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Assessment of the Antibacterial Activity of Lavender Cultivated in Tasmania and Identifying its Geographical and Botanical Origins

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Abstract

Objectives: This study compared the antimicrobial activity of lavender honey manufactured in Tasmania Australia with Manuka honey as a control.

Methods: Lavender essential oil also examined for antimicrobial activity. The volatile compounds were identified to find the bioactive compounds responsible for the antibacterial activity. Next, the volatile data of the Lavender honey and essential oil from *Lavandula angustifolia* cultivated in Tasmania, were used to indicate the geographical and botanical origins of the using head space solid-phase micro extraction (HS SPME) and Gas Chromatography Mass Spectrometry (GC-MS). The antimicrobial activity of Lavender Honey and essential oil from Tasmania were examined using the broth micro-dilution method to determine the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC). Bacteriostatic end points were determined spectrophotometrically, then bactericidal end points were determined by plating. Methicillin-sensitive and methicillin-resistant strains of *Staphylococcus aureus*, *Escherichia coli* and *Pseudomonas aeruginosa* were used in this study.

Results: Lavender honey showed similar, and in some bacterial species, slightly higher activity than Manuka honey. The MICs and MBCs for lavender honey ranged from 6.25% to 25% v/v compared to MICs of Manuka honey which ranged between 12.5% and 25% v/v. The MIC and MBC values of lavender honey and Manuka honey against *P. aeruginosa* were 12.5% v/v and 25% v/v respectively. The corresponding values for a methicillin-sensitive strain of *S. aureus* were 6.25% v/v and 12.5% v/v respectively. The MIC and MBC were the same for both honey for *E. coli* equal to 12.5% v/v and for MRSA equal to 6.25% v/v. The growth of *S. aureus*, including MRSA and *E. coli* completely inhibited by Lavender *E. oil* at concentrations of 2.25%. Whereas, the growth of *P. aeruginosa* partly inhibited by the same concentrations. Use of a spectrophotometer facilitated reading of MIC values.

Conclusion: These results suggest that lavender honey and essential oil could be used as an antimicrobial agent for infections caused by *S. aureus* including MRSA, *E. coli* and *P. aeruginosa*.

Keywords: Antibacterial activity, Lavandula, Tasmania

Introduction

The World Health Organization (WHO) distinguishes traditional medicinal plants as natural plant products used in the absence of industrial production for the treatment of diseases on a local or regional scale. Traditional herbal medicine has been used for thousands of years in developing and developed countries, since it is natural and causes relatively few complications.[1] Herbs and spices with medicinal properties served in food preservation and food supplements, pharmaceutical, alternative, modern, and folk medicine. Also, they are used in pharmaceutical intermediates and chemical entities for synthetic drugs, natural therapies, and nutraceuticals.[2,3] The medicinal plants generate secondary metabolites some of these compounds namely phytoanticipins and flavonoids are synthesized and stored during the process of growth and development.[4-6] These compounds with their biocidal features they function to protect plants against predators, bacteria, viruses, and fungi.[4,6,7] As the production of these compounds occurs naturally, they will be biodegraded effectively and eco-friendly. Thus, antibacterial, antiviral, fungicidal agents, natural antioxidants, cytotoxic, and nutrients have gained popularity among consumers.[8]

Lavandula angustifolia is from the family Lamiaceae, native to the Mediterranean region. Nowadays, this species is naturalized almost all over Europe, Australia, United States, and North Africa.[9] It is considered for its value as an aromatic plant traditionally used in aromatherapy and as a medicinal plant. It is used in the treatment of cardiovascular, gastrointestinal, urinary, and respiratory infections, possibly because of the biologically active substances present in it.[10,11]

Honey has been used for thousands of years as a medicinal substance and as a topical treatment for wounds. The use of honey in modern practice is based on its broad antimicrobial properties and its ability to stimulate rapid wound healing.[12] The antibacterial properties of honey depend on its physicochemical and bioactive antibacterial components present on it. Honey's composition and antibacterial properties depend on several factors, including nectar source, age-related functionality of the hypopharyngeal gland, storage, temperature and dilution.[13-17]

