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Composition and variability of moena alcanfor (*Endlicheria krukovii* (A.C.Sm.) Kosterm.) essential oil

Alexis St-Gelais, Robin Van Loon and Guy Collin

Abstract

Ten samples of essential oils from *Endlicheria krukovii* (moena alcanfor) branches, obtained in recent years, show considerable compositional variability. α - and β -pinenes (20% each), are observed in three batches. Four other samples contain less pinenes and about 40% of sesquiterpene hydrocarbons distributed amongst about 55 different molecules. β -Elemene (7 to 11%) and β -selinene (1.6 to 2.7%) are the most important ones. In addition, two samples feature a relatively high amount of sesquiterpenes (52 and 69%), which are not systematically the same as those observed in the four previous samples. One last sample features monoterpene hydrocarbons (20%), sesquiterpene hydrocarbons (14%), and oxygenated sesquiterpenes (17%). Finally, several unidentified compounds are variously distributed between all samples. These observations can be relevant for the quality control of the species and suggest that further examination of the underlying factors of the variability (e.g., chemotypes, maturity...) will be needed in the future.

Keywords *Endlicheria krukovii*, moena alcanfor, essential oil composition

1. Introduction

The Madre de Dios department of Peru has been experiencing dramatic ecological and demographical changes in the past decades, particularly with the completion in 2013 of the Interoceanic Highway between the Peruvian coast and Brazil. This project induced local population growth and the construction of multiple secondary roads, which in turn increased the share of land dedicated to agriculture, urban areas and gold mining to the detriment of the intact Amazonian rainforest that characterizes this region ^[1] while disrupting the hydric equilibrium that heavily relies on evapotranspiration in this part of the world ^[2]. As part of efforts to reconcile this development pressure with sound biodiversity and ecological conservation, one tool is to promote viable revenues for local populations through non-timber forest products obtained from actively managed reforestation zones. The non-profit organization Camino Verde, which plants several hundred ligneous species under agroforestry management within their reforestation center in the buffer zone of the Tambopata National Reserve, is therefore actively exploring valorization possibilities in this perspective.

In recent years, the attention of Camino Verde and local partner farmers interested in agroforestry was drawn to several aromatic Lauraceae species of the genera *Aniba*, *Ocotea*, *Nectandra*, and *Endlicheria*, locally known as moenas, and the possibility of producing essential oils thereof. One of these species is *E. krukovii* (A.C. Sm.) Kosterm., or moena alcanfor (also moena alcanforada). Other common names for this tree found across Peru and Ecuador as well as in northern Bolivia and westernmost Brazil include ajua, moenilla, tinchi, yuwich and louro, and it was previously known as *Aniba krukovii* ^[3]. First planted in 2010, the young trees' lateral branches and leaves could be pruned starting in 2013 to distill essential oil, which was in the following years progressively introduced in small volume on the international markets. Until now, there was no scholarly account for the essential oil composition, which in turn is important for product authentication, safety assessment and quality control. This study therefore presents analytical data for several accessions of *E. krukovii* essential oil to assess its variability.

2. Materials and Methods

2.1 Plant Material

Five hundred fifty *Endlicheria krukovii* (A.C.Sm.) Kosterm. trees were planted in registered reforestation area of Camino Verde (12°50'04.1"S 69°26'45.6"W), close to the Tambopata

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River, southwest of Puerto Maldonado (Madre de Dios, Peru; Figure 1), between January and March of 2010. A voucher specimen was collected by Margot Salome Sairitupa and Alexis Marvin Medrano in 2017 and formally identified by

taxonomist Hernando Hugo Dueñas (Peru Ministry of Agriculture); a second voucher, collected by Cinthya Araoz, was identified by Carlos Reynel from the Universidad Nacional Agraria La Molina again in 2017.



Fig 1: Map situating the reforestation area of Camino Verde in Peru (red marker). The Inter-oceanic Highway (noted by code 30C) is clear on the zoomed region of Puerto Maldonado, as is its impact on its vicinity in terms of forest coverage.

2.2 Distillation of oils

Lateral woody branches (<15 cm diameter) of the plant, manually defoliated (Figure 2), were shredded by a wood chipper then steam/hydrodistilled for 5 hours using two locally-fabricated stainless steel distillers with 40 kg and 60

kg chipped biomass capacity respectively. Both distillers were operated with natural gas burner stoves and both had condensers consisting of a modified full-sized oil drum with a stainless steel serpentine inside. Distillation loads and yields are described in Table 1.



Fig 2: Plant collection process in the plantation. Small branches are manually defoliated before being subjected to chipping and distillation.

Table 1: Description of distilled samples.

