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Research Article

Chemical and olfactory analysis of essential oils of *Hedychium gardnerianum*, *Hedychium flavescens*, *Pittosporum senacia* and *Psidium cattleianum* from Reunion Island

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Abstract

Four essential oils (EOs), rarely described in the literature, and never for samples originating from Reunion Island, were studied by gas chromatography with flame ionisation detector (GC-FID) and gas chromatography coupled with mass spectrometry and olfactometry (GC/MS-O). The chemical composition, as well as the main olfactory properties, of the following four EOs were determined: longose (*Hedychium gardnerianum*), yellow ginger (*Hedychium flavescens*), bois de joli coeur (*Pittosporum senacia*), and Chinese guava (*Psidium cattleianum*). The chemical compositions were found to be rich in mono- and sesquiterpene hydrocarbons. The main components of *H. gardnerianum* flowers EO were β-farnesene (12.1%), α-cadinol (9.7%) and α-farnesene (7.1%). The composition of essential oil from *Hedychium flavescens* leaves is reported for the first time with β- and α-pinene (47.8 and 18.7%, respectively) as well as β-caryophyllene (17.5%) as the main compounds. The main components of *P. senacia* leaves EO and *P. cattleianum* floral tops EO were identified as nonane (36.2%) and β-caryophyllene (43.7%), respectively. With such a chemical composition, herbal, citrus, green, pine tree, and in some cases floral and woody odors were determined by GC/MS-O.

1. Introduction

The genus *Hedychium* is part of the Zingiberaceae family and includes about 80 species distributed mainly in Asia. *H. gardnerianum* is a plant native to the Himalayas whose stem can be 2 meters long and its leaves 30 cm long. Its flowers can be pink or orange yellow [1-3]. It is considered an invasive plant in most of the Azores archipelago [1]. The rhizomes of the *Hedychium* species are known to be fleshy and aromatic. Some species are cultivated only to extract the fragrant essential oil from their rhizomes. Aerial parts of the *Hedychium* species can be used in the paper industry and its flowers as culinary ingredients [4]. The bloom of the *Hedychium* species is very brief and usually occurs during the monsoon. The chemical profile of *Hedychium sp.* EO is reported as complex and comprising monoterpene and sesquiterpene derivatives. The compounds α-pinene, β-pinene, eucalyptol, linalool and nerolidol, although quite ubiquitous, are described as markers of the genus *Hedychium* [4].

The genus *Pittosporum* belongs to the Pittosporaceae family and encompasses ca. 200 species [5]. Among these, *Pittosporum senacia* is a species found in the Indian Ocean Islands. The chemical composition of EO from the whole plant from Mauritius was described in 2020 and 2021 by Jugreet et al. [5, 6]. In their most recent article, the distillation yield for *P. senacia* was found to be 0.77%. The chemical composition mainly comprised monoterpene hydrocarbons (up to 71.9%), and particularly β-myrcene (62.2%). Other compounds found were germacrene D (7.8%), limonene (3.4%), and β-phellandrene (2.9%). In an earlier article from 1998, EO from the leaves of *P. senacia coursii*, endemic to Madagascar, was studied [7]. With a distillation yield of 0.67%, 95% of the chemical composition of the EO was determined by GC-FID and GC/MS. With monoterpene hydrocarbons accounting for only 20.4%, including β-myrcene (6.3%), α-terpinene (4.6%) and camphene (3%), the main compounds were found to be sesquiterpene hydrocarbons and derivatives (69.5%) such as α-cadinol (19%), α-muurolol (15.9%), and δ-cadinene (11.3%). In the same study, the antimicrobial activity of this EO against *Staphylococcus aureus* was shown to outperform streptomycin, while it was in the same order of magnitude as streptomycin against *Streptococcus faecalis* [7].

The genus *Psidium* belongs to the Myrtaceae family which contains ca. 5500 species [8, 9]. This genus is known for presenting rich essential oil bearing plants [9]. *Psidium cattleianum* is a species found in Oceania, Brazil, North America and the Caribbean [8]. The shrub is typically between 1 and 4 meters in height. The EO from the leaves of *P. cattleianum* has been described as having antifungal activities against *Candida spp*. and antibacterial activities against several strains such as *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa* in qualitative analyses with the antibiotic ampicillin as control [8].

The chemical composition of EO from *P. cattleianum* leaves has been studied with plants coming mainly from Brazil [8-12]. Older studies describe *P. cattleianum* EO harvested in Hawaii [13], Cuba [14], and California [15].

As part of a project dedicated to the chemical and sensory evaluation of plants from Reunion Island for applications in perfumery, the chemical composition and olfactory properties of four essential oils (EOs) for which literature data are scarce or non-existent were studied. The four species, from the Zingiberaceae, Pittosporaceae, and Myrtaceae botanical families illustrated in Figure 1 are listed hereafter:

- Longose (*Hedychium gardnerianum* Sheppard ex Ker-Gawl) – flowers,
- Yellow ginger (*Hedychium flavescens* Carey ex Roscoe) – leaves,
- Bois de joli coeur (*Pittosporum senacia* Putt.) – leaves,
- Chinese guava (*Psidium cattleianum* Afzel. Ex Sabine) – floral tops.

The aim of these studies was to determine the chemical composition of these essential oils and evaluate their olfactory profile for potential applications in perfumery.

Figure 1. The four species studied: (1) *H. gardnerianum*, flowers; (2) *H. flavescens*, leaves; (3) *P. senacia*, leaves; (4) *P. cattleianum*, floral tops.

2. Materials and methods

2.1 Plant materials

H. gardnerianum, H. flavescens, P. senacia and *P. cattleianum* were collected in 2020 on Reunion Island, in the wild between 800 and 1300 meters of altitude and their essential oils were obtained from OLICA (19 Rue Fangourin, Saint-Leu 97424, La Réunion, FRANCE). The four pictures of the species in Figure 1 are licensed under the Creative Commons Attribution-Share Alike 3.0 Unported license without modification. Authors are (1) and (4) B. Navez, (2) Forest and Kim Starr, (3) Change-ecorce.

2.2 GC/MS-FID analyses

The analyses of the four EOs chemical compositions were performed on an Agilent GC 7820 chromatograph coupled to an Agilent 5977B electron ionization mass spectrometer and equipped with a flame ionization detector. The column used was Agilent HP5-MS capillary column (30 m x 0.25 mm i.d., film thickness 0.25 µm). The sample of EO was diluted to 1% v/v in ethyl acetate. One microliter of the sample was injected with a split ratio of 1/10. Carrier gas was helium with a flow rate of 1.2 mL/min. The temperatures of injector and source were 250 °C and 230 °C, respectively. The oven temperature was programmed to stay 4 min at 40°C, then to rise from 40 to 200°C with an increase of 2 °C/min and finally from 200 to 270 °C with an increase of 8 °C/min. For the MS, ionization energy was 70 eV and the range was from 35 to 350 m/z. The FID detector was set at 270 °C with an air flow of 400 mL/min and a hydrogen flow of 40 mL/min.