Since online shopping for honey is increasing globally, the identification of honey origin and authenticity have become a hot topic amongst consumers. In the last 15 years, the research for chemical markers has been the centre of attention for many research programs. Aroma is one of the distinguishable characteristics of honeys made from different flowers. It was considered worthwhile to discover if the volatile components of honey could be used for the fast and reliable identification of the geographical and botanical origins of honey. HS-SPME is a good method to isolate volatile compounds because it obviates the need for heat treatment of samples.[18]

This project compared the antimicrobial activity of Manuka honey, as a control with lavender honey manufactured in Tasmania Australia. Also, the Lavender essential oil was tested for its antimicrobial activity. The volatile compounds were identified to find the bioactive compounds responsible for the antibacterial activity. Next, the volatile data

were used to indicate the geographical and botanical origins of the Lavender honey and essential oil using Solid Phase Micro Extraction (SPME).

Methods

Antimicrobial Activity

Lavender honey and essential oil (*Lavandula angustifolia*) from Tasmania (Bridestowe Lavender Estate) and Manuka (*Leptospermum scoparium*) from New Zealand, (UMF® 20+ Watson and Son) were tested against different bacteria. Methicillin-sensitive and methicillin-resistant strains of *Staphylococcus aureus, Escherichia coli* and *Pseudomonas aeruginosa* were tested. To determine the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC), the broth micro-dilution method was used as described in detailed by Yamani et al., (2015).[19] After determining bacteriostatic end points using a spectrophotometer at 620 nm (Omega BMG LabTech, Ortenberg, Germany), bactericidal end points were determined by plating. The honey dilutions were prepared in Mueller-Hinton Broth to make the main stock of 50% then the solution was diluted in two-fold dilutions to make other concentrations. The antibacterial activity of the essential oil was tested using the same method as honey, with some modifications as described by Yamane et al., (2016).[20]

Determining the Volatile Organic Bioactive Compound Profile Using (HS-SPME and GC/MS)

Extraction of the volatiles from the honey and essential oils was performed by HS-SPME using a 85-µm polyacrylate (PA) fibre fitted to a manual sampling fibre holder (Supelco, Bellefonte, PA, USA). The fibre was conditioned according to the manufacturer's instructions (injected into the gas chromatograph (GC) injection port at 250°C for 30 min) before use. The preconditioned PA fibre was inserted into the headspace of the vial containing the sample, and then placed in a heating block at 40°C for 50 min. The volatiles were desorbed by placing the fibre into the gas chromatograph (GC) injection port for 5 min. Adjusting the equilibrium time profile was developed using the method of Da Porto et al., (2008) with slight modification as described by Yamani et al., (2016).[20,21]

Statistical Analysis

For the statistical analysis, the Statistical Package for the Social Sciences (SPSS, v.22) was used.

Results and Discussion

Results

Lavender honey showed similar or slightly higher activity than Manuka honey against methicillin-sensitive and methicillin-resistant strains of Staphylococcus aureus, *Escherichia coli* and *Pseudomonas aeruginosa*. The MICs and MBCs for lavender honey ranged from 6.25% to 25% v/v compared to MICs of Manuka honey which ranged between 12.5% and 25% v/v. The MIC and MBC values of lavender honey and Manuka honey against *P. aeruginosa* were 12.5% v/v and 25% v/v respectively. The corresponding values for a methicillin-sensitive strain of *S. aureus* were 6.25% v/v and 12.5% v/v respectively. The MIC and MBC were the same for both honey for *E. coli* equal to 12.5% v/v and for MRSA equal to 6.25% v/v. Lavender honey was active at 6.5% (v/v) against both strains of *S. aureus* (Figures 1 & 2), while 12% v/v was required for *E. coli* and *P. aeruginosa* (Figures 3 & 4). The growth of *S. aureus*, including MRSA and *E. coli* completely inhibited by Lavender *E. oil* at concentrations of 2.25%. Whereas, the growth of *P. aeruginosa* partly inhibited by the same concentrations (Figure 5).

