracted from trees of the genus *Protium*, which are found in the Amazon rainforest, predominantly within Brazil. This resin has been an integral part of indigenous cultures for centuries, serving various traditional uses ranging from medicinal applications to spiritual practices. Almescar (Breu Branco) is particularly valued for its distinctive, pleasant aroma and its wide range of beneficial properties.

### Extraction and Uses

The resin is traditionally harvested by making incisions in the tree's bark, allowing the sap to exude and harden into a resinous mass. This method of extraction is sustainable, as it does not harm the tree when done correctly, and allows for continuous harvesting from the same individual over many years (Figure 1).

**Figure 1:** Resin secreted from the bark of *Protium heptaphyllum*.





**Citation:** Hanus LO, Giladi Y, Martins MLA. Chemical Analysis of Solid Tree Resins of Protium Heptaphyllum and Protium Icicariba. J Plant Chem and Ecophysiol. 2024; 4(1): 1024.

Almescar resin is known for its antiseptic, anti-inflammatory, analgesic, and gastroprotective properties [1-3], making it a valuable resource in traditional medicine for treating wounds, skin infections, and various other health issues. It is also used in aromatherapy due to its calming and grounding scent.

### Environmental and Economic Impact

The sustainable harvesting of Almescar resin can have positive environmental and economic impacts. It provides a renewable resource that encourages the preservation of the Amazon rainforest and its biodiversity. Economically, it supports local communities by creating income opportunities that are aligned with the conservation of their natural environment. There's a growing interest in non-timber forest products like Almescar resin, as they offer a way to value the standing forest, providing an alternative to logging and other destructive practices.

### Scientific Research

*Protium heptaphyllum* was for the first time published by Marchand [4] in 1873 and *Protium icicariba* by the same author [5] in 1867. Research into Almescar and other Amazonian resins is ongoing, with scientists exploring their potential applications in modern medicine and industry.

In this study we collected resin samples (Figure 2–5) of *Protium heptaphyllum* and *Protium icicariba* from different sources (Figure 6). We analyzed their chemical compositions and made a comparison of the results.

## Materials And Methods

### Plant Materials

(Figure 2 to Figure 6)

### Sample Preparation

120 mg of tree resin was used for analysis. Headspace gas chromatography/ mass spectroscopy analysis was used for the indirect determination of volatile constituents in solid samples by analyzing the associated vapor phase. Analytical method validation - selectivity, specificity, accuracy, precision, linearity, range, limit of detection, limit of quantification, ruggedness, and robustness are beyond the scope of this manuscript and will be published elsewhere.

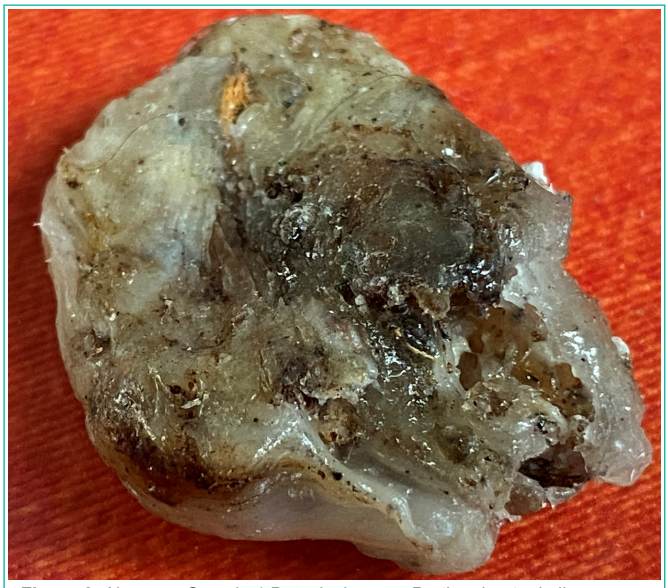


**Figure 2:** Almescar Sample 1 Botanical name: *Protium heptaphyllum* Originated from: Caraíva - Bahia, Brazil Sample type: fresh resin.