2.3 Characterization of the EOs

GC/MS was used for identification and GC-FID for quantification. The identification of EO constituents was carried out by matching the retention index (RI) determined against a series of C7-C40 alkanes as well as by *matching the EI-MS mass spectra obtained with various databases (NIST20, Wiley6n and internal database).*

2.4 GC/MS-O analyses

GC/MS-O analyses were performed on a Perkin Elmer Clarus 690 chromatograph coupled with a Perkin Elmer Clarus SQ8T mass selective detector and equipped with a Perkin Elmer sniffing port. The column was a Perkin Elmer Elite 5-MS (30m x 0.32mm i.d., film thickness 0.25μm). The sample of EO was diluted to 10% v/v in ethyl acetate. One microliter of the sample was injected with a split of 72 mL/min (inlet pressure: 23 psi). The split between the MS and the Olfactometry detector was 1:7 (v/v). The oven temperature was programmed to stay 2 min at 60 °C, to rise from 60 to 200 °C with an increase of 5 °C/min, then from 200 to 280 °C with an increase of 8 °C/min and finally held at 280 °C for 5 min. The solvent delay was 5.5 min. Four panelists carried out the GC/MS-O analysis in duplicate, on each of the four EOs. Compounds were annotated by matching the EI-MS mass spectra obtained with databases (NIST20).

3. Results and discussion

3.1 Hedychium gardnerianum and Hedychium flavescens

Essential oils obtained from the rhizomes of the two species *H. gardnerianum* and *H. flavescens* have been described in the literature [2-4, 16-18]. For example, Ray et al. studied 10 species of *Hedychium*, including *H. gardnerianum* and *H. flavescens*, cultivated under the same conditions in India [4]. After harvesting, the EO of each plant was collected from the rhizomes and analyzed by GC/MS and GC-FID. The distillation yield of *H. gardnerianum* and *H. flavescens* species was about 0.20%, which is lower than other species of the genus such as *H. thyrsiforme* (0.75%) and *H. gracile* (0.65%), and higher than others such as *H. flavum* (0.10%) and *H. greenii* (0.05%). The EO of *H. gardnerianum* was described as dark yellow and that of *H. flavescens* as dark brown. The chemical compositions of the two EOs were determined, accounting for 75.9% and 92.8% of oils of *H. gardnerianum* and *H. flavescens*, respectively. Both were composed mainly of monoterpene derivatives, mostly β-pinene and α-pinene (28.03% and 21.15% for *H. gardnerianum* and 29.76% and 13.17% for *H. flavescens*, respectively). Eucalyptol, one of the main compounds of *H. flavescens* (12.80%), was found in a much smaller fraction in *H. gardnerianum* (0.42%) [4].

The EO of *H. gardnerianum* flowers has been very little studied; to the best of our knowledge, only two papers published in 2002 and 2003 described the EO obtained from this part of the plant [1, 2] and EO extracted from the leaves of *H. flavescens* has never been described. Medeiros et al. studied the chemical composition of EO from *H. gardnerianum* flowers from three locations on San Miguel Island in the Azores [1]. The composition of these was determined using GC/MS analysis alone, accounting for 87%, 94% and 91% of the total EO from the three locations, respectively. Although they came from the same island, significant differences in the relative percentages of compounds were observed, although GC/MS alone can hardly provide reliable quantitative information. The main compounds of the three EOs were monoterpene hydrocarbons with α-pinene (8.38-18.13%), β-pinene (5.06-11.99%), p-cymene (3.85-8.16%), γ-terpinene (3.15-14.43%) and the sesquiterpene derivatives α-cadinol (6.42-14.59%), β-caryophyllene (7.04-8.89%), δ-cadinene (4.89-8.76%) and τ-muurolol (2.64-5.86%). The chemical composition of EO from *H. gardnerianum* flowers from Fiji was studied by Smith et al. [2]. Up to 75% of its chemical composition was characterized by GC/MS-FID analyses. β-Caryophyllene (17.4%) and β-pinene (17.0%) were found to be the two main compounds.

3.2 Hedychium gardnerianum flowers EO analysis

The sample of *H. gardnerianum* flowers EO was found to be chemically very complex (Fig. 2). As shown in Table 1, hundred compounds were detected by monodimensional gas chromatography and those identified accounted for more than 87% of the EO. The sample was mainly composed of sesquiterpene derivatives including β-farnesene (12.05%), α-cadinol (9.71%), α-farnesene (7.09%), τ-muurolol (5.89%) and δ-cadinene (5.83%). The monoterpene derivatives

Table 1. Chemical composition of *Hedychium gardnerianum* flowers essential oil.