The analysis of the Lavender honey volatile components resulted in the identification of 33 volatile components and

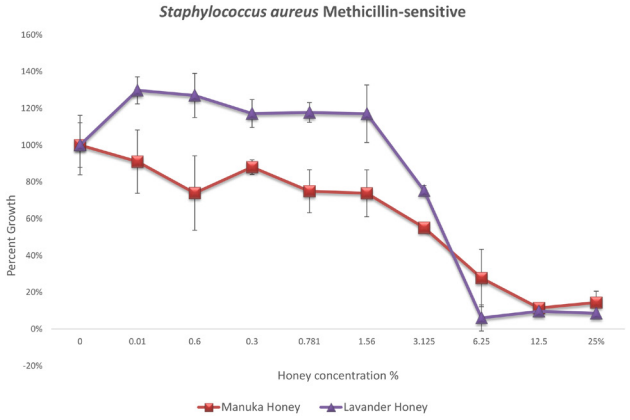

Fig. 1 ***S. aureus* MICs by spectrophotometer.**

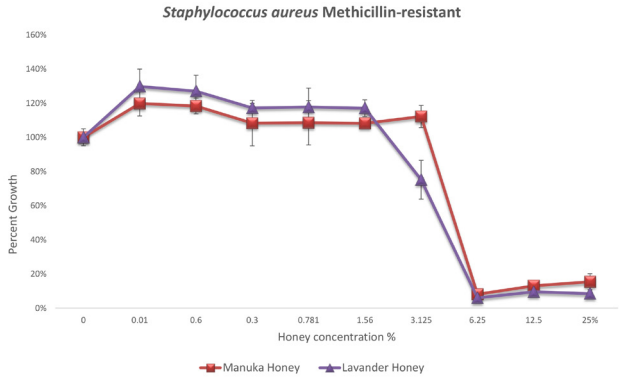

Fig. 2 ***S. aureus* MRSA MICs by spectrophotometer.**

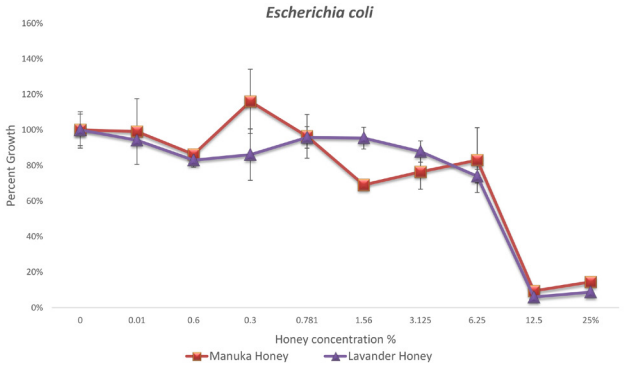

Fig. 3 ***E. coli* MICs by spectrophotometer.**

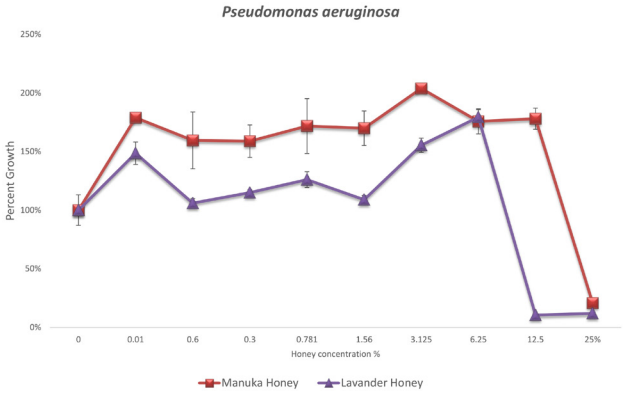

Fig. 4 ***P. aeruginosa* MICs by spectrophotometer.**

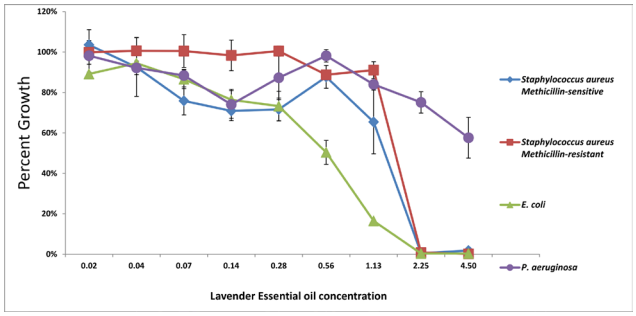

Fig. 5 **Lavender Essential oil MICs by spectrophotometer.**

88 volatile components for the Lavender oil (Tables 1 & 2). monoterpenes and sesquiterpenes were the most abundant of the volatile components in both. The common compound detected in the honey was Methyl syringate, with a concentration of (7.58%). This was followed by 2-Furancarboxaldehyde, 5-(hydroxymethyl) with a concentration of (4.22%). Then, Coumarin comprised 2.38% of the total volatile compounds followed by Benzene acetaldehyde with slightly different concentration of 2.25%. Also, hexanal, heptanal have been identified with lower concentration.

On the other hand, Lavender *E. oil* has higher volatile composition with 88 volatile components. The most abundant compound detected in was Linalyl acetate, with a concentration of (25.41%). This was followed by Linalool with a concentration of (24.33%). The third most identified compound was Ocimene (Z)-Beta- that comprised 6.25% of the total volatile compounds followed by Octanone-3- and Terpinen-4-Ol with slightly different concentration of 4.94% and 3.61% respectively.

Discussion

Antimicrobial Activity of Lavender Honey and Essential Oil

Antimicrobial agents are essential for the reduction of the global burden of infectious diseases. However, as resistant bacteria grow and spread, the effectiveness of antibiotics has reduced. This form of bacterial resistance to antimicrobial agents is very harmful to public health.[15] Therefore, alternative antimicrobial strategies are needed and this situation has led to a re-estimation of the therapeutic use of traditional medicines like plants and plant-based products.