**Figure 3:** Almescar Sample 2 Botanical name: *Protium heptaphyllum* Originated from: Jambreiro-Bahia Brazil.

**Figure 4:** Almescar Sample 3 Botanical name: *Protium icicariba* Originated from: caraíva Bahia Brazil Sample type: fresh resin.

**Figure 5:** Almescar Sample 4 Botanical name: *Protium icicariba* Originated Belém- Pará Brazil Sample type: dry after curing.

### General Experimental Procedures

**Experimental conditions:** For the GC/MS analysis, we employed


**Figure 6:** Illustration of the map of Brazil showing: location A where samples 1-3 were collected and location B where sample 4 was collected.

an Agilent 7890B GC combined with an Agilent 5977B MSD and a PAL 3 (RSI 85) chromatograph. The column used was HP-5MS UI, 30 m × 0.25 mm with a film thickness of 0.25 µm, provided by Agilent Technologies, Inc. The analytical conditions were set with the column initially held at 35°C for 5 min. Subsequently, the temperature was programmed to rise from 35°C to 150°C at a rate of 5°C/min, then increasing by 15°C/min to 250°C, with a hold time of 90 min. The specific settings were as follows: Inlet temperature at 250°C, detector temperature at 280°C, split injection ratio of 1:5, initial temperature at 100°C, and initial time set to 4.0 min. Helium was used as the carrier gas with a flow rate of 1 mL/min. Incubation time: 6 min; Incubation temperature: 80°C.

### Identification

For compound detection and identification, we referenced various standards, retention times, and retention indices (Chromatogram 1,2, Table 1; Chromatogram 3,4, Table 2). Additionally, we consulted multiple libraries: NIST/EPA/NIH Mass Spectral Library 2017, Wiley Registry of Mass Spectral Data 11th Edition, FFNSC3, © 2015, and the Adams EO library, Mass Spectral Library, containing 2205 compounds. The identification of volatile compounds in the samples was based on a comparison of their mass spectra and retention times, along with their Kovats retention indices, either to those of injected standards or by referencing the National Institute of Standards and Technology's Mass Spectral Library database.

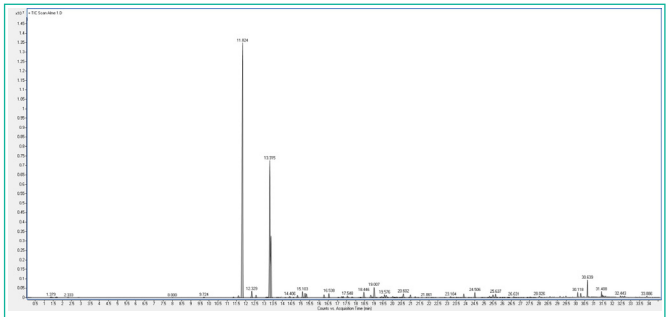
Commercially available standards for α-pinene, camphene, β-pinene, myrcene, Δ3-carene, α-terpinene, p-cymene, limonene, 1,8-cineole, α-ocimene, trans-β-ocimene, γ-terpinene, terpinolene, linalool, isopulegol, geraniol, β-caryophyllene, α-humulene, cis-nerolidol, trans-nerolidol, caryophyllene oxide, guaiol, and α-bisabolol were obtained from Restek (Bellefonte, PA, USA).

## Results

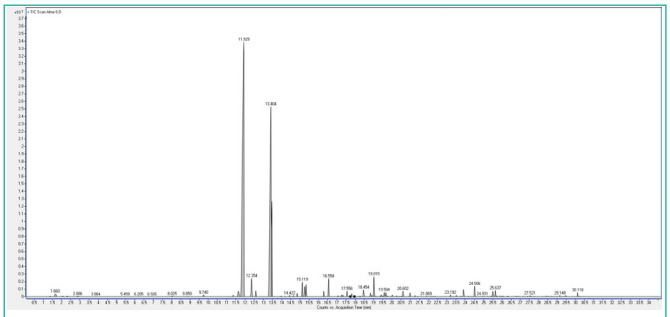
All samples contained high amounts of pinene (α and β). Both samples of *P. heptaphyllum* contained high amounts of sabinene while the two samples of *P. icicariba* did not revealed any sabinene. Sample 4 of *P. icicariba* contained a unique chemical composition with high amounts of *p*-cymene and α- and β-phellandrene.

