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Volatile Components of the Wood of Spanish Cedar, *Cedrela odorata*, from Costa Rica

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Abstract
Cedrela odorata, "cedro amargo", is a valuable lumber tree, which has fragrant smelling wood. The essential oil from the wood of *Cedrela odorata* from Guanacaste, Costa Rica, was obtained by hydrodistillation and analyzed by gas chromatography – mass spectrometry. The wood oil was rich in sesquiterpene hydrocarbons, including δ-cadinene (26%), β-curcumene (13%), and calarene (6%). In comparison, a commercial *C. odorata* wood oil sample from Colombia was dominated by δ-cadinene (53%), along with germacrene D (4%). The pleasant aroma and chemical components of *C. odorata* wood essential oil suggest that it may be an important resource for the cosmetic and flavor industries.

Keywords: Essential oil composition; δ-cadinene; β-curcumene; calarene

1. Introduction
Cedrela odorata L., "cedro amargo" (Meliaceae), is a large canopy tree that ranges from Mexico, through Central America and the West Indies, and into South America, including Peru, Brazil, and northern Argentina [1–3]. The wood is soft and light, easily worked and in much demand for carpentry, musical instruments, floors, ceilings, overlays, and crafts [3], resulting in overexploitation over much of its natural range [2]. The heartwood of *C. odorata* contains an aromatic, antifungal, and insect-repelling resin [4]. There have been previous reports on essential oils of *C. odorata* from the leaves from Nigeria [5] and Brazil [6], the bark from São Tomé y Príncipe [7] and Costa Rica [8], the stems from Brazil [6], and commercial wood oil [9]. In this work, we present thecomposition of the wood essential oil from *C. odorata* from Guanacaste Province, Costa Rica, and a commercial wood essential oil sample from Colombia.

2. Materials and Methods
2.1 Essential Oils
Wood shavings of *C. odorata* were obtained from the workshop of Leonardo Vargas Garcia, La Cruz, Abangares, Guanacaste, Costa Rica. Two different samples of 500 g of wood were hydrodistilled using a Mountain Home Biological SL-SS 20 L stainless steel essential oil distiller to give the wood oils in 1% yield. The wood essential oil from Colombia was a commercial sample provided by Daniel Sheffield (Essential Oil Quality Alliance, Charlestown, Indiana, USA).

2.2 Gas Chromatography – Mass Spectrometry
The *C. odorata* wood essential oils were analyzed by gas chromatography-mass spectrometry (GC-MS) using a Shimadzu GCMS-QP2010 Ultra operated in the electron impact (EI) mode (electron energy = 70 eV), scan range = 40–400 atomic mass units, scan rate = 3.0 scans/s, and GC-MS solution software v. 4.20 (Shimadzu Scientific Instruments, Columbia, MD, USA). The GC column was a ZB-5 fused silica capillary column (Phenomenex, Torrance, CA, USA) with a (5% phenyl)-polymethylsiloxane stationary phase and a film thickness of 0.25 μm. The carrier gas was helium with a column head pressure of 552 kPa and flow rate of 1.37 mL/min. The injector temperature was 260 °C and the ion source temperature was 260 °C. The GC oven temperature program was programmed for 50 °C initial temperature, temperature increased at a rate of 2 °C/min to 260 °C. A 5% *w/v* solution of the sample in CH_2Cl_2 was prepared and 0.1 μL was injected with a splitting mode (30:1). Identification of the oil components was based on their retention indices determined by reference to a homologous series of *n*-alkanes, and by comparison of their mass spectral fragmentation patterns with those reported in the literature

[10]. and stored in our in-house library [11].

3. Results and Discussion

The yellow, fragrant-smelling wood essential oils of *C. odorata* were obtained in 1% yield. The chemical compositions of the *C. odorata* wood essential oils from Costa Rica and from Colombia are compiled in Table 1. The *C. odorata* wood essential oils from Costa Rica were rich in sesquiterpene hydrocarbons δ-cadinene (26%), β-curcumene (13%), and calarene (6%), as well as the sesquiterpene alcohol α-cadinol (5%). In contrast, the wood oil from Colombia was dominated by δ-cadinene (53%), along with germacrene D (4%). Unfortunately, the chemical composition percentages were not reported in a previously published *C. odorata* wood oil [9]. From the published chromatogram, however, the major components were δ-cadinene, α-copaene, and α-cubebene. The wood oil samples in this current work showed very little α-copaene or α-cubebene.