[22,23] The main types of volatile compounds found in this research (monoterpenes and sesquiterpenes) also have been found in other researches. There are remarkable quantitative variations in the distribution of these compounds in plants. These variations may refer to the geographical origin of plant cultivars and environmental conditions that have a major effect on the volatile compound composition, percentage, and the process of extraction and analysis.

Agricultural Research Service, 2000, reported that different species of lavenders have similar major chemical constituents and ethnobotanical properties, nevertheless, there are some differences in the reported therapeutic uses for different species. For instance, many lavenders are considered to have carminative actions but *L. latifolia* is traditionally used as an abortifacient, *L. angustifolia* as a diuretic and *L. stoechas* for headaches. Lis-Balchin et al., 1998 and Hammer et al., 1999 found that Lavender oil (*L. angustifolia*) has antimicrobial activity against several species of fungi and bacteria (cited in).[24] *L. angustifolia oil* was confirmed to have in bactericidal activity against both VRE (vancomycin-resistant Enterococcus faecalis) and MRSA, therefore, suggested in treating bacterial infections that are resistant to antibiotics (Nelson, 1997a) (cited in).[24]

The antibacterial property of Lavender honey and essential oil is possibly due to the presence of several biologically active substances identified. A total of 88 components of lavender essential oil were detected. The most abundant compound identified was Linalyl acetate (25.41%) followed by Linalool (24.33%). The third most identified compound was Ocimene (Z)-Beta- followed by Octanone-3- and Terpinen-4-Ol. French lavender *E. oil* which contains 43.2% linalyl acetate and 29.1% linalool, was effective against 13 bacteria sp. while Bulgarian Lavender *E. oil* contains 9.5% linalyl acetate and 51.9% linalool, was effective against 23 of 25 bacterial sp.[25] Linalool, which is one of the main elements of lavender *E. oil* examined by Pattnaik et al. (1997).[26] The results indicated that, Linalool inhibited 17 of 18 Gram-positive and Gram-negative bacteria and 10 of 12 fungi.[24]