As we did not have all the main compounds as standards, it was impossible to quantify all these volatiles exactly. Percentage compositions (in Tables as % were obtained from electronic integration measurements without considering relative response factors).

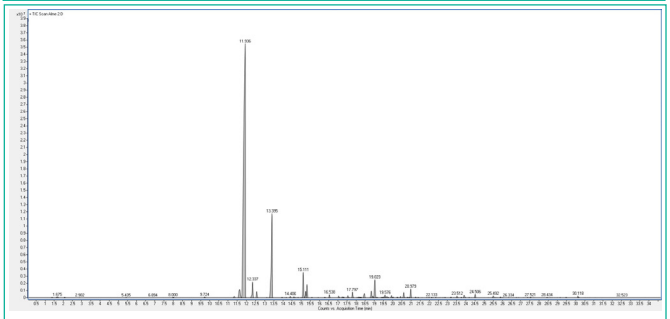
(Chromatogram 1 to 4 & Table 1 & 2)



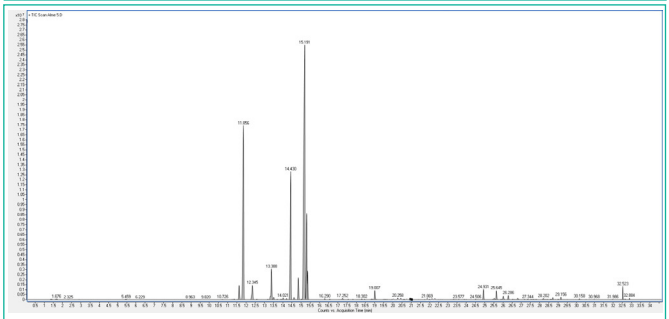
**Chromatogram 1:** GC/MS chromatogram of the sample 1 (*Protium heptaphyllum*).