Sample #	Collection date	Distilled biomass (kg)	Oilyield (g)	Oilyield (% m/m)
A	February 10, 2016	20	112	0.56
B	March 18, 2017	21	102	0.49
C	September 2, 2017	20.5	96	0.47
D	July 9, 2016	20	105	0.53
E	March 3, 2019	45	145	0.32
F	December 31, 2018	44	130	0.30
G	February 2, 2019	48	160	0.33
H	May 5, 2019	47	141	0.30
I	May 4, 2019	48	156	0.33
J	April 12, 2018	20	88	0.44

2.3 Gas chromatographic analyses

GC-FID analyses were carried out on an Agilent 7890A GC with a split/splitless injector and two FID detectors. Samples were injected through a two-hole ferrule simultaneously onto two columns: DB-5 (10 m × 0.10 mm × 0.10 μm, Agilent Technologies, CA, USA) and DB-Wax (10 m × 0.10 mm × 0.10 μm film thickness, Agilent Technologies). The temperature program was set at 35 °C for 1 min then heated at 9 °C/minute up to 250 °C. The injection port was heated at 250 °C. Oils were injected neat with an injection volume of 0.03 μL, except for sample I which was more viscous and had to be diluted in one part methanol and was therefore injected with twice that volume. The initial inlet pressure was set to 216.5 kPa in constant flow mode, with hydrogen as the carrier gas (flow rate: 0.7 mL/min). Injections were performed in split mode (300:1). The FID detectors were parameterized as follows: Temperature of 250 °C, H₂ flow of 40 mL/min, air flow of 450 mL/min, make-up gas flow (N₂) of 45 mL/min, sampling rate of 0.01 min.

2.3 GC-MS analyses

Injections were performed on an Agilent 7890B GC with a split/splitless injector coupled to an Agilent 5977B mass spectrometer. Samples were injected on either one of two columns: HP-5MS 30 m × 0.25 mm × 0.25 μm film thickness (Agilent Technologies), or DB-WaxUI 30 m × 0.25 mm × 0.25 μm film thickness (Agilent Technologies). The temperature program was set at 40 °C for 2 min, then heated at 3 °C/minute up to 220 °C which was maintained for 2 min. The injection port was heated at 250 °C. The injection volume was 0.5 μL, except for sample I where 1.0 μL was injected. The initial inlet pressure was set to 48.7 kPa in constant flow mode, with helium as the carrier gas (1.0 mL/min). Injections were performed in split mode (200:1). The detector was parameterized as follows: MS interface temperature of 250 °C, MS mode in EI, mass scan range of 40–550 amu, scan

speed of 1562 amu/s.

2.4 Data interpretation

FID data files were handled with Unichrom, and MS data files with Mass Hunter Qualitative Analysis B.07.00. Compounds were identified from their retention indices as calculated from C7 to C40 unbranched alkane standards and/or from MS databases (NIST17, Adams^[4], Mondello^[5], Tkachyov^[6], and custom libraries built from pure compounds and commercial essential oils) and through comparison of MS and FID chromatograms for both apolar and polar columns. For essential oils, semiquantitative data was obtained from the FID detector response on the DB-5 column in priority without any correction factor, using the internal normalization method. Figure 4 was prepared using Past3 statistical software using data from Table 2 (the individual sample data is available as Supporting Information), where non-detected compounds were considered as zeroes and trace values were all converted to a numerical 0.03% value.

3. Results & Discussion

Ten batches of essential oils, distilled across four years from the same plantation, were analyzed; representative chromatograms are shown in Figure 3. Moena alcanfor oil is overall complex, with 197 known compounds identified in at least one of the accessions (Table 2). While for some accessions this covers most of the oil's composition, there are nevertheless numerous minor unknown constituents, mostly belonging to the group of oxygenated sesquiterpenes based on the molecular ions and retention indices. Unknowns with a well-defined mass spectrum accounting for at least 0.5% of one of the oils were listed for future reference (Table 3), the rest forming in most chromatograms a zone of heavily overlapping minor peaks with a maximum observed in sample I.