The most common compound detected in the Lavender honey was Methyl syringate with a concentration of (7.58%), which could be responsible for its bioactivity. This was followed by 2-Furancarboxaldehyde, 5-(hydroxymethyl), then Coumarin and Benzene acetaldehyde. Moreover, components found in honey that have antibacterial potency individually, will have additive, synergetic or suppressing effect on each other. This high antibacterial potency of manuka honey against bacteria was reported by.[27-29] The potency was found to be associated with methylglyoxal which is described as a Unique Manuka Factor (UMF), as well as, due to its total phenols content rating.[30] Methyl syringate (MSYR) also recognized as one of the bioactive compounds in Manuka honey.[31]

Identification of the Volatile Compounds to Indicate the Geographical and Botanical Origins

To our knowledge, no research has focused on establishing distinctive floral markers of *L. angustifolia* cultivated in Tasmania. Therefore, we have investigated the volatile compounds of honey and e, oil using head space solid-phase micro extraction (HS-SPME) and Gas Chromatography Mass Spectrometry (GC-MS) to indicate the geographical and botanical origins.

Table 1. **Volatile compound concentrations (%) in lavender honey identified using HS-SPME / GC-MS (results is an average of two or three replicates)**

No.	RT	Library/ID	Qual	% R1	% R2	% R3	Average	Std dev.	CV%
1	15.00	2,3-Dihydro-3,5-dihydroxy-6-methyl-4H-pyran-4-one	83	0.82	1.32	0.96	1.03	0.26	0.15
2	16.97	2-Furancarboxaldehyde, 5-(hydroxymethyl)	94	2.46	6.20	3.99	4.22	1.88	1.08
3	13.40	2-Furancarboxylic acid, hydrazide	86	0.56	0.44	0.70	0.57	0.19	0.11
4	14.65	2-Propanamine, N-methyl-N-nitroso	87	0.07	0.09	0.08	0.09	0.01	0.01
5	7.20	3-Furanmethanol	87	0.17	0.21	0.17	0.18	0.02	0.01
6	13.04	Acetophenone	83	0.10	0.06	0.10	0.09	0.02	0.01
7	17.79	Anisaldehyde <para->	96	1.27	1.47	1.82	1.52	0.28	0.16
8	10.19	Benzaldehyde	95	0.51	0.25	0.45	0.40	0.14	0.08
9	24.98	Benzaldehyde, 3,4,5-trimethoxy	98	2.04	0.54	1.00	1.19	0.77	0.44
10	22.62	Benzaldehyde, 3,4-dimethoxy	95	0.63	1.07	0.57	0.75	0.27	0.16
11	12.46	Benzene acetaldehyde	91	2.84	1.68	2.24	2.25	0.58	0.34
12	14.80	Benzene, 1-ethenyl-4-methoxy	90	0.35	0.20	0.35	0.30	0.09	0.05
13	14.15	Benzofuran, 2-methyl	93	0.31	0.16	0.26	0.24	0.08	0.04
14	15.35	Benzoic acid	83	1.57	0.88	0.80	1.08	0.42	0.24
15	22.41	Benzoic acid, 2-methoxy	90	0.20	1.74	1.30	1.08	0.79	0.46
16	24.60	Benzoic acid, 3,5-dimethoxy, methyl ester	97	1.81	0.76	0.85	1.14	0.58	0.33
17	28.09	Methyl syringate	96	11.07	5.98	5.69	7.58	3.03	1.75
18	12.19	Benzyl alcohol	97	0.12	0.09	0.22	0.14	0.07	0.04
19	22.82	Butanoic acid	94	0.20	0.74	0.30	0.41	0.29	0.17
20	21.81	Coumarin	93	4.18	1.49	1.48	2.38	1.56	0.90
21	16.11	Ethanol, 2-(2-butoxyethoxy)	90	0.51	0.34	1.03	0.62	0.36	0.21
22	25.89	Ethanone, 1-(2,4,5-trimethylphenyl	90	0.52	1.07	0.67	0.75	0.28	0.16
23	8.67	Ethanone, 1-(2-furanyl)	80		0.12	0.13	0.12	0.01	0.01
24	6.49	Furfural	90	2.69	2.32	1.98	2.33	0.35	0.20
25	8.51	Heptanal (=Enanthal; Oenanthal)	83	0.57	0.41	0.58	0.52	0.10	0.06
26	5.69	Hexanal	95	1.68	0.72	1.35	1.25	0.49	0.28
27	7.58	Hexanol<N->	83	1.66	0.65	1.57	1.29	0.56	0.32
28	13.96	Linalool	86	0.68	0.20	0.37	0.42	0.24	0.14
29	14.09	Nonanal	83	0.52	0.26	0.48	0.42	0.14	0.08
30	17.97	Nonanoic acid	96	0.45	0.35	0.34	0.38	0.06	0.03
31	14.89	Pristane	92	3.25	1.66	2.41	2.44	0.80	0.46
32	19.12	Phenol, 3,4,5-trimethyl	90	0.48	0.08	0.16	0.24	0.21	0.12
33	14.26	Phenyl ethyl alcohol	91	0.61	0.29	0.42	0.44	0.16	0.09