**Chromatogram 2:** GC/MS chromatogram of the sample 2 (*Protium heptaphyllum*).



**Chromatogram 3:** GC/MS chromatogram of the sample 3 (*Protium icicariba*).



**Chromatogram 4:** GC/MS chromatogram of the sample 4 (*Protium icicariba*).

**Table 1:** *Protium heptaphyllum* (Aubl.) Marchand - concentrations of content compounds (% of total).

| No | RT | Compound | 1 | 2 |
|---|---|---|---|---|
| | | | % | % |
| 1 | 2.301 | 2-methyl-3-butene-2-ol | | 0.06 |
| 2 | 3.864 | 3-ethyl-2,2-dimethyloxirane | | 0.03 |
| 3 | 6.205 | 3-methyl-2-butenal | | 0.02 |
| 4 | 6.758 | hexenal | | 0.02 |
| 5 | 8.025 | 3,3,5,5-tetramethylcyclopentene | 0.03 | 0.07 |
| 6 | 11.368 | tricyclene | 0.12 | 0.17 |
| 7 | 11.52 | cumene | | 0.02 |
| 8 | 11.68 | α-thujene | 0.35 | 0.79 |
| 9 | 12.025 | α-pinene | 44.62 | 45.68 |
| 10 | 12.37 | camphene | 1.08 | 1.54 |
| 11 | 12.594 | dehydrosabinene | 0.4 | 0.47 |
| 12 | 13.428 | sabinene | 21.43 | 28.05 |
| 13 | 13.484 | β-pinene | 8.78 | 6.28 |
| 14 | 13.901 | 6-methyl-5-hepten-2-one | | 0.01 |
| 15 | 14.205 | trans-p-menth-2-ene | | 0.02 |
| 16 | 14.422 | α-phellandrene | | 0.12 |
| 17 | 14.614 | o-methyl-anisole | 0.04 | 0.09 |
| 18 | 14.847 | α-terpinene | 0.32 | 0.26 |
| 19 | 15.175 | p-cymene | 0.83 | 1.12 |
| 20 | 15.288 | limonene | 0.67 | 0.81 |
| 21 | 15.352 | 1,8-cineole | 0.56 | 0.93 |
| 22 | 16.29 | γ-terpinene | 0.43 | 0.42 |
| 23 | 16.546 | cis-sabinene hydrate | 0.59 | 1.43 |
| 24 | 17.332 | 2-(2,2,4-trimethyl-1-cyclopent-3-enyl) acetaldehyde | 0.17 | 0.13 |
| 25 | 17.644 | linalool | 0.01 | 0.02 |
| 26 | 17.813 | 3-thujen-2-ol | | 0.25 |
| 27 | 18.157 | β-thujone | 0.01 | 0.01 |
| 28 | 18.246 | dehydrosabinaketone | | 0.04 |
| 29 | 18.454 | α-campholenal | 0.91 | 0.63 |
| 30 | 18.839 | trans-pinocarveol | 0.47 | 0.36 |
| 31 | 19.015 | camphor | 1.66 | 1.83 |
| 32 | 19.36 | 3-thujen-2-one | 0.09 | 0.07 |
| 33 | 19.424 | sabina ketone | 0.2 | 0.16 |
| 34 | 19.512 | pinocamphone | 0.04 | 0.03 |
| 35 | 19.584 | pinocarvone | | 0.35 |
| 36 | 19.673 | endo-borneol | 0.52 | 0.37 |
| 37 | 20.049 | terpinen-4-ol | 0.31 | 0.13 |
| 38 | 20.434 | α-terpineol | 0.05 | 0.03 |
| 39 | 20.61 | myrtenal | 0.62 | 0.43 |
| 40 | 20.987 | verbenone | 0.4 | 0.32 |
| 41 | 21.26 | trans-carveol | 0.13 | 0.08 |
| 42 | 21.861 | cumin aldehyde | 0.04 | 0.03 |
| 43 | 21.989 | carvone | 0.01 | 0.01 |
| 44 | 22.142 | 2,5-dimethoxytoluene | | 0.03 |
| 45 | 23.192 | bornyl acetate | 0.16 | 0.15 |
| 46 | 23.616 | undecanal | 0.03 | |
| 47 | 24.603 | δ-elemene | | 0.01 |
| 48 | 24.931 | α-cubebene | | 0.03 |
| 49 | 25.3 | butoxyethoxyethyl acetate | 0.28 | |
| 50 | 25.42 | cyclosativene | | 0.03 |
| 51 | 25.637 | copaene | 0.51 | 0.49 |
| 52 | 25.741 | daucene | | 0.06 |
| 53 | 25.885 | α-bourbonene | 0.06 | 0.07 |
| 54 | 26.005 | β-cubebene | 0.06 | |
| 55 | 26.054 | β-elemene | | |
| 56 | 26.286 | cyperene | | 0.02 |
| 57 | 26.126 | tetradecane | 0.04 | |
| 58 | 26.374 | dodecanal | 0.1 | |
| 59 | 26.631 | β-ylangene | | 0.01 |
| 60 | 26.968 | sibirene | | 0.01 |
| 61 | 27.368 | guaia-6,9-diene | 0.07 | 0.04 |
| 62 | 27.833 | 9-epi-(E)-caryophyllene | | 0.02 |
| 63 | 28.026 | dodecanol | 0.22 | |
| 64 | 28.202 | γ-muurolene | | 0.02 |
| 65 | 28.282 | α-amorphene | | 0.02 |
| 66 | 28.443 | β-selinene | 0.05 | 0.06 |
| 67 | 28.531 | δ-selinene | 0.02 | 0.02 |
| 68 | 28.603 | pentadecane | 0.11 | |
| 69 | 28.627 | α-selinene | | 0.02 |
| 70 | 28.715 | α-muurolene | 0.01 | 0.03 |
| 71 | 28.996 | γ-cadinene | 0.01 | 0.03 |
| 72 | 29.148 | δ-cadinene | 0.11 | 0.08 |
| 73 | 29.268 | dauca-4(11),8-diene | | |
| 74 | 29.468 | cis-dracunculifoliol | 0.14 | |
| 75 | 30.639 | isopropyl laurate | 1.6 | |
| 76 | 31.408 | lauryl acrylate | 0.49 | |
| 77 | 31.473 | heptadecane | 0.25 | |
| 78 | 32.443 | octadecane | 0.13 | |
| 79 | 33.493 | 14-methyl-pentadecanoic acid methyl ester | 0.04 | |
| | | | 90.80% | 94.90% |