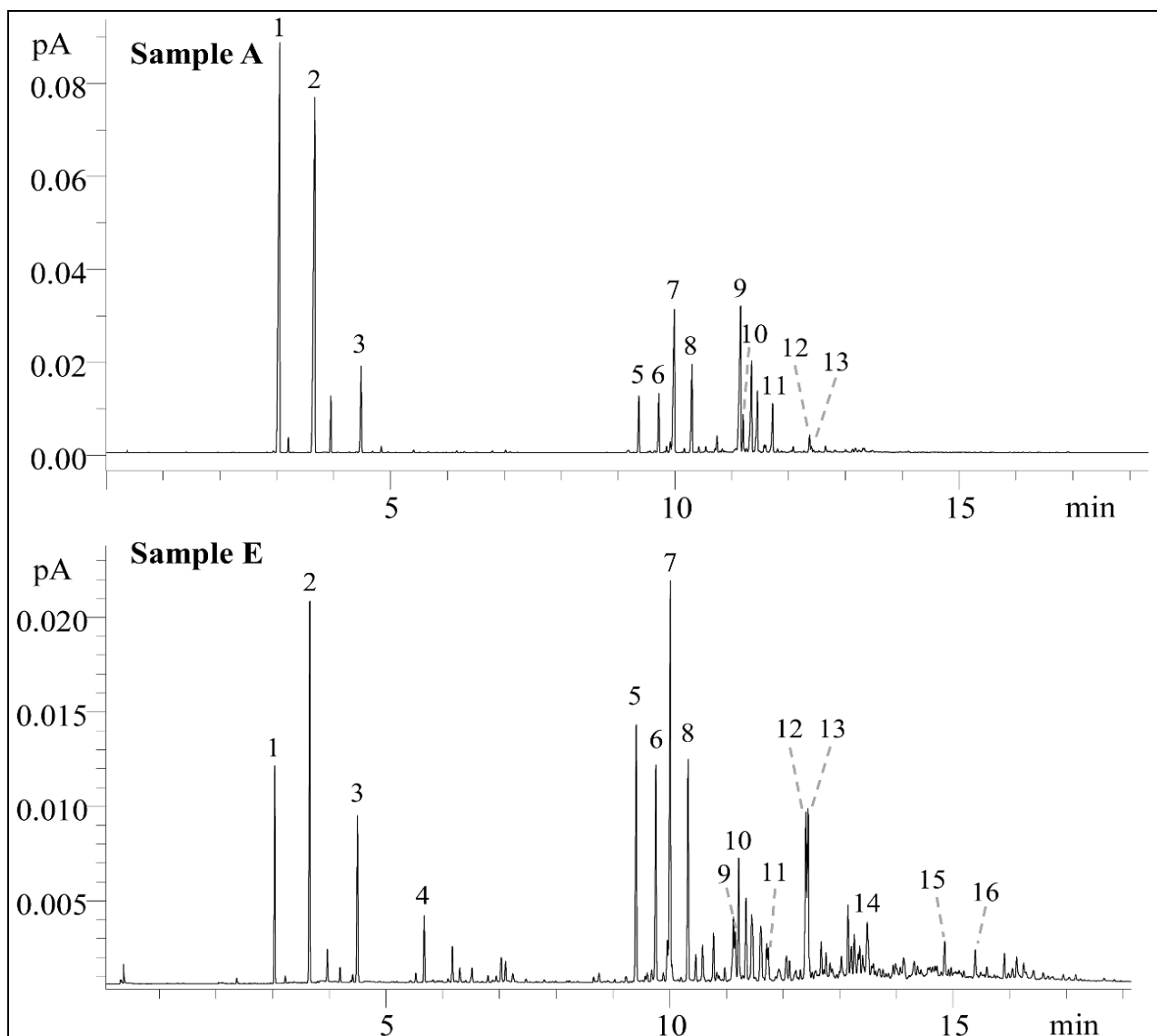


Fig 3: Representative FID chromatograms on DB-5 column for samples A and E. Identified compounds: 1. α -pinene; 2. β -pinene; 3. limonene+1,8-cineole; 4. linalool; 5. α -cubebene; 6. α -copaene; 7. β -elemene; 8. β -caryophyllene; 9. germacrene D; 10. β -selinene; 11. δ -cadinene; 12. spathulenol; 13. caryophyllene oxide; 14. unknown #11; 15. unknown #15; 16. unknown #16 (see table 3 for unknowns)

The oils all share some common features despite important variability. Both α - and β -pinenes are the major monoterpenes, together accounting for 2.3 up to 44.6% of the signal, except in sample G where (*E*)- β -ocimene precedes. Oxygenated monoterpenes, albeit numerous, do not overall represent a major fraction of the oils. The principal commonly shared characteristics are found in the group of sesquiterpenes, with α -cubebene (1.3-4.9%), α -copaene (1.9-8.7%) and β -elemene (2.3-12.0%) being important individual constituents of all batches. The sesquiterpenol spathulenol (0.7-6.4%) and the ether caryophyllene oxide (0.5%-3.7%) are also typical, as are some more minor compounds such as the group of τ - and α -cadinols and muurolols, 1-*epi*-cubenol, selin-11-en-4 α -ol, and both isomers of calamenen-10-ol.

There are however obvious differences between the batches. Some samples can be regrouped by similarity on the basis of their correlation (Figure 4). The proportion of pinenes is much higher in samples A, B and C. Oils D, E, F and J are generally similar, diverging from A-C mostly in the pinenes-to-sesquiterpenes proportions. Sample G, as mentioned earlier, features an ocimene as its main monoterpene, and alongside

sample H, its also contains three times more linalool than the other batches. The oil G furthermore contains distinctly more α - and β -selinenes as well as some peculiar molecules not or only marginally observed in the other batches, comprising 2,6-dimethylocta-3,5,7-trien-2-ols isomers, α -copaen-11-ol, *trans*-cadinene ether, brachyl oxide, the series of costols, dehydrofukinone and phytol. Sample H, with some correlation to samples A and C, is distinctly richer in germacrene D and bicyclogermacrene, and also singularly features viridiflorene, germacrene B and globulol which are either minor or absent in other oils. Sample I stands out as the sample richest in unknown minor oxygenated sesquiterpenes (Table 3), meanwhile featuring somewhat higher concentrations of oxygenated monoterpenes (chiefly *trans*-pinocarveol, *trans*-verbenol, myrtenal and myrtenol), including the unique occurrence of *trans*-sobrrol reported here. The same sample almost entirely lacks β -caryophyllene, α -humulene, germacrenes A, B and D, guaiol, and an important unknown at $R_{I_{DB-5}} = 1660$, which are otherwise present in all other samples to some extent.