Table 2. **Volatile compound concentrations (%) in lavender E. oil identified using HS-SPME / GC-MS (results is an average of two or three replicates)**

No.	R.T.	Library/ID	Qual	% R1	% R2	% R3	Average	Std dev.	CV%
1	26.234	trans-Caryophyllene	80	0.021	0.007	0.019	0.016	0.008	0.483
2	25.973	Cadinol<epi-alpha->	87	0.136	0.074	0.159	0.123	0.044	0.357
3	24.878	(-)-Caryophyllene oxide	93	0.63	0.345	0.587	0.521	0.154	0.295
4	23.945	Cadinene<alpha->	98	0.011	0.008	0.009	0.009	0.002	0.159
5	23.665	Sesquiphellandrene<beta->	93	0.029	0.018	0.026	0.024	0.006	0.233

(*Continued*)

Table 2. **Volatile compound concentrations (%) in lavender E. oil identified using HS-SPME / GC-MS (results is an average of two or three replicates)—Continued**

No.	R.T.	Library/ID	Qual	% R1	% R2	% R3	Average	Std dev.	CV%
6	23.625	Calamenene<cis->	96	0.031	0.024	0.027	0.027	0.004	0.128
7	23.488	Cadinene<gamma->	97	0.522	0.386	0.445	0.451	0.068	0.151
8	23.341	Bisabolene<beta->	98	0.114	0.084	0.100	0.099	0.015	0.151
9	23.147	Bicyclogermacrene	94	0.02	0.017	0.019	0.019	0.002	0.082
10	23.071	Zingiberene <alpha->	90	0.018	0.014	0.016	0.016	0.002	0.128
11	22.855	Germacrene D	97	0.726	0.595	0.630	0.650	0.068	0.104
12	22.792	Curcumene<ar->	94	0.018	0.0141	0.000	0.011	0.009	0.885
13	22.727	Italicene	93	0.031	0.026	0.029	0.029	0.003	0.088
14	22.538	Curcumene<gamma->	96	0.009	0.009	0.010	0.009	0.001	0.062
15	22.457	Copaene<beta->	93	0.037	0.03	0.034	0.034	0.004	0.104
16	22.335	.alpha.-Humulene	86	0.304	0.264	0.270	0.279	0.022	0.077
17	22.226	Sesquiphellandrene<beta->	81	0.18	0.154	0.165	0.166	0.013	0.079
18	22.179	Farnesene<(e)-beta->	83	0.326	0.241	0.280	0.282	0.043	0.151
19	21.966	Sesquiphellandrene<beta->	95	0.045	0.041	0.044	0.043	0.002	0.047
20	21.818	Bergamotene<alpha-trans->	98	0.679	0.591	0.611	0.627	0.046	0.074
21	21.613	Caryophyllene<E->	99	3.84	3.589	3.442	3.624	0.201	0.056