**Table 2:** *Protium icicariba* (DC.) Marchand - concentrations of content compounds (% of total) in samples 3 and 4.

| No | RT | Compound | 3 | 4 | RI |
|---|---|---|---|---|---|
| | | | % | % | |
| 1 | 5.459 | toluene | 0.04 | 0.07 | 763 |
| 2 | 6.229 | 3-methyl-2-butenal | | 0.01 | 782 |
| 3 | 8 | 3,3,5,5-tetramethylcyclopentene | 0.08 | | 857 |
| 4 | 10.726 | bornylene | | 0.02 | 906 |
| 5 | 11.247 | 5,5-dimethyl-1-vinylbicyclo[2.1.1]hexane | | 0.02 | 921 |
| 6 | 11.351 | tricyclene | 0.19 | 0.07 | 925 |
| 7 | 11.512 | cumene | | 0.02 | 927 |
| 8 | 11.616 | α-thujene | 1.79 | 1.56 | 929 |
| 9 | 11.856 | α-pinene | 66.61 | 20.43 | 937 |
| 10 | 12.345 | camphene | 1.89 | 1.74 | 952 |
| 11 | 12.586 | dehydrosabinene | 0.64 | 0.05 | 956 |
| 12 | 13.388 | β-pinene | 12.25 | 3.22 | 979 |
| 13 | 13.7 | trans-p-menth-2-ene | 0.04 | 0.04 | 981 |
| 14 | 13.901 | 6-methyl-5-hepten-2-one | | 0.04 | 986 |
| 15 | 14.277 | Δ2-carene | | 0 | 1001 |
| 16 | 14.43 | α-phellandrene | | 13.05 | 1005 |
| 17 | 14.606 | Δ3-carene | 0.13 | 0.24 | 1011 |
| 18 | 14.847 | α-terpinene | | 2.06 | 1017 |
| 19 | 15.007 | p-ment-1-ene | | 0.05 | 1025 |
| 20 | 15.191 | p-cymene | 2.67 | 39.5 | 1025 |
| 21 | 15.239 | limonene | 0.68 | | 1030 |
| 22 | 15.296 | β-phellandrene | | 7.73 | 1031 |
| 23 | 15.352 | 1,8-cineole | 1.35 | 1.99 | 1032 |
| 24 | 15.64 | cis-β-ocimene | | 0 | 1038 |
| 25 | 16.29 | γ-terpinene | 0.06 | 0.09 | 1060 |
| 26 | 16.554 | cis-sabinene hydrate | 0.32 | 0.06 | 1070 |
| 27 | 17.252 | terpinolene | | 0.17 | 1088 |
| 28 | 17.324 | 2-(2,2,4-trimethyl-1-cyclopent-3-enyl) acetaldehyde | 0.08 | | |
| 29 | 17.821 | 3-thujen-2-ol | 0.61 | 0.03 | 1107 |
| 30 | 18.149 | β-thujone | 0.11 | | 1114 |
| 31 | 18.462 | α-campholenal | 0.6 | 0.03 | 1125 |
| 32 | 18.823 | trans-pinocarveol | 0.75 | | 1139 |
| 33 | 18.911 | verbenol | 0.16 | | 1140 |
| 34 | 19.007 | camphor | | 0.89 | 1142 |
| 35 | 19.32 | menthone | | 0 | 1154 |
| 36 | 19.52 | pinocamphone | 0.08 | 0.02 | 1160 |
| 37 | 19.592 | pinocarvone | 0.29 | 0.02 | 1164 |
| 38 | 19.68 | borneol | 0.19 | 0.01 | 1166 |
| 39 | 19.937 | cis-pinocamphone | 0.22 | 0.01 | 1173 |
| 40 | 20.033 | terpinen-4-ol | 0.07 | 0.03 | 1177 |
| 41 | 20.258 | p-cymen-8-ol | 0.07 | 0.14 | 1183 |