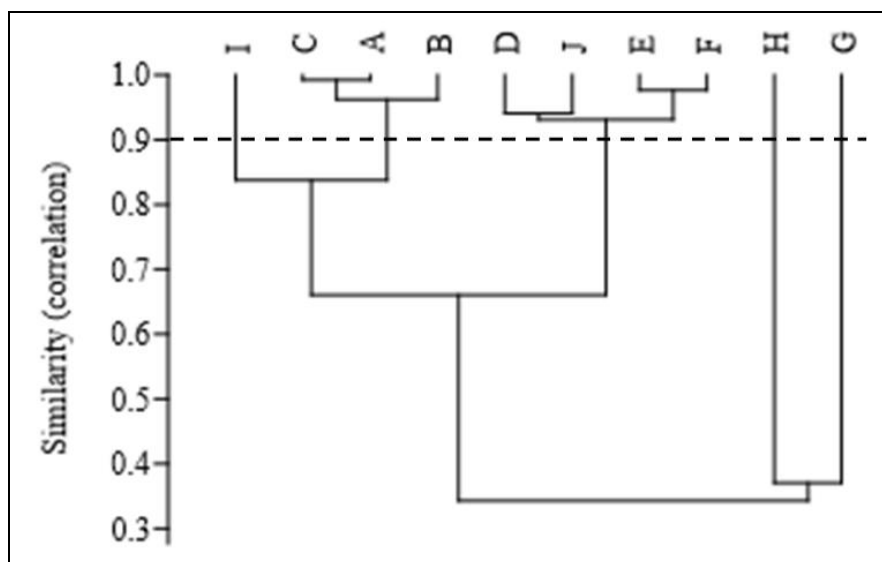


Fig 4: Dendrogram of 10 moena alcanfor essential oil samples A-J, based on the correlation similarity from the list of identified constituents. Correlation >0.90 was used as the threshold to group samples in Table 2.

At this time, this variability could not be correlated to any given factor. The saplings were established based on seeds collected from the wild, implying that if any chemotypic distribution exists in nature for the species, this diversity could fully translate into the plantation. Given the small scale at which distillation was conducted during production, some

batches might haphazardly feature more individuals belonging to a given possible chemotype than the others, which would explain the observed variability. This question remains to be elucidated by further studies at the individual tree level, which was beyond the scope of this study.

Table 2: Composition of moena alcanfor oils.

Compound	RI ^a	RI ^b	GC-FID signal % for sample				
			A, B and C	D, E, F, and J	G	H	I
Toluene	753	1006	t - 0.1	–	–	–	–
3-Acetyl-3-methyl-cyclopentene	881	933	t	0 - 0.1	–	t	t
α -Thujene	925	1000	0.1	t	t	t	t
α -Pinene	930	993	19.7 – 22.8	2.5 – 6.5	1.1	1.6	7.8
Camphene	942	1028	0.4 – 0.5	0.1	t	0.1	0.3
Thuja-2,4(10)-diene	949	1085	t	t	–	–	0.1
3,7,7-Trimethylcyclohepta-1,3,5-triene	965	1134	–	t	–	–	–
β -Pinene	971	1068	19.3 – 22.4	5.0 – 9.2	1.2	1.3	9.4
Sabinene	971	1085	0.4 – 0.7	t - 0.2	t	t	0.1
Myrcene	992	1134	1.4 – 1.7	0.4 – 0.5	0.2	0.2	0.1
Δ^3 -Carene	1006	1111	t	0.1 - 0.2	0.5	0.5	0.3
<i>para</i> -Cymene	1021	1227	0.1	0.1 - 0.3	0.1	0.1	0.1
Limonene	1026	1159	2.4 – 3.2	1.3 – 2.1	0.8	0.5	1.3
1,8-Cineole	1026	1168	1.4 – 2.3	1.1 – 1.8	0.2	0.1	1.0
(<i>Z</i>)- β -Ocimene	1039	1204	t	–	0.9	t	t
(<i>E</i>)- β -Ocimene	1049	1219	t - 0.1	–	3.2	0.1	0.1
<i>cis</i> -Sabinene hydrate	1064	1431	0 - t	t	–	–	0.1
<i>cis</i> -Linalool oxide (fur.)	1070	1404	0 - t	t	0.1	t	t
Terpinolene	1084	1240	t - 0.1	t	0.4	0.1	0.1
<i>trans</i> -Linalool oxide (fur.)	1084	1431	0 - t	t	t	t	0.1
α -Pinene oxide	1091	1322	t - 0.3	0.1 – 0.2	t	–	0.1
<i>trans</i> -Sabinene hydrate	1094	1512	–	–	–	–	0.1
Linalool	1101	1519	t - 0.1	0.3 - 1.0	3.4	3.1	1.0
<i>endo</i> -Fenchol	1108	1540	0 - t	t	t	t	0.1
<i>cis-para</i> -Menth-2-en-1-ol	1116	1523	t	t	–	–	0.1
(<i>E</i>)-4,8-Dimethyl-1,3,7-nonatriene	1118	1276	–	–	–	0.1	–
<i>trans-para</i> -Mentha-2,8-dien-1-ol	1118	1583	–	t - 0.1	t	–	t
α -Campholenal	1121	1438	t	t - 0.1	t	–	0.7
Nopinone	1128	1535	t - 0.1	0.1	–	–	0.5
<i>trans</i> -Pinocarveol	1133	1605	0.1 – 0.7	0.6 – 0.8	t	t	3.1
<i>cis</i> -Pinene hydrate	1136	1557	–	–	–	–	0.1
<i>trans-para</i> -Menth-2-en-1-ol	1137	1587	–	0.1	–	–	t
<i>cis</i> -Verbenol	1137	1612	t	–	–	–	0.2
<i>trans</i> -Verbenol	1142	1634	0.1 – 0.3	0.3 - 0.4	0.1	t	2.6
Epoxyterpinolene	1143	1418	–	–	0.1	–	–