22	21.55	Santalene<alpha->	99	2.456	2.214	2.169	2.280	0.154	0.068
23	21.407	Bergamotene<alpha-cis->	99	0.206	0.19	0.191	0.196	0.009	0.046
24	21.26	Caryophyllene <Z	97	0.016	0.018	0.019	0.018	0.002	0.086
25	21.15	Zingiberene <alpha->	91	0.061	0.051	0.054	0.055	0.005	0.092
26	20.808	Bourbonene<beta->	95	0.177	0.167	0.166	0.170	0.006	0.037
27	20.739	Hexanoic acid, hexyl ester	91	0.056	0.045	0.050	0.050	0.006	0.109
28	20.567	Geranyl propanoate	86	0.605	0.503	0.553	0.554	0.051	0.092
29	20.13	Neryl propanoate	90	0.441	0.369	0.412	0.407	0.036	0.089
30	22.099	Santalene<beta->	91	0.1003	0.1022	0.000	0.068	0.058	0.866
31	19.068	Piperitenone	87	0.018	0.027	0.021	0.022	0.005	0.208
32	18.702	Cymen-7-ol<para->	93	0.025	0.039	0.042	0.035	0.009	0.260
33	18.552	Bornyl acetate	86	0.037	0.045	0.040	0.041	0.004	0.100
34	18.478	Lavandulyl acetate	83	2.92	2.744	2.665	2.776	0.131	0.047
35	17.841	Linalyl acetate	91	25.691	25.906	24.629	25.409	0.684	0.027
36	17.559	Cumin aldehyde	96	0.201	0.219	0.218	0.213	0.010	0.047
37	17.355	Hexyl 2-methyl butanoate	83	0.049	0.061	0.061	0.057	0.007	0.121
38	17.241	Bornyl formate	90	0.043	0.053	0.053	0.050	0.006	0.117
39	17.134	Nerol	94	0.068	0.087	0.091	0.082	0.012	0.148
40	17.024	trans-Carveol	86	0.028	0.045	0.046	0.040	0.010	0.252
41	16.741	1,3,8-p-Menthatriene	87	0.038	0.0701	0.072	0.060	0.019	0.317
42	16.222	Cryptone	94	0.244	0.257	0.247	0.249	0.007	0.027
43	16.11	Terpinen-4-ol	94	3.585	3.643	3.591	3.606	0.032	0.009
44	15.884	Borneol	94	0.957	0.991	0.987	0.978	0.019	0.019
45	15.641	4-Hexen-1-ol, 5-methyl-2-(1-methylethenyl), (R)	87	0.838	0.882	0.895	0.872	0.030	0.034
46	15.261	Camphor	94	0.242	0.271	0.272	0.262	0.017	0.065
47	15.2	Hexyl isobutanoate	86	0.136	0.146	0.149	0.144	0.007	0.048

(*Continued*)

Table 2. **Volatile compound concentrations (%) in lavender E. oil identified using HS-SPME / GC-MS (results is an average of two or three replicates)—Continued**