Peak #	RT (min)	Compound	Area %	Formula	RI	RI litt.
1	**17.625**	**α-pinene**	**4.48**	$C_{10}H_{16}$	931	937
2	18.563	camphene	0.08	$C_{10}H_{16}$	945	952
3	20.344	sabinene	0.15	$C_{10}H_{16}$	971	974
4	**20.493**	**β-pinene**	**4.46**	$C_{10}H_{16}$	973	979
5	21.682	β-myrcene	0.21	$C_{10}H_{16}$	991	991
6	22.460	α-phellandrene	0.39	$C_{10}H_{16}$	1002	1005
7	22.853	3-carene	0.04	$C_{10}H_{16}$	1008	1011
8	23.339	α-terpinene	0.24	$C_{10}H_{16}$	1015	1017
9	23.892	*p*-cymene	1.46	$C_{10}H_{14}$	1022	1025
10	24.175	limonene	0.52	$C_{10}H_{16}$	1026	1030
11	24.363	eucalyptol	0.08	$C_{10}H_{16}O$	1029	1032
12	25.000	(*Z*)-β-ocimene	0.23	$C_{10}H_{16}$	1038	1038
13	**25.705**	**(*E*)-β-ocimene**	**2.97**	$C_{10}H_{16}$	1048	1049
14	**26.355**	**γ-terpinene**	**2.46**	$C_{10}H_{16}$	1057	1060
15	28.431	terpinolene	0.09	$C_{10}H_{16}$	1086	1088
16	28.888	methyl benzoate	0.06	$C_8H_8O_2$	1093	1094
17	**29.371**	**linalool**	**2.22**	$C_{10}H_{18}O$	1100	1099
18	30.504	(*E*)-4.8-Dimethyl-nona-1,3,7-triene	0.12	$C_{11}H_{18}$	1116	1116
19	31.954	sabinol	0.01	$C_{10}H_{16}O$	1137	1143
20	33.804	endo-borneol	0.09	$C_{10}H_{18}O$	1164	1167
21	34.654	terpinen-4-ol	0.10	$C_{10}H_{18}O$	1176	1177
22	35.662	methyl salicylate	0.11	$C_8H_8O_3$	1191	1192
23	41.904	bornyl acetate	0.06	$C_{12}H_{20}O_2$	1285	1285
24	41.921	2-undecanone	0.06	$C_{11}H_{20}O_2$	1285	1294
25	43.170	indole	0.01	C_8H_7N	1304	1295
26	45.202	δ-elemene	0.05	$C_{15}H_{24}$	1336	1338
27	45.945	α-cubebene	0.16	$C_{15}H_{24}$	1348	1351
28	47.567	α-copaene	0.19	$C_{15}H_{24}$	1374	1376
29	48.614	β-elemene	0.21	$C_{15}H_{24}$	1391	1391
30	49.628	α-gurjunene	0.04	$C_{15}H_{24}$	1407	1409
31	50.219	β-caryophyllene	1.38	$C_{15}H_{24}$	1417	1419
32	51.67	guaia-6,9-diene	0.07	$C_{15}H_{24}$	1442	1443
33	**52.281**	**humulene**	**3.93**	$C_{15}H_{24}$	1452	1454
34	**52.640**	**(6*E*)-β-farnesene**	**12.05**	$C_{15}H_{24}$	1458	1457
35	52.848	allo-aromadendrene	0.01	$C_{15}H_{24}$	1462	1461
36	53.484	γ-gurjunene	0.18	$C_{15}H_{24}$	1472	1473
37	53.680	γ-muurolene	0.45	$C_{15}H_{24}$	1476	1477
38	53.914	germacrene D	0.96	$C_{15}H_{24}$	1480	1481
39	54.061	α-curcumene	0.21	$C_{15}H_{22}$	1482	1483
40	54.537	Bicyclosesqui-phellandrene	0.17	$C_{15}H_{24}$	1490	1489
41	54.822	bicyclogermacrene	1.67	$C_{15}H_{24}$	1495	1495
42	55.070	α-muurolene	1.05	$C_{15}H_{24}$	1499	1499
43	55.461	β-cadinene	0.43	$C_{15}H_{24}$	1506	1518
44	**55.646**	**(3*E*,6*E*)α-farnesene**	**7.09**	$C_{15}H_{24}$	1509	1508
45	55.848	γ-cadinene	1.03	$C_{15}H_{24}$	1513	1513
46	**56.449**	**δ-cadinene**	**5.83**	$C_{15}H_{24}$	1523	1524
47	56.891	cadina-1,4-diene	0.09	$C_{15}H_{24}$	1531	1532
48	57.186	α-cadinene	0.24	$C_{15}H_{24}$	1536	1538
49	57.476	α-calacorene	0.12	$C_{15}H_{20}$	1542	1542
50	**57.897**	**Elemol**	**3.00**	$C_{15}H_{26}O$	1549	1549

Table 1. (*Continued*)

Peak #	RT (min)	Compound	Area %	Formula	RI	RI litt.
51	58.246	204 161 121 105 93 69	0.18	-	1555	-
52	58.548	204 161 121 109 93 41	0.14	-	1561	-
53	**58.767**	**(*E*)-nerolidol**	**2.11**	$C_{15}H_{26}O$	1564	1564
54	59.140	202 69 41 79 93 109 55	0.59	-	1571	-
55	**59.372**	**222 161 119 105 91 81**	**4.33**	**-**	**1575**	**-**
56	59.444	spathulenol	0.55	$C_{15}H_{24}O$	1576	1576
57	59.735	caryophyllene oxide	0.75	$C_{15}H_{24}O$	1582	1581
58	60.000	204 161 119 105 91 81	0.19	-	1586	-
59	60.332	202 159 97 83 69 55	0.18	-	1592	-
60	60.622	220 121 107 93 88 67	1.41	-	1597	-
61	60.851	204 122 107 93 81 69	0.26	-	1602	-
62	61.179	humulene oxide	1.46	$C_{15}H_{24}O$	1608	1604
63	61.358	222 179 105 91 69 41	0.55	-	1611	-
64	62.25	220 119 93 81 67 41	1.35	-	1628	-
65	62.413	γ-eudesmol	0.97	$C_{15}H_{26}O$	1631	1631
66	**63.024**	**τ-muurolol**	**5.89**	$C_{15}H_{26}O$	1642	1642
67	63.225	204 161 119 105 95	0.84	-	1646	-
68	63.411	β-eudesmol	0.67	$C_{15}H_{26}O$	1649	1649
69	**63.749**	**α-cadinol**	**9.71**	$C_{15}H_{26}O$	1655	1653
70	64.460	200 157 142 123 93 69	0.16	-	1669	-
71	64.929	cadalene	0.10	$C_{15}H_{18}$	1677	1674
72	65.504	204 161 119 105 84 81	0.38	-	1688	-
73	66.212	220 177 159 131 117	0.12	-	1701	-
74	67.089	220 187 159 145 131	0.06	-	1719	-
75	68.005	oplopanone	0.21	$C_{15}H_{26}O_2$	1736	1730
76	70.851	1-octadecene	0.06	$C_{18}H_{36}$	1792	1793
77	71.662	147 119 91 77 69 55	0.07	-	1808	-
78	72.253	187 159 119 107 93 77	0.10	-	1821	-
79	74.520	benzyl salicylate	0.79	$C_{14}H_{12}O_3$	1867	1869
80	80.459	97 91 83 69 57 55	0.06	-	1993	-
81	81.149	(8β.13β)-kaur-16-ene	0.05	$C_{20}H_{32}$	2008	2012
82	**82.173**	**kaur-16-ene**	**2.42**	$C_{20}H_{32}$	2032	2041
83	85.762	Coronarin E	0.11	$C_{20}H_{28}O$	2123	2136
84	87.726	207 91 83 77 69 57	0.03	-	2194	-
85	89.042	298 146 123 91 77	0.04	-	2259	-
86	89.229	281 109 96 81 67 55	0.04	-	2269	-
87	89.325	9-tricosene	0.26	$C_{23}H_{46}$	2274	2278
88	89.806	324 99 85 71 57 43	0.15	-	2299	-
89	90.032	298 174 146 131 109	0.34	-	2313	-
90	90.719	207 151 81 69 55 40	0.03	-	2358	-
91	90.956	314 190 162 95 81 55	0.52	-	2373	-
92	92.293	283 109 95 82 67 55	0.05	-	2470	-
93	92.346	281 111 97 83 69 57	0.16	-	2475	-
94	92.402	290 108 95 79 67 55	0.19	-	2479	-
95	92.658	327 113 99 85 71 57	0.04	-	2498	-
Total identified			***87.43 %***			
Monoterpenes /Monoterpenoids			20.28 %			
Sesquiterpenes /Sequiterpenoids			63.21 %			

RT: retention time; RI: retention indices; RI litt. from NIST 2020 database. NI: Not identified (12.55%). Bold: main compounds.