Pinocarvone	1156	1506	0.1 – 0.3	0.2 – 0.3	–	–	1.2
Borneol	1162	1623	0 - t	t	t	–	t
Isopinocampnone	1167	1487	t	t	t	–	0.1
Terpinen-4-ol	1174	1558	0.1	0.1 - 0.2	t	t	0.1
Cryptone	1179	1605	t	t - 0.1	t	–	0.1
<i>para</i> -Cymen-8-ol	1184	1801	t	0.1 - 0.2	0.2	t	0.2
Myrtenal	1189	1565	0.1 – 0.5	0.2 - 0.4	–	t	1.8
α -Terpineol	1189	1654	t – 0.1	0.1 – 0.3	t	0.1	0.1
Myrtenol	1194	1744	0.1 – 0.5	0.4 – 0.5	–	t	2.1
Verbenone	1203	1641	t – 0.2	0.2	–	–	1.2
(3 <i>Z</i> ,5 <i>E</i>)-2,6-Dimethyl-octa-3,5,7-trien-2-ol	1205	1770	–	–	0.1	–	–
(3 <i>E</i> ,5 <i>E</i>)-2,6-Dimethyl-octa-3,5,7-trien-2-ol	1212	1786	–	–	0.4	–	–
<i>trans</i> -Carveol	1219	1789	t – 0.1	0.1	–	–	0.7
<i>cis</i> -Carveol	1231	1818	t	t	–	–	0.1
Carvone	1241	1673	t – 0.1	0.1	–	–	0.3
Carvacrolmethylene	1246	1554	–	–	0.2	–	–
<i>trans</i> -Ascaridole glycol	1272	2041	0 - t	t -- 0.1	–	–	0.1
Car-3-en-5-one	1302	1845	–	0.1	t	–	–
Bicycloax-4(15)-ene	1332	–	0 - 0.1	0.1	t	t	0.1
δ -Elemene	1336	1431	0.1	0.1	0.1	1.3	0.2
Limonene <i>cis</i> -glycol	1336	2179	–	–	–	–	0.2
α -Cubebene	1349	1422	2.7 - 3.9	2.6 0 - 4.9	3.5	1.3	1.8
Cyclosativene I	1360	1434	0.1	0.2	0.2	0.1	0.3
Cyclosativene II	1363	1440	0.1 – 0.2	0.1 - 0.2	0.1	0.3	0.3
Isoledene	1368	1426	–	–	–	0.1	–
α -Ylangene	1368	1438	0.1	t – 0.1	t	0.3	0.2
<i>trans</i> -Sobrerol	1372	–	–	–	–	–	1.3
α -Copaene	1374	1449	2.7 – 3.5	3.8 – 8.7	2.7	5.4	1.9
β -Bourbonene	1380	1471	t	0.1 – 0.3	t	t	0.1
<i>cis</i> - β -Elemene	1383	1535	0.1 - 0.3	0.2 – 0.4	0.2	0.1	t
β -Cubebene	1388	1495	0.4 – 0.6	0.8 - 1.1	0.5	0.3	0.2
β -Elemene	1392	1548	4.4 - 9.2	6.4 – 12.0	4.5	3.6	2.3
Cyperene	1393	1472	0.1 - 0.2	0.2 - 0.3	0.1	–	0.2
Isocaryophyllene	1401	1529	–	0.1	0.1	t	–
Ylang-2,4(15)-diene	1401	1559	t	–	–	–	0.1
α -Gurjunene	1405	1482	0.1 - 0.2	0.1 - 0.2	0.1	0.1	t
β -Ylangene	1414	1523	0.1	0.1 – 0.2	0.1	0.2	–
<i>cis</i> - α -Bergamotene	1414	1529	t	0.1 – 0.3	0.1	0.1	–
β -Caryophyllene	1414	1545	2.2 - 4.5	3.8 - 4.4	5.5	7.3	0.1
γ -Maaliene	1417	1548	t	t - 0.1	–	0.1	–
β -Copaene	1424	1540	t – 0.3	0.5	0.3	0.3	0.3
α -Guaiene + <i>trans</i> - α -Bergamotene	1428	1545	0.1	0 - 0.1	0.3	0.1	t
α -Maaliene	1428	1558	–	0 - 0.3	–	0.1	–
γ -Elemene	1429	1591	t	–	t	0.3	–
Aromadendrene	1433	1555	0.3	0.7 - 0.9	0.1	1.4	0.6
Selina-5,11-diene	1438	1565	–	0 - 0.1t	–	t	–
6,9-Guaiadiene	1440	1558	–	0 - 0.1t	0.1	0.1	–
1,2,2 α ,3,3,4,6,7,8,8 α -Decahydro-2 α ,7,8-trimethyl-acenaphthylene	1441	1563	t	0 - 0.3	0.2	–	0.1
Dihydrocurcumene	1441	1634	0 - t	t - 0.1	t	0.1	0.2
α -Humulene	1448	1612	0.6 - 0.8	0.9 - 1.0	1.4	1.0	–
Rotundene	1452	1578	0.1	0.1 – 0.2	0.1	–	–
Selina-4(15),7-diene	1452	1587	0 - t	t – 0.1	t	t	–
<i>allo</i> -Aromadendrene	1455	1589	0.1 – 0.3	0.2 _ 0.4	0.1	0.6	0.1
Valerena-4,7(11)-diene	1457	1583	–	–	–	0.2	–
<i>cis</i> -Muurolo-4(15),5-diene	1457	1618	–	–	0.1	0.2	–
4,5- <i>diepi</i> -Aristolochene	1462	1618	–	0 - 0.1	0.1	t	0.1
γ -Gurjunene	1463	1600	t	t - 0.1	t	t	–
Selina-4,11-diene	1472	1623	0.1 - 0.2	0.2 - 0.3	1.3	0.2	–
γ -Muurolole + α -Amorphene	1474	1637	0.5 – 0.7	1.1 – 1.4	1.2	1.9	0.9
Germacrene D	1476	1652	1.8 – 8.1	0.4 – 1.0	1.0	11.2	–
<i>allo</i> -Aromadendr-9-ene	1481	1639	t - 0.1	0.1 – 0.2	0.1	–	t
β -Selinene	1481	1660	1.2 - 1.6	1.6 - 2.7	8.9	0.7	0.7
δ -Selinene	1482	1646	–	–	t	0.1	–
<i>ar</i> -Curcumene	1482	1730	–	–	0.1	–	–
γ -Amorphene + Valencene	1486	1662	0.1 - 0.2	0.1 – 0.2	0.7	0.3	0.1
α -Selinene	1490	1665	0.6 - 1.1	0.8 -- 1.1	7.1	0.8	0.2
Bicyclogermacrene	1490	1673	0.1 - 2.5	0.2 - 0.3	t	11.2	–
<i>epi</i> -Cubebol	1490	1840	0.3 – 0.5	0.3 – 0.9	0.3	0.3	0.8
Viridiflorene	1491	1641	0 - 0.1	–	0.2	1.1	–