Table 1: Chemical compositions (%) of the wood essential oils of *Cedrela odorata*.

RI[a]	Compound	Costa Rica #1	Costa Rica #2	Colombia
931	α-Pinene	0.1	0.1	0.2
948	Camphene	tr[b]	tr	---
971	Sabinene	tr	tr	---
977	β-Pinene	tr	tr	---
987	Myrcene	tr	tr	tr
1006	α-Phellandrene	tr	tr	---
1024	*p*-Cymene	tr	tr	tr
1028	Limonene	tr	tr	3.2
1030	β-Phellandrene	tr	tr	---
1031	1,8-Cineole	tr	tr	0.4
1044	(*E*)-β-Ocimene	tr	tr	---
1057	γ-Terpinene	tr	tr	---
1084	Terpinolene	tr	tr	---
1099	Linalool	tr	tr	---
1152	Citronellal	tr	tr	---
1298	Carvacrol	tr	tr	---
1330	Bicycloelemene	tr	tr	---
1333	δ-Elemene	tr	tr	0.5
1345	α-Cubebene	tr	tr	0.3
1367	α-Ylangene	---	---	0.6
1374	α-Copaene	0.3	0.2	1.3
1386	β-Cubebene	---	---	0.3
1388	β-Elemene	0.6	0.5	1.1
1405	α-Gurjunene	0.1	0.1	---
1413	*cis*-α-Bergamotene	2.7	2.6	0.9
1415	2-*epi*-β-Funberene	0.2	0.2	---
1417	β-Caryophyllene	---	---	0.1
1418	Aristolene	1.9	1.8	---
1424	β-Cedrene	0.8	0.7	---
1427	γ-Elemene	---	---	0.7
1428	Aromadendrene	0.4	0.4	---
1431	*trans*-α-Bergamotene	---	---	tr
1432	β-Gurjunene (Calarene)	5.5	5.7	---
1433	α-Guaiene	---	---	tr
1435	α-Maaliene	3.4	3.4	---
1439	6,9-Guaiadiene	---	---	1.7
1439	(*Z*)-β-Farnesene	0.4	0.3	---
1444	*cis*-Muurola-3,5-diene	0.1	0.1	---
1448	*trans*-Muurola-3,5-diene	0.2	0.2	0.5
1453	(*E*)-β-Farnesene	2.7	2.5	0.5
1455	Amorpha-4,11-diene	---	---	0.1
1455	α-Humulene	0.6	0.6	0.9
1458	α-Acoradiene	1.8	1.8	---
1461	Alloaromadendrene	2.6	2.5	2.8
1468	β-Acoradiene	4.5	4.6	---
1472	*cis*-Cadina-1(6),4-diene	0.3	0.3	0.1
1476	*trans*-Cadina-1(6),4-diene	4.1	4.2	0.5
1478	γ-Muurolene	---	---	1.0
1479	α-Amorphene	---	---	0.9
1480	Germacrene D	---	---	4.0
1481	*ar*-Curcumene	1.2	1.4	---
1483	(*Z,Z*)-α-Farnesene	0.4	0.4	0.1
1485	δ-Selinene	---	---	0.2
1487	β-Selinene	---	---	0.4
1490	*trans*-Muurola-4(14),5-diene	---	---	0.6
1491	Viridiflorene (Ledene)	1.3	1.3	---