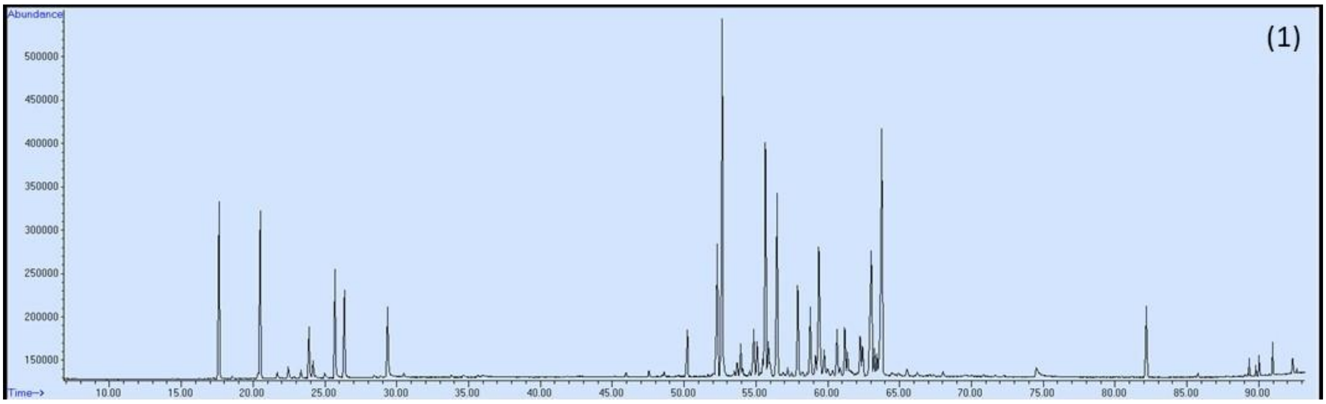

Figure 2. Chromatogram of *Hedychium gardnerianum* flowers essential oil.

identified accounted for ca. 20% with α-pinene, β-pinene and humulene as main representatives (4.48%, 4.46% and 3.93%, respectively). The sample also contained diterpene derivatives including kaur-16-ene (2.42%).

Our results are in agreement with the article by Medeiros et al. concerning the study of the Eos of longose leaves and flowers (*H. gardnerianum*) from the island of San Miguel (Azores) [1]. In their study, the main compounds were α-pinene, β-pinene, p-cymene, γ-terpinene, β-caryophyllene, β-cadinene and α-cadinol. These compounds were all present in the sample studied herein. However, β-farnesene, the main compound in our sample, was identified to a much lesser extent (ca. 3%) in the study by Medeiros et al. This could suggest a particular role of farnesene in plant defense particularly in the Reunion Island territory for a compound known to be associated with insect attraction [19].

3.3 Hedychium flavescens leaves EO analysis

The EO sample of *H. flavescens* leaves was found to be relatively simple and to contain mainly three compounds: β-pinene (47.81%), α-pinene (18.74%) and β-caryophyllene (17.47%), which together accounted for 84.02% of the sample (Fig. 3). As shown in 2, in total, 96.26% of the EO was identified. In addition of these three compounds, monoterpene and sesquiterpene derivatives were found in smaller proportions such as the monoterpene hydrocarbons D-limonene (0.60%), β-myrcene (0.16%), γ-terpinene (0.05%) and sesquiterpene hydrocarbons bicyclogermacrene (2.65%), germacrene B (1.29%) and β-cadinene (1.14%).

To our knowledge, the chemical composition of the EO obtained solely from the leaves of *H. flavescens* have not been published so far. In the most recent article on the EO of *H. flavescens* rhizomes, 78.05% of a sample obtained from a plant grown in India could be identified [4]. The main compounds described were β-pinene (24.77%) and α-pinene (11.17%), both present in large proportions in our sample (47.81 and 18.74%, respectively), together with β-caryophyllene and bicyclogermacrene.

3.4 Pittosporum senacia leaves EO analysis

The relatively simple composition of the EO from *Pittosporum senacia* leaves was determined for more than 99% of the total EO (Fig. 4). As presented in its chemical profile essentially contained four compounds: the C9 linear alkane hydrocarbon nonane (36.24%) and three monoterpene derivatives, β-pinene (25.11%), β-myrcene (19.19%) and α-pinene (7.36%), which together accounted for 87.9%. Moreover, the chemical profile included monoterpene derivatives such as limonene (1.46%), (*Z*)- and (*E*)-β-ocimene (0.01% and 0.09%, respectively), sesquiterpene derivatives like germacrene D (3.68%), humulene (0.40%), as well as other alkanes like decane (0.09%) and undecane (0.56%).

Many of the metabolites present in the study by B. S. Jugreet et al. published in 2021 on the EO of *P. senacia* (whole plant) from Mauritius [5], were also identified in our samples such as β-myrcene, germacrene D, α-muurolene, limonene, α-pinene, α-thujene, p-cymene, β-ocimene, β-elemene, β-caryophyllene, and humulene. The alkanes nonane, decane, and undecane were not reported in the article by B. S. Jugreet et al. However, some alkanes, including nonane, have already been identified in the EO of the genus *Pittosporum*, such as in an endemic species of the Philippines, *P. resiniferum* [20]. Interestingly, nonane, a compound described as an insect attractant, [21] was found in 36.24% of our sample.

Table 2. Chemical composition of *Hedychium flavescens* leaves essential oil.