α -Murolene	1498	1673	0.1 - 1.4	0.3 - 1.0	1.1	1.0	0.7
Germacrene A	1499	1701	0.8 - 2.0	0.5 - 1.3	1.0	1.2	–
δ -Guaiene	1502	1662	0.5 - 1.2	0.1	0.6	0.3	–
β -Bisabolene	1510	1683	–	–	0.2	–	–
γ -Cadinene + 7- <i>epi</i> - α -Selinene	1510	1701	0.3 - 0.5	0.5 - 1.0	1.1	1.2	0.6
Cubebol	1511	1890	0.4 - 0.6	0.3 - 0.9	0.5	0.1	0.6
<i>trans</i> -Calamenene	1518	1773	0.4	0.4 - 0.9	1.0	0.7	0.8
δ -Cadinene	1520	1704	0.8 - 2.0	0.3 - 0.7	4.0	6.6	0.1
<i>trans</i> -Cadina-1,4-diene	1523	1725	t - 0.1	0 - 0.1	0.2	0.2	–
Selina-4(15),7(11)-diene	1529	1718	–	–	–	0.1	–
α -Cadinene	1531	1735	0.1	0.1	0.2	0.3	t
α -Calacorene	1535	1851	0.1	0.1 - 0.3	0.1	0.2	0.3
Selina-3,7(11)-diene	1536	1718	–	–	–	0.2	–
α -Copaen-11-ol	1537	2002	–	–	1.1	–	–
<i>trans</i> -Cadinene ether?	1542	–	–	–	0.2	–	–
Isocaryophyllene epoxide B	1545	1854	0.1	0.2	0.1	t	0.1
α -Elemol	1545	2029	0.1 - 0.2	0.1 - 0.3	0.3	0.4	0.4
Salviadienol?	1545	2054	0 - 0.2	0.1 - 0.3	–	–	0.5
Germacrene B	1550	1764	0.1 - 0.3	0.1 - 0.2	0.2	4.2	–
β -Calacorene	1558	1890	0.1	0.1 - 0.3	0.4	0.1	t
1,5-Epoxyvalial-4(14)-ene	1559	1851	t - 0.1	0.1 - 0.3	–	t	–
Maaliol	1559	1937	–	–	–	0.2	–
Palustrol	1560	1865	–	–	–	0.1	–
Caryolan-8-ol	1565	1897	–	–	0.2	–	–
(<i>E</i>)-Nerolidol	1565	2002	0.1	0.2 - 0.3	0.1	0.5	0.4
Germacrene D-4-ol	1574	1996	0.1 - 0.2	–	–	–	–
Caryophyllene oxide isomer + 10- <i>epi</i> -Junenol	1574	1902	0.1 - 0.3	0.7	0.7	0.2	0.4
Spathulenol	1574	2064	1.3 - 1.7	3.7 - 6.4	0.7	2.6	2.8
Caryophyllene oxide	1576	1910	0.4 - 1.1	3.0 - 3.5	1.8	0.5	3.7
Globulol	1578	2015	0 - t	0.1 - 0.3	–	1.2	–
Salvial-4(14)-en-1-one	1581	1941	t - 0.1	0.1 - 0.2	–	–	0.2
Viridiflorol	1584	2023	t - 0.1	–	–	0.6	–
Cubeban-11-ol	1585	1990	t	–	0.1	0.3	–
Brachyl oxide	1588	1851	–	–	0.4	–	–
Humulene epoxide I	1590	1949	–	–	0.1	–	–
Guaiol	1594	2037	0.4 - 0.6	0.2 - 0.7	0.6	1.0	–
Eudesm-5-en-11-ol	1597	2055	–	–	0.2	0.3	–
Ledol	1598	1969	t - 0.1	0.1 - 0.2	0.1	0.1	0.1
Humulene epoxide II	1601	1964	0.1 - 0.2	0.5	0.5	–	0.9
Copaborneol	1601	2111	0.1	0 - 0.4	0.1	0.1	–
Torilenol	1606	2165	–	0.2 - 0.5	0.1	–	0.7
Junenol	1609	1986	0.1	0.1 - 0.4	0.2	0.1	0.1
10- <i>epi</i> - γ -Eudesmol	1610	2036	–	–	–	0.1	–
α -Corocalene	1616	1996	0.1	0.1 - 0.2	0.1	0.3	0.1
Rosifoliol	1619	2055	–	–	–	0.1	–
1- <i>epi</i> -Cubenol	1623	2002	0.1 - 0.3	0.1 - 0.8	0.8	0.4	0.4
Isospathulenol	1629	2161	0.1	0.1	–	0.3	–
Cubenol	1632	1993	0 - t	0.1 - 0.3	0.3	–	–
τ -Cadinol	1637	2114	0.1 - 0.2	0.2 - 0.3	0.7	0.4	0.1
τ -Muurolol	1637	2127	0.1 - 0.2	0.1 - 0.4	0.7	0.6	0.3
α -Muurolol	1641	2141	0.1	0.2 - 0.3	0.5	0.2	0.4
β -Eudesmol	1642	2161	–	–	0.7	0.3	0.1
α -Cadinol	1647	2170	0.4 - 0.5	0.3 - 0.7	1.0	1.1	0.8
α -Eudesmol	1649	2154	–	–	0.3	–	–
<i>cis</i> -Calamenen-10-ol	1649	2271	t - 0.1	0.3 - 0.4	0.4	0.2	0.4
Selin-11-en-4 α -ol	1654	2184	0.2 - 0.5	0.2 - 0.6	1.3	0.3	0.3
<i>trans</i> -Calamenen-10-ol	1656	2300	0.1 - 0.2	0.1 - 0.5	0.2	0.1	0.6
Bulnesol	1660	2146	0.2 - 0.3	0 - 0.1	–	0.3	–
(3 <i>Z</i>)-Caryophylla-3,8(13)-dien-5 β -ol	1662	2308	–	–	0.4	–	0.7
Cadalene	1667	2154	t - 0.1	0.1 - 0.2	0.2	0.1	0.3
Isocyperol	1667	2244	–	0.1 - 0.2	0.2	–	–
Mustakone	1672	2176	–	0.1	0.1	0.1	0.4
Cyperol	1672	2258	–	0 - 0.2	0.2	–	–
Eudesma-4(15),7-dien-1 β -ol	1683	2229	0.1 - 0.2	0.2 - 0.3	0.1	0.2	0.4
Patchoulone	1735	2257	t - 0.1	0.2 - 0.3	0.1	–	0.4
γ -Costol	1740	2436	–	–	0.5	–	–
β -Costol	1758	2501	–	–	1.6	0.1	–
α -Costol	1764	2498	–	–	1.5	0.1	–
Dehydrofukinone	1790	2349	–	–	0.4	–	–