No.	R.T.	Library/ID	Qual	% R1	% R2	% R3	Average	Std dev.	CV%
48	15.109	trans-Pinocarveol	94	0.172	0.188	0.191	0.184	0.010	0.056
49	15.036	Nopinone	81	0.162	0.172	0.175	0.170	0.007	0.039
50	14.842	E isomer, N-butyl ester	91	0.092	0.099	0.100	0.097	0.005	0.046
51	14.73	Ocimene<allo->	97	0.511	0.587	0.512	0.537	0.044	0.081
52	14.309	Acetic acid, heptyl ester	83	0.065	0.0761	0.000	0.047	0.041	0.874
53	14.235	Octen-3-yl acetate<1->	83	2.742	2.901	2.810	2.818	0.080	0.028
54	14.178	Linalool	91	23.947	24.521	24.508	24.325	0.328	0.013
55	13.772	3-Methyl-2-(2-methyl-2-butenyl) furan	86	0.082	0.088	0.092	0.087	0.005	0.057
56	13.662	Rosefuran	87	0.593	0.574	0.618	0.595	0.022	0.037
57	13.518	Alpha.-terpinolene	91	0.029	0.042	0.052	0.041	0.012	0.282
58	13.242	Linalool Oxide<cis->(furanoid)	80	0.694	0.684	0.746	0.708	0.033	0.047
59	12.904	Terpinene<gamma->	94	0.12	0.136	0.136	0.131	0.009	0.070
60	12.589	Ocimene<(E)-beta->	95	1.24	1.314	1.312	1.289	0.042	0.033
61	12.431	Butyl 2-methylbutanoate	83	0.028	0.032	0.034	0.031	0.003	0.096
62	12.338	Ocimene<(Z)-beta->	94	6.031	6.339	6.379	6.250	0.190	0.030
63	12.126	Limonene	97	0.536	0.568	0.581	0.562	0.023	0.041
64	11.992	Cymene<ortho->	95	0.51	0.566	0.574	0.550	0.035	0.063
65	11.85	Cymene<ortho->	95	0.169	0.189	0.194	0.184	0.013	0.072
66	11.784	Terpinene<alpha->	91	0.036	0.038	0.038	0.037	0.001	0.032
67	11.636	Acetic acid, hexyl ester	90	0.192	0.197	0.208	0.199	0.008	0.042
68	11.556	Tricyclene	87	0.255	0.278	0.281	0.271	0.014	0.052
69	11.236	Octanol<3->	83	1.03	1.106	1.196	1.111	0.083	0.075
70	11.036	Myrcene	94	0.669	0.742	0.744	0.718	0.043	0.059
71	10.951	Octanone<3->	94	4.85	4.887	5.077	4.938	0.122	0.025
72	10.803	1-Octen-3-ol	90	0.43	0.462	0.520	0.471	0.046	0.097
73	10.697	Pinene<beta->	94	1.455	1.536	1.553	1.515	0.052	0.035
74	10.557	Sabinene	94	0.196	0.224	0.230	0.217	0.018	0.084
75	10.205	Benzaldehyde	91	0.045	0.046	0.045	0.045	0.001	0.016
76	9.901	Camphene	95	0.176	0.189	0.194	0.186	0.009	0.050
77	9.433	Pinene<alpha->	94	0.589	0.626	0.627	0.614	0.022	0.035
78	9.227	Phellandrene<alpha->	91	0.128	0.141	0.142	0.137	0.008	0.058
79	9.111	Tricyclene	95	0.035	0.038	0.039	0.037	0.002	0.051
80	8.717	Butyl Propanoate	83	0.017	0.016	0.026	0.020	0.006	0.290
81	7.594	1-Hexanol	83	0.042	0.051	0.062	0.052	0.010	0.196
82	7.194	Hexenol<3Z>	91	0.239	0.291	0.324	0.285	0.043	0.150
83	7.131	2-Hexenal, (E)	96	0.023	0.021	0.021	0.022	0.001	0.062
84	6.402	Hexane, 1-methoxy	83	0.111	0.111	0.114	0.112	0.002	0.014
85	5.275	2-Butenal, 3-methyl	80	0.043	0.043	0.044	0.043	0.001	0.016
86	4.867	Benzene, methyl	91	0.069	0.06	0.056	0.062	0.007	0.109
87	4.253	Methyl Isobutyl Ketone	80	0.007	0.009	0.010	0.009	0.001	0.160
88	3.493	Furan, 2