Peak #	RT (min)	Compound	Area %	Formula	RI	RI litt.
1	**17.625**	**α-pinene**	**18.74**	$C_{10}H_{16}$	931	937
2	18.553	camphene	0.04	$C_{10}H_{16}$	945	952
3	**20.553**	**β-pinene**	**47.81**	$C_{10}H_{16}$	974	979
4	21.715	β-myrcene	0.16	$C_{10}H_{16}$	991	991
5	23.562	α-terpinene	0.05	$C_{10}H_{16}$	1018	1017
6	24.093	*p*-cymene	0.02	$C_{10}H_{14}$	1025	1025
7	24.183	limonene	0.60	$C_{10}H_{16}$	1026	1030
8	24.352	eucalyptol	0.42	$C_{10}H_{18}O$	1029	1032
9	25.113	(*Z*)-β-ocimene	0.05	$C_{10}H_{16}$	1040	1038
10	25.799	(*E*)-β-ocimene	0.05	$C_{10}H_{16}$	1049	1049
11	26.391	γ-terpinene	0.05	$C_{10}H_{16}$	1058	1060
12	28.483	α-terpinolene	0.03	$C_{10}H_{16}$	1087	1088
13	29.398	linalool	0.02	$C_{10}H_{18}O$	1100	1099
14	31.920	pinocarveol	0.01	$C_{10}H_{16}O$	1137	1138
15	34.619	terpinen-4-ol	0.02	$C_{10}H_{18}O$	1176	1177
16	35.661	1-dodecene	0.03	$C_{12}H_{24}$	1191	1190
17	45.195	δ-elemene	0.90	$C_{10}H_{18}O$	1336	1338
18	47.567	α-copaene	0.02	$C_{11}H_{18}$	1374	1376
19	48.606	β-elemene	0.24	$C_{15}H_{24}$	1391	1391
20	49.650	β-maaliene	0.06	$C_{15}H_{24}$	1408	1398
21	**50.269**	**β-caryophyllene**	**17.47**	$C_{15}H_{24}$	1418	1419
22	51.215	γ-elemene	0.33	$C_{15}H_{24}$	1434	1434
23	51.673	guaia-6,9-diene	0.66	$C_{15}H_{24}$	1442	1443
24	51.996	204 161 133 119 105	1.19	-	1447	-
25	52.257	humulene	1.20	$C_{15}H_{24}$	1452	1454
26	52.658	(3*E*,6*E*)-α-farnesene	0.27	$C_{15}H_{24}$	1458	1457
27	52.683	allo-aromadendrene	0.27	$C_{15}H_{24}$	1459	1461
28	53.430	204 161 121 105 93 55	0.12	-	1471	-
29	53.659	204 161 133 119 105	0.08	-	1475	-
30	53.902	germacrene D	0.55	$C_{15}H_{24}$	1479	1481
31	54.202	204 189 147 122 108	0.02	-	1484	-
32	54.369	β-selinene	0.08	$C_{15}H_{24}$	1487	1486
33	54.521	204 189 161 104 91	0.14	-	1490	-
34	**54.818**	**bicyclogermacrene**	**2.65**	$C_{15}H_{24}$	1495	1495
35	55.057	161 136 105 95 91 53	0.02	-	1499	-
36	55.298	204 147 107 93 81 67	0.45	-	1503	-
37	55.454	β-cadinene	1.14	$C_{15}H_{24}$	1506	1518
38	56.277	204 161 136 121 105	0.89	-	1520	-
39	56.647	122 119 107 91 77	0.02	-	1527	-
40	57.524	α-calacorene	0.03	$C_{15}H_{20}$	1542	1542
41	58.010	106 91 79 41	0.02	-	1551	-
42	58.235	germacrene B	1.29	$C_{15}H_{24}$	1555	1557
43	59.428	spathulenol	0.07	$C_{15}H_{24}O$	1576	1576
44	59.706	caryophyllene oxyde	0.49	$C_{15}H_{24}O$	1581	1581
45	59.987	204 161 119 105 91 81	0.44	-	1586	-
46	60.843	161 105 93 81 77 67	0.08	-	1601	-
47	61.360	204 179 161 119 105	0.18	-	1610	-
48	62.099	204 161 119 105 91	0.07	-	1624	-
49	62.309	isospathulenol	0.43	$C_{15}H_{24}O$	1627	1638
50	63.668	204 161 121 91 81	0.01	-	1651	-

Table 2. (*Continued*)

Total identified	***96.26 %***
Monoterpenes /Monoterpenoids	68.08 %
Sesquiterpenes /Sequiterpenoids	28.16 %

RT: retention time; RI: retention indices; RI litt. from NIST 2020 database. NI: Not identified (3.72%). Bold: main compounds.

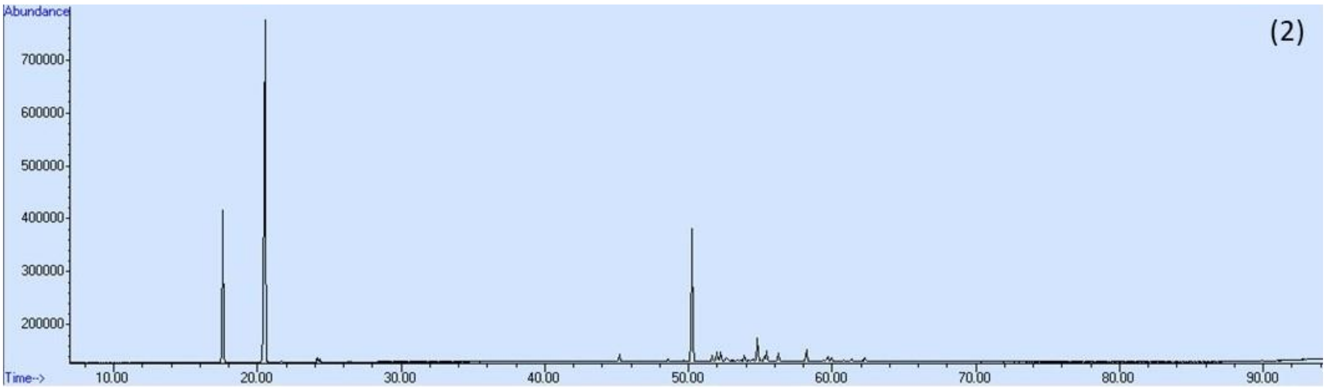

Figure 3. Chromatogram of *Hedychium flavescens* leaves essential oil.

Table 3. Chemical composition of *Pittosporum senacia* leaves essential oil.

Peak #	RT (min)	Compound	Area %	Formula	RI	RI litt.
1	**15.492**	**nonane**	**36.24**	$\mathbf{C_9H_{20}}$	**900**	**900**
2	17.233	α-thujene	0.03	$C_{10}H_{16}$	925	929
3	**17.578**	**α-pinene**	**7.36**	$\mathbf{C_{10}H_{16}}$	**930**	**937**
4	18.984	camphene	0.06	$C_{10}H_{16}$	951	952
5	**20.464**	**β-pinene**	**25.11**	$\mathbf{C_{10}H_{16}}$	**973**	**979**
6	**21.675**	**β-myrcene**	**19.19**	$\mathbf{C_{10}H_{16}}$	**991**	**991**
7	22.628	decane	0.09	$C_{10}H_{22}$	1004	1000
8	22.843	α-phellandrene	0.05	$C_{10}H_{16}$	1008	1005
9	23.605	α-terpinene	0.07	$C_{10}H_{16}$	1018	1017
10	24.131	*p*-cymene	0.06	$C_{10}H_{14}$	1026	1025
11	24.183	limonene	1.46	$C_{10}H_{16}$	1026	1030
12	25.145	(*Z*)-β-ocimene	0.01	$C_{10}H_{16}$	1040	1038
13	25.818	(*E*)-β-ocimene	0.09	$C_{10}H_{16}$	1050	1049
14	26.414	γ-terpinene	0.22	$C_{10}H_{16}$	1058	1060
15	28.474	terpinolene	0.08	$C_{10}H_{16}$	1087	1088
16	29.383	undecane	0.56	$C_{11}H_{24}$	1100	1100
17	30.518	(*E*)-4,8-dimethyl-nona-1,3,7-triene	0.04	$C_{11}H_{18}$	1116	1116
18	35.662	1-dodecene	0.05	$C_{12}H_{24}$	1191	1190
19	36.632	decanal	0.05	$C_{10}H_{20}O$	1205	1206
20	45.180	δ-elemene	0.81	$C_{15}H_{24}$	1336	1338
21	45.941	α-cubebene	0.03	$C_{15}H_{24}$	1348	1351
22	47.279	α-ylangene	0.05	$C_{15}H_{24}$	1370	1372
23	47.557	α-copaene	0.12	$C_{15}H_{24}$	1374	1376
24	48.602	β-elemene	0.56	$C_{15}H_{24}$	1391	1391
25	50.222	β-caryophyllene	0.48	$C_{15}H_{24}$	1417	1419
26	50.795	β-copaene	0.15	$C_{15}H_{24}$	1427	1432
27	51.134	γ-elemene	0.15	$C_{15}H_{24}$	1433	1434
28	51.405	α-guaiene	0.05	$C_{15}H_{24}$	1437	1439
29	51.682	guaia-6,9-diene	0.10	$C_{15}H_{24}$	1442	1443
30	52.006	161 133 105 91 79 69	0.20	-	1447	-