Phytol	2112	2574	–	–	0.1	–	–
Total monoterpene hydrocarbons ^c			44.1 – 50.6	10.4 – 17.9	8.4	4.5	19.7
Total sesquiterpene hydrocarbons ^c			26.1 – 44.7	37.3 – 41.8	51.9	69.2	14.1
Total oxygenated sesquiterpene ^c			5.9 – 6.3	15.2 – 19.4	20.7	18.0	17.1
Total identified ^c			89.9 – 96.8	75.9 – 79.8	85.3	79.8	70.1

^aRetention index on a non-polar DB-5 column. ^bRetention index on a polar DB-Wax column. ^c: These values do not include the percentages of unidentified compounds appearing in Table 3.t: Between 0.01 and 0.05%.

The genus *Endlicheria* is part of the Lauraceae family within the major group Angiosperms (flowering plants). As the time of this writing, the World Flora Online catalogue lists 88 *Endlicheria* species [7]. As far as the volatile oils are concerned, only a few of them have received attention. A survey of the SciFinder database shows that either the composition or bioactive properties of *Endlicheria* essential oils are at least partially detailed for 4 of them, with an overall quite recent interest for the genus in that regard [8]. The chemical composition as well as the antioxidant and antimicrobial activities of the essential oil (EO) of *E. arenosa* from the Amazon region were described [9] and its leaf EO features some similarity with *E. krukovii* sample H analyzed

herein, owing to its high proportions of β -caryophyllene, germacrene D and bicyclogermacrene. EO of *E. bracteolat* [10, 11] was tested against *Leishmania amazonensis* [11]. Both EOs contains mainly sesquiterpenes (Table 4), with important differences between the various samples; this suggests that, as observed here with *E. krukovii*, *E. bracteolata* might feature important EO variability or even chemotypes. Some biological activities of the leaves and branches of *E. citriodora* oil, with methyl geranate as the major constituent (94.4 \pm 0.7%) were studied and characterized [12]. Finally, the antimicrobial potential of EOs from a series of plants, which include the EO obtained from *E. paniculata* was evaluated [13].

Table 3: Mass spectra of unidentified compounds.