1494	α-Selinene	---	---	0.9
1495	β-Alaskene	3.0	2.9	---
1498	α-Muurolene	0.9	0.9	2.1
1501	β-Cadinene	---	---	0.4
1511	δ-Amorphene	---	---	1.6
1514	β-Curcumene	13.0	12.8	2.2
1522	*trans*-Calamenene	---	---	0.3
1525	δ-Cadinene	26.0	26.3	53.2
1528	Zonarene	---	---	0.9
1530	(*E*)-γ-Bisabolene	---	---	0.1
1534	*trans*-Cadine-1,4-diene	0.1	0.1	0.3
1538	α-Cadinene	0.3	0.3	0.6
1543	α-Calacorene	0.1	0.1	0.7
1546	Elemol	---	---	0.4
1557	Germacrene B	---	---	1.4
1561	(*E*)-Nerolidol	1.2	1.1	---
1563	β-Calacorene	0.1	0.1	0.2
1571	Maaliol	0.3	0.2	---
1577	Spathulenol	0.1	0.1	tr
1580	*trans*-Sesquisabinene hydrate	tr	tr	---
1585	Gleenol	---	---	0.1
1587	Globulol	0.8	0.8	0.2
1595	Viridiflorol	0.4	0.4	0.2
1597	*allo*-Cedrol	0.2	0.2	---
1606	Ledol	0.6	0.6	0.1
1608	Rosifoliol	0.1	0.1	---
1612	Cedrol	2.4	2.5	---
1615	1,10 di-*epi*-Cubenol	0.3	0.3	0.1
1620	Junenol	---	---	0.1
1621	Selina-6-en-4β-ol	---	---	0.1
1625	*epi*-Cedrol	0.5	0.4	---
1628	1-*epi*-Cubenol	0.5	0.5	1.6
1629	γ-Eudesmol	---	---	0.1
1632	*cis*-Cadin-4-en-7-ol	---	---	0.2
1633	α-Acorenol	0.2	0.2	---
1638	β-Acorenol	0.1	0.1	---
1644	τ-Cadinol	2.6	2.6	1.3
1647	τ-Muurolol	2.2	2.2	1.8
1648	α-Muurolol (Torreyol)	1.0	1.0	0.8
1659	α-Cadinol	4.7	5.0	2.7
1662	Selin-11-en-4α-ol	0.1	0.2	0.2
1666	*trans*-Calamenen-10-ol	tr	tr	0.1
1670	β-Bisabolol	1.2	1.3	tr
1674	Sesquiterpineol	0.1	0.1	---
1685	α-Bisabolol	0.3	0.3	---
1695	Eudesm-7(11)-en-4-ol (Juniper camphor)	---	---	0.1
1723	(*Z*)-Nuciferol	0.1	0.1	---
1753	β-(*Z*)-Curcumen-12-ol	0.1	0.1	---
1963	Sandaracopimara-8(14),15-diene	0.1	0.1	---
2132	Nezukol	0.1	tr	---
	Monoterpene hydrocarbons	0.1	0.1	3.4
	Oxygenated monoterpenoids	tr	tr	0.4
	Sesquiterpene hydrocarbons	79.6	79.3	83.9
	Oxygenated sesquiterpenoids	19.9	20.3	10.0
	Diterpenoids	0.2	0.1	0.0
	Total Identified	99.8	99.8	97.6

[a] RI = Retention Indices determined with respect to a homologous series of *n*-alkanes on a ZB-5 column.
[b] tr = trace (< 0.05%).

The differences in essential oil compositions of *C. odorata* are not surprising. Significant genetic differentiation has been observed between northern Pacific and Atlantic populations of *C. odorata* in Costa Rica [12]. Likewise, there are significant genetic differences between populations of *C. odorata* from the Yucatán of Mexico and those from northwestern Costa Rica and Nicaragua [13]. Not surprisingly, there are also striking differences between the leaf essential oils of *C. odorata* from Nigeria [5], with α-santalene (9.5%), β-acoradiene (7.1%), β-elemene (6.8%), and caryophyllene oxide (6.0%), as the major components, and the leaf oil from Viçosa, Brazil [6], which had germacrene A (22.6%), β-elemene (19.3%), and bicyclogermacrene (7.6%) as the main essential oil compounds. Similarly, the bark essential oil of *C. odorata* from São Tomé y Príncipe was rich in α-copaene (14.4%), α-cadinol (11.2%), β-eudesmol (9.4%), and δ-cadinene (9.2%) [7]. *Cedrela odorata* bark oil from Costa Rica, on the other hand, was dominated by β-elemene (20.3%)

and germacrene D (15.4%). Although the compositions of *C. odorata* essential oils are remarkably different, they are all dominated by sesquiterpene hydrocarbons regardless of the plant tissue or geographical location.

4. Conclusions

Cedrela odorata wood essential oil has a pleasant aroma and if overharvesting can be prevented, may be an important source of natural ingredients for the cosmetic and flavor industries. The chemical compositions of *C. odorata* wood essential oils are generally dominated by δ-cadinene, but the relative concentrations of minor components vary widely. The organoleptic properties of *C. odorata* wood oil, then, can be profoundly influenced by the geographical source of the oil; a comprehensive analysis of essential oils of *C. odorata* from different geographical locations would be a welcome addition to our knowledge of the phytochemical properties of this tree.

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6. Conflicts of Interest

The authors declare no conflicts of interest. The funding sponsor, dō TERRA International, played no role in the design of the study; in the collection, analysis, or interpretation of the data; conclusions of the study; or in the decision to publish the results.

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