Table 3. (*Continued*)

Peak #	RT (min)	Compound	Area %	Formula	RI	RI litt.
31	52.242	humulene	0.40	$C_{15}H_{24}$	1451	1454
32	52.842	*cis*-muurola-4(15),5-diene	0.03	$C_{15}H_{24}$	1461	1463
33	**53.910**	**germacrene D**	**3.68**	$C_{15}H_{24}$	1479	1481
34	54.213	β-selinene	0.03	$C_{15}H_{24}$	1485	1486
35	54.519	161 105 91 44	0.06	-	1490	-
36	54.720	161 105 91	0.07	-	1493	-
37	55.057	α-muurolene	0.06	$C_{15}H_{24}$	1499	1499
38	55.304	α-elemene	0.21	$C_{15}H_{24}$	1503	1462
39	55.834	γ-cadinene	0.11	$C_{15}H_{24}$	1512	1513
40	56.407	cadina-1(10),4-diene	0.39	$C_{15}H_{24}$	1523	1524
41	56.650	122 43	0.03	-	1527	-
42	58.244	germacrene B	0.65	$C_{15}H_{24}$	1555	1557
43	60.289	1-hexadecene	0.10	$C_{16}H_{32}$	1591	1592
44	61.085	rosifoliol	0.04	$C_{15}H_{26}O$	1606	1600
45	63.633	τ-muurolol	0.09	$C_{15}H_{26}O$	1653	1642
46	70.847	1-octadecene	0.03	$C_{18}H_{36}$	1792	1793
Total identified			***99.09 %***			
Monoterpenes/Monoterpenoids			53.78 %			
Sesquiterpenes/Sequiterpenoids			8.19 %			

RT: retention time; RI: retention indices; RI litt. from NIST 2020 database. NI: Not identified (0.41%). Bold: main compounds.

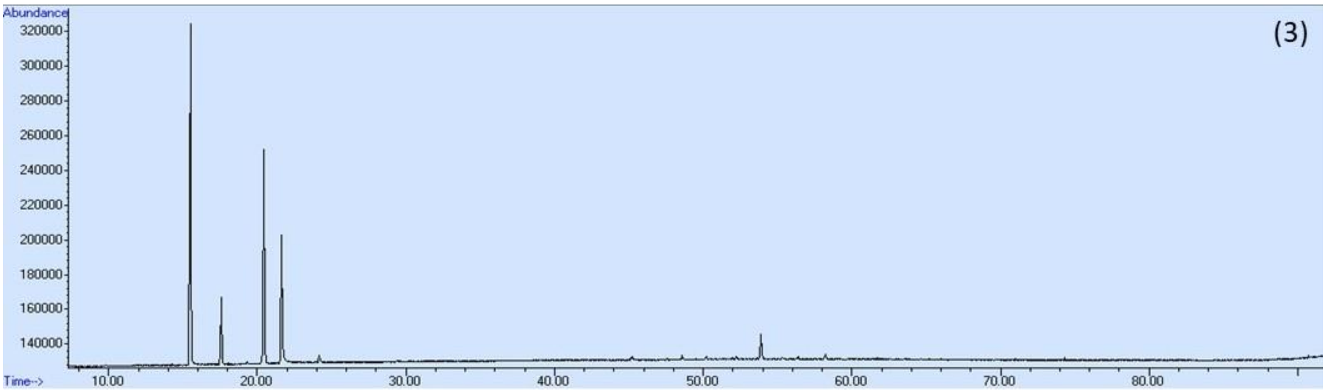

Figure 4. Chromatogram of *Pittosporum senacia* leaves essential oil.

3.5 Psidium cattleianum floral tops EO analysis

In the most recent study, a distillation yield of 0.83% was reported for EO from *P. cattleianum* leaves [8]. A total of 68 compounds were observed within the oil, 60 of which could be identified. β-Caryophyllene was the main compound found in 14.7%, followed by eucalyptol (11.7%) and γ-muurolene (5.6%). The second most recent paper, published in 2019, describes the EO of the leaves of *P. cattleianum*. The EO was mainly composed of sesquiterpene and monoterpene derivatives (47.8% and 28.7%, respectively). A total of 46 compounds were identified with β-caryophyllene (23.4%), caryophyllene oxide (11.4%) and α-pinene (11.3%) as the main compounds [9]. Our results are in agreement with this study (Fig. 5), whose main compounds described were β-caryophyllene and α-pinene at 23.42% and 11.31%, respectively, caryophyllene oxide being present at 1.67%. Indeed, the chemical profile of the EO sample from *P. cattleianum* floral tops was identified at 88.41%. As shown in Table 4, nearly 70% of the composition consisted of sesquiterpene derivatives including the main compound, β-caryophyllene, present at 43.68% In addition, fifteen monoterpene derivatives have been observed and identified. The four main monoterpenes were β-myrcene (4.67%), α-pinene (4.50%), (Z)-β-ocimene (3.23%) and terpinolene (2.98%).

Table 4. Chemical composition of *Psidium cattleianum* leaves essential oil.