| 42 | 20.426 | α-terpineol | 0.12 | 0.09 | 1189 |
| 43 | 20.61 | myrtenal | 0.56 | 0.05 | 1193 |
| 44 | 20.795 | homomyrtenol | 0.06 | | 1194 |
| 45 | 20.995 | verbenone | 0.88 | 0.02 | 1205 |
| 46 | 21.252 | trans-carveol | 0.07 | | 1217 |
| 47 | 21.725 | thymol methyl ether | | 0.01 | 1235 |
| 48 | 21.869 | cumin aldehyde | 0.03 | 0.07 | 1239 |
| 49 | 21.981 | carvone | 0.03 | | 1242 |
| 50 | 21.989 | carvacrol methyl ether | | 0.03 | 1244 |
| 51 | 22.101 | carvotanacetone | | 0.03 | 1246 |
| 52 | 22.158 | thymoquinone | | 0.02 | 1250 |
| 53 | 22.133 | 2,5-dimethoxytoluene | 0.05 | | 1251 |
| 54 | 22.286 | piperitone | | 0.07 | 1253 |
| 55 | 22.615 | 3,5-dimethoxytoluene | | 0.01 | 1274 |
| 56 | 23.184 | bornyl acetate | 0.08 | | 1285 |
| 57 | 23.288 | p-cymen-7-ol | | 0.03 | 1289 |
| 58 | 23.577 | carvacrol | | 0.03 | 1299 |
| 59 | 24.603 | δ-elemene | | 0.01 | 1338 |
| 60 | 24.931 | α-cubebene | | 0.87 | 1351 |
| 61 | 25.428 | cyclosativene | | 0.01 | 1368 |
| 62 | 25.525 | ylangene | | 0.15 | 1372 |
| 63 | 25.645 | copaene | 0.03 | 0.79 | 1376 |
| 64 | 25.741 | daucene | | 0 | 1381 |
| 65 | 25.893 | α-bourbonene | 0.09 | 0.03 | 1384 |
| 66 | 26.014 | β-cubebene | | 0.38 | 1389 |
| 67 | 26.286 | cyperene | | 0.39 | 1399 |
| 68 | 26.535 | α-gurjunene | 0.01 | 0.05 | 1409 |
| 69 | 26.879 | γ-maaliene | 0.02 | | 1435 |
| 70 | 27.16 | α-bergamotene | | 0.03 | 1435 |
| 71 | 27.248 | α-guaiene | | 0.01 | 1439 |
| 72 | 27.368 | guaia-6,9-diene | 0.04 | | 1450 |
| 73 | 27.649 | α-humulene | | 0.03 | 1454 |
| 74 | 28.202 | γ-muurolene | | 0.13 | 1477 |
| 75 | 28.314 | α-curcumene | | 0.02 | 1483 |
| 76 | 28.442 | β-selinene | 0.04 | 0.03 | 1486 |
| 77 | 28.523 | δ-selinene | 0.01 | | 1490 |
| 78 | 28.627 | α-selinene | 0.02 | | 1494 |
| 79 | 28.715 | α-muurolene | 0.02 | 0.16 | 1499 |
| 80 | 28.996 | γ-cadinene | 0.02 | 0.05 | 1513 |
| 81 | 29.156 | δ-cadinene | 0.03 | 0.18 | 1524 |
| 82 | 29.316 | cadina-1,4-diene | | 0 | 1533 |
| 83 | 29.509 | α-calacorene | | 0.01 | 1542 |
| 84 | 29.837 | β-calacorene | | 0 | 1563 |
| 85 | 30.158 | caryophyllene oxide | | 0.06 | 1581 |
| 86 | 30.527 | humulene epoxide I | | 0.01 | 1604 |
| 87 | 30.968 | δ-cadinol | | 0.02 | 1645 |
| | | | 94.15% | 97.50% | |