Unknown #	RI ^a	Main ions ^b <i>m/z</i> (relative intensity)	Observed in samples within...		
			0.1-0.5%	0.6-1.0%	1.1-1.5%
1	1101	43 (100), 109 (82), 95 (54), 67 (54), 69 (48)	A, B, C, D, E, F, J	I	–
2	1222	119 (100), 93 (40), 91 (37), 43 (25), 41 (24)	–	I	–
3	1301	43 (100), 93 (66), 91 (44), 41 (38), 69 (35), ... 152(?) (1)	I	–	–
4	1406	108 (100), 93 (48), 95 (20), 109 (18), 41 (12)	I	–	–
5	1522	122 (100), 105 (39), 107 (38), 91 (32), 81 (31), 161 (30) ... 207 (20)	–	H	–
6	1535	108 (100), 107 (100), 43 (92), 91 (91), 93 (90), ... 220(?) (5)	D, E, F, G, J	–	–
7	1589	159 (100), 81 (56), 123 (52), 91 (50), 105 (44), ... 220 (7)	–	I	–
8	1594	43 (100), 95 (75), 93 (63), 41 (59), 109 (58), 67 (58)	E, F, H, J	D	–
9	1620	161 (100), 43 (74), 105 (57), 121 (45), 81 (43), ... 204 (31)	B, C, D, E, F, G, H	–	–
10	1632	43 (100), 93 (89), 91 (88), 79 (87), 123 (76), 81 (75)	A, C, H, J	D	B, E, F
11	1660	81 (100), 41 (46), 79 (46), 93 (39), 91 (33), ... 206(?) (8)	A, B, C	D, G, H, J	E, F
12	1669	159 (100), 177 (59), 135 (57), 91 (47), 105 (47), ... 220(?) (25)	G	–	–
13	1675	43 (100), 109 (81), 93 (80), 81 (74), 177 (67), 136 (55), ...	I	–	–
14	1728	43 (100), 194 (68), 136 (63), 81 (63), 177 (56), ... 238 (3)	–	–	I
15	1777	123 (100), 43 (86), 179 (71), 81 (66), 95 (59)	J	D, F, E	–
16	1824	123 (100), 191 (88), 81 (86), 41 (86), 151 (80)	A, B, C, H	D, E, F, I, J	–
17	1843	43 (100), 107 (97), 81 (83), 121 (77), 123 (74), ... 220(?) (26)	B, D, E, F, H, J	I	–
18	1871	91 (100), 93 (98), 81 (92), 41 (92), 105 (86)	A, B, C, D, H, J	E, F, I	–
19	1891	123 (100), 81 (96), 41 (74), 43 (64), 91 (62)	A, B, C, H, I, J	D, E, F	–

^a: Retention index on a non-polar DB-5 column; ^b: Bold characters: molecular ion or (?) hypothetic molecular ion, when observed

The essential oil yield of Brazilian *E. lorastemon*, *E. verticillata* and *E. anomala* was also measured in the 0.01-0.15% range depending on the plant part [14]. The two latter studies however did not report any chromatographic analysis of these EOs.

Several other genera of the Lauraceae are well-known for essential oil production and spices, and this aspect has been recently partially reviewed at the botanical family scale [15]. More specifically, Lauraceae genera that have commercial value in that regard include *Aniba* (rosewood [16]),

Cinnamomum (cinnamons [17], ravintsara [18], camphor tree [19]...), *Cryptocarya* (massoia [20], ravensara [18]), *Laurus* (bay laurel [21]), *Litsea* (may-chang [22]), *Ocotea* (ishpingo [23]), and historically *Sassafras* [19]. The small production of moena alcanfor EO is now offered in the trade, which paves the way for addition of *Endlicheria* to the list of commercially relevant Lauraceae genera, warranting increased future efforts to study the EO of its numerous species and, as suggested by the results included above, potential chemotypical variability.

Table 4: Main constituents (>10%) of EOs of *E. arenosa* and *E. bracteolata*

Species	Compounds	EO %	
		Leaves	Twigs
<i>E. arenosa</i> ^[9]	Bicyclogermacrene	42.2	–
	Germacrene D	12.5	0.6
	β -Caryophyllene	10.1	0.6
	Limonene	2.2	33.2
	Terpinen-4-ol	0.8	15.6
<i>E. bracteolata</i> ^[10]		Leaves	
	Guaiol	46.4	
	10-epi- γ -Eudesmol	17.9	
<i>E. bracteolata</i> ^[11]		Dry season	Rainy season
	β -Caryophyllene	21.2	17.7
	Guaia-10(14),11-diene	17.5	–
	α -Bulnesene (δ -guaiene)	13.7	–
	Valencene	–	30.0
	α -Phellandrene	–	10.4
	α -Selinene	2.1	9.2

4. Conclusions

The composition of 10 batches of moena alcanfor (*Endlicheria krukovii*) essential oil was studied, showing that characteristic constituents include α - and β -pinenes, α -cubebene, α -copaene, β -elemene, spathulenol, and caryophyllene oxide, alongside some other oxygenated sesquiterpenes. Nevertheless, considerable qualitative and quantitative variability was also observed, with several constituents being uniquely found in a single batch of oil. These results overall highlight that moena alcanfor oil distilled from genetically diverse populations should be expected to feature variability around the core common characteristics. On a broader scale, this study offers some perspective on the expected chemical composition of moena alcanfor on the market.

5. Disclosure statement

Robin Van Loon is the founder and director of the non-profit organization Camino Verde, which may benefit financially from the marketing of moena alcanfor essential oil ^[24]. The coauthors attest that R. Van Loon was only involved in the plant collection and in the distillation process, and that all conclusions presented in this report were reached by the other authors on an independent basis. A. St-Gelais and G. Collin declare no conflicting financial interest.

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