Peak #	RT (min)	Compound	Area %	Formula	RI	RI litt.
1	16.610	5,5-Dimethyl-1-vinylbicyclo[2,1,1]hexane	0.03	$C_{10}H_{16}$	916	921
2	17.214	α-thujene	0.15	$C_{10}H_{16}$	925	929
3	**17.611**	**α-pinene**	**4.50**	$C_{10}H_{16}$	931	937
4	18.920	camphene	0.01	$C_{10}H_{16}$	950	952
5	20.475	β-pinene	0.19	$C_{10}H_{16}$	973	979
6	**21.677**	**β-myrcene**	**4.67**	$C_{10}H_{16}$	991	991
7	22.467	α-phellandrene	0.24	$C_{10}H_{16}$	1002	1005
8	22.864	3-carene	0.14	$C_{10}H_{16}$	1008	1011
9	23.360	4-carene	0.12	$C_{10}H_{16}$	1015	1009
10	23.901	*p*-cymene	0.19	$C_{10}H_{14}$	1022	1025
11	24.181	limonene	1.07	$C_{10}H_{16}$	1026	1030
12	**24.984**	**(*Z*)-β-ocimene**	**3.23**	$C_{10}H_{16}$	1038	1038
13	25.710	(*E*)-β-ocimene	0.56	$C_{10}H_{16}$	1048	1049
14	26.346	γ-terpinene	0.63	$C_{10}H_{16}$	1057	1060
15	**28.421**	**terpinolene**	**2.98**	$C_{10}H_{16}$	1086	1088
16	40.039	linalyl acetate	0.23	$C_{12}H_{20}O_2$	1257	1257
17	45.984	161 136 121 105 93 67	0.27	-	1349	-
18	47.293	α-ylangene	0.44	$C_{15}H_{24}$	1370	1372
19	47.581	α-copaene	1.18	$C_{15}H_{24}$	1374	1376
20	48.127	α-bourbornene	0.07	$C_{15}H_{24}$	1383	1384
21	48.598	204 121 108 93 81 55	0.12	-	1391	
22	49.495	tetradecene	0.03	$C_{14}H_{28}$	1405	1392
23	49.641	204 189 161 119 105	0.03	-	1408	-
24	**50.374**	**β-caryophyllene**	**43.68**	$C_{15}H_{24}$	1420	1419
25	50.818	γ-elemene	0.42	$C_{15}H_{24}$	1427	1434
26	51.387	aromadendrene	0.07	$C_{15}H_{24}$	1437	1440
27	51.672	204 161 133 119 105 91	0.10	-	1442	-
28	52.009	204 161 119 105 91 79	0.16	-	1447	-
29	**52.278**	**humulene**	**6.49**	$C_{15}H_{24}$	1452	1454
30	52.709	9-epi-caryophyllene	0.18	$C_{15}H_{24}$	1459	1466
31	**53.640**	**γ-muurolene**	**2.32**	$C_{15}H_{24}$	1475	1477
32	53.874	α-amorphene	0.50	$C_{15}H_{24}$	1479	1482
33	54.197	β-selinene	1.27	$C_{15}H_{24}$	1484	1486
34	54.307	204 133 119 107 93 79	0.29	-	1486	-
35	54.517	204 189 161 133 91	0.25	-	1490	-
36	54.727	204 161 133 119 105 93	1.70	-	1493	-
37	55.059	α-muurolene	0.34	$C_{15}H_{24}$	1499	1499
38	55.454	204 161 134 119 105	0.51	-	1506	-
39	55.575	122 109 93 79 69	0.26	-	1508	-
40	55.837	β-bisabolene	0.87	$C_{15}H_{24}$	1513	1509
41	56.175	γ-cadinene	0.88	$C_{15}H_{24}$	1519	1513
42	**56.401**	**cadina-1(10),4-diene**	**2.38**	$C_{15}H_{24}$	1523	1524
43	**57.015**	**204 189 161 133 105 91**	**2.35**	-	1533	-
44	57.184	204 189 161 133 105	0.74	-	1536	-
45	**57.385**	**selina-3,7(11)-diene**	**2.06**	$C_{15}H_{24}$	1540	1542
46	57.987	161 109 95 91 79 69	0.11	-	1551	-
47	58.238	germacrene B	1.84	$C_{15}H_{24}$	1555	1557
48	58.604	204 189 133 119 105	0.17	-	1562	-
49	58.749	nerolidol	0.33	$C_{15}H_{26}O$	1564	1564
50	58.978	204 161 123 111 69 55	0.19	-	1568	-
51	59.701	caryophyllene oxyde	1.67	$C_{15}H_{24}O$	1581	1581

Table 4. (*Continued*)

Peak #	RT (min)	Compound	Area %	Formula	RI	RI litt.
52	60.284	204 161 119 105 91 79	0.44	-	1591	-
53	60.593	204 161 119 107 93 79	0.07	-	1597	-
54	60.746	161 133 121 93 82 77	0.10	-	1600	-
55	60.956	204 161 133 119 105 95	0.09	-	1603	-
56	61.162	147 138 109 96 93 67	0.17	-	1607	-
57	61.623	202 187 131 123 91	0.29	-	1616	-
58	62.084	204 161 119 105 91	0.71	-	1624	-
59	62.221	204 161 119 105 91	0.78	-	1627	-
60	62.424	204 179 161 119 105	0.54	-	1631	-
61	62.642	159 136 107 91 79 69	0.14	-	1635	-
62	62.969	τ-cadinol	1.09	$C_{15}H_{26}O$	1641	1640
63	63.198	204 161 119 105 93	0.36	-	1645	-
64	63.489	202 187 121 105 91	0.41	-	1651	-
65	63.630	τ-muurolol	0.87	$C_{15}H_{26}O$	1653	1642
66	64.190	204 189 161 133 107	0.20	-	1664	-
67	65.113	126 119 111 77 55	0.06	-	1681	-
68	65.807	eudesm-7(11)-en-4-ol	0.49	$C_{15}H_{26}O$	1694	1692
Total identified			***88.41 %***			
Monoterpenes /Monoterpenoids			18.70 %			
Sesquiterpenes /Sequiterpenoids			69.99 %			

RT: retention time; RI: retention indices; RI litt. from NIST 2020 database. NI: Not identified (11.61%). Bold: main compounds.

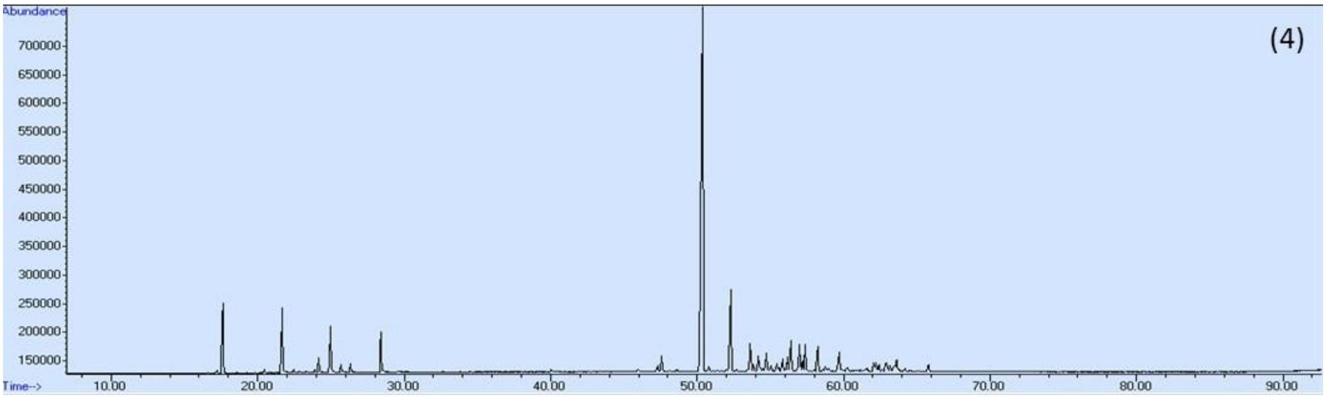

Figure 5. Chromatogram of *Psidium cattleianum* leaves essential oil.