**Table 3:** The main compounds and the main differences in samples of *P. heptaphyllum* and *P. icicariba*.

| | *P. heptaphyllum sample 1 (%)* | *P. heptaphyllum sample 2 (%)* | *P. icicariba sample 3 (%)* | *P. icicariba sample 4 (%)* | RI |
|---|---|---|---|---|---|
| α-thujene | 0.35 | 0.79 | 1.79 | 1.56 | 929 |
| α-pinene | 44.62 | 45.68 | 66.61 | 20.43 | 937 |
| camphene | 1.08 | 1.54 | 1.89 | 1.74 | 952 |
| sabinene | 21.43 | 28.05 | 0 | 0 | 974 |
| β-pinene | 8.78 | 6.28 | 12.25 | 3.22 | 979 |
| α-phellandrene | 0 | 0.12 | 0 | 13.05 | 1005 |
| p-cymene | 0.83 | 1.12 | 2.67 | 39.5 | 1025 |
| limonene | 0.67 | 0.81 | 0.68 | 0 | 1030 |
| β-phellandrene | 0 | 0 | 0 | 7.73 | 1031 |
| 1,8-cineole | 0.56 | 0.93 | 1.35 | 1.99 | 1032 |
| cis-sabinene hydrate | 0.59 | 1.43 | 0.32 | 0.06 | 1070 |
| terpinolene | 0 | 0 | 0 | 0.17 | 1088 |
| camphor | 1.66 | 1.83 | 0 | 0.89 | 1142 |
| isopropyl laurate | 1.6 | 0 | 0 | 0 | 1618 |

## Discussion

Previous studies suggest that the outcomes of resin analysis are influenced by multiple factors, including the freshness of the sample, preservation methods, processing techniques (e.g., steam distillation, hydrodistillation, organic solvent extraction), seasonal variation, and the geographic origin of the collected samples. These variables significantly impact the chemical composition of the resin..In resin produced by *Protium heptaphyllum*, the predominant terpenes and terpenoids identified in previous studies include limonene [6-8], terpinolene [9-14], p-cymene [13,15-17], and p-cymen-8-ol [7,9,11-13], with α-pinene [10,13-15], 1,8-cineole [3,7,8,18], α-phellandrene [8,10,13,18], and sabinene [3,7-10,15,18] observed in smaller concentrations.*Protium icicariba* has only been analyzed in three scientific papers. Siani et al. [19] analyzed the essential oils from the oleoresin in three different years.

The main compounds were *p*-cymene (20-40%), *p*-cymen-8-ol (10-26%), terpinolene (5.8-31.0%), limonene (5.8-8.0%), α-pinene (5.6-7.7%), and sabinene (1.6-2.3%). Pereira et al. [20] studied dehiscent/indehiscent ripe fruits and found as the main compounds E-β-ocimene (31.07/28.14%), α-fenchene (27.67/12.83%), limonene (16.10/21.29%), and α-phellandrene (8.86/12.50%). da Paz Lima et al. [21] found in *Protium icicariba* lupeol, and α- and β-amyrin.

(Table 3)

The evaluation and the ranking of the most prominent substances in all four samples is compared in Table 3. All four samples contained very high amounts of α-pinene and high amounts of β-pinene. Both samples of *P. heptaphyllum* contained high amounts of sabinene while the two *P. icicariba* samples contained no sabinene at all. *P. icicariba* sample 4 contained a unique chemical composition with high amounts of *p*-cymene and α- and β-phellandrene. Some compounds reported in previous studies, such as limonene [6-8] terpinolene [9-14], and p-cymen-8-ol [7,9,11-13], were found in negligible concentrations or were not detected in our samples. This discrepancy may stem from factors beyond sample processing, such as genetic variability, environmental conditions, or differences in collection and preservation methods.

The research of these substances in *P. heptaphyllum* and *P. icicariba* deserves greater attention due to the frequent use of their resins in indigenous cultures. Further research is essential to fully explore their chemical composition and potential applications.

## Author Statements

### Conflict of Interest Statement

No potential conflict of interest was reported by the author.

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