3.6 Olfactory analysis

Olfactory evaluation of the four essential oils was performed by a panel of 4 persons by GC/MS-O analysis. The objective was to obtain an overview of the main contributors to the overall scent of each EO which was found to be generally woody, a family of olfactory properties highly priced in modern perfumery. In Table 5, the main aroma-active compounds and their odor properties are presented. *Hedychium gardnerianum* flowers EO presented three characteristic areas, a woody area identified by 2 panelists out of 4, and two floral areas for 2 panelists out of 4.

GC/MS-O analysis of EO from *Hedychium flavescens* leaves revealed a main contributor with a fresh, woody and green scent which was annotated as γ-elemene. The presence of woody, earthy, and green areas were highlighted by 5 panelists out of 5, floral and rose area by 4 panelists out of 5 and mint, herbal, and citrus areas by 2 panelists out of 5.

The main aroma-active compounds of *Pittosporum senacia* leaves EO were annotated as β-myrcene with a The main aroma-active compounds of *Pittosporum senacia* leaves EO were annotated as β-myrcene with a green, woody and spicy scent and as terpinolene with a moss and woody scent. The GC/MS-O analysis

Table 5. Overview of the main contributors of the four EOs.

Samples	Annotated compound	Scent description	RT (min)	RI_{apolar}
H. gardnerianum, flowers EO	Sabinol*	Floral	9.55	1144
	Unknown**	Woody	17.23	N.D.
	Unknown	Floral	22.48	16.94
H. flavescens, leaves, EO	Terpinolene	Woody	8.55	1093
	trans-a-bisabolene	Woody, rose	17.35	1512
P. senacia, *leaves*, EO	β-pinene	Pine, Green	6.61	N.D.
	Terpinolene	Woody	8.53	1092
P. cattleianum, floral tops, EO	β-pinene	Pine, Green	6.42	979
	Unknown**	Woody	8.26	1078
	Unknown	Citrus, spicy	11.80	1261

*Tentative assignation. **No peak detectable.

revealed herbal, and pine tree area for 5 panelists out of 5 as well as floral and citrus area for 5 panelists out of 5.

Finally, *Psidium cattleianum* floral tops EO showed three characteristic scents with β-myrcene and two unknown compounds, eluting at 8.9 min and 13.25 min, respectively, both with floral scent. In addition of these markers, pine tree scent was found by 4 panelists out of 4, woody, and earthy area by 4 panelists out of 4, floral area by 2 panelists out of 4, and citrus with mossy/earthy area by 2 panelists out of 4. In addition to these main contributors, other smaller contributors as linalool, with floral and fresh scent, were detected in each of the four EOs GC/MS-O analyses.

In general, the chemical composition of an EO varies according to many factors such as the year of harvest, the geographical area, the climate, the storage of the raw material, the duration of storage of the plant before extraction, the extraction process [22]. Two EOs from the same species may therefore have a different chemical composition. Nevertheless, the chemical profile and chemical markers may be specific to a given plant or chemotype. The analysis and authentication tasks can be sometimes complicated by conformity or adulteration issues [23, 24]. Olfactory analysis is thus an useful addition to physico-chemical analysis.

4. Conclusions

The main goal of our work was to characterize for the first time the EOs of the four species harvested on Reunion Island and to compare their chemical profiles with those described in the literature with samples collected in other locations. We used two complementary analyses, gas chromatography coupled with mass spectrometry (GC/MS) and flame ionization detector (GC-FID), to obtain the most complete description. Additionally, an olfactory analysis was performed on these four EOs by gas chromatography coupled with mass spectrometry and olfactometry (GC/MS-O). The chemical composition of each essential oil was identified in more than 87.43% for *H. garderianum* flowers, 96.26% for *H. flavescens* leaves, 99.09% for *P. senacia* leaves and 88.41% for *P. cattleianum* floral tops.

The chemical composition of *H. gardnerianum* EO, mostly composed of mono- and sesquiterpene hydrocarbons of low complexity, was found to be consistent with other EOs within natural variability due to differences in their geographical origin (islands from the Atlantic, Pacific, and Indian oceans). The sample was mainly composed of sesquiterpene derivatives including β-farnesene (12.05%), α-cadinol (9.71%), α-farnesene (7.09%), τ-muurolol (5.89%) and δ-cadinene (5.83%). The monoterpene derivatives identified accounted for about 20% (mostly α-pinene, β-pinene and humulene).

For the EO from *H. flavescens* leaves, our study provided the first description of its chemical composition, which appeared to be rather simple and to contain mostly hydrocarbons. The main compounds were found to be β-pinene (47.81%), α-pinene (18.74%) and β-caryophyllene (17.47%), which together accounted for 84.02% of the sample.

For the *P. senacia*, while β-myrcene was found to be an important constituent of the EO, as was the case for material from Madagascar and Mauritius, which are geographically close to French Reunion, the composition was different but consistent, and the striking difference was the presence of nonane. The oil primarily contained nonane (36.24%), β-pinene (25.11%), β-myrcene (19.19%) and α-pinene (7.36%), together accounting for 87.9% of the composition.

Lastly, the composition of the *P. cattleianum* EO was very consistent with other studies, with 70% sesquiterpene derivatives including the main compound, β-caryophyllene, present at 43.68%.

With these compositions mostly based on mono- and sesquiterpene hydrocarbons, it came as no surprise that the panelists described the scent of these EOs as herbal, citrus, green, pine tree, and in some cases floral and woody.

With these results in hand, these endemic essential oils from Reunion could receive in the future further attention for applications in fragrance and cosmetic products. Future work could include the determination of odor impact molecules by aroma extract dilution analysis based on the GC-O studies presented herein.

Authors' contributions

Conceptualization, M.C and S.A.; Methodology, M.C and S.A.; Investigation, M.C, M.T. and S.A.; Resources, S.A.; Data Curation, M.C, M.T. and S.A.; Writing – original draft preparation, M.C and S.A.; Writing – review & editing, M.C, M.T. and S.A.; Supervision, S.A.; Project administration, M.C, M.T. and S.A.

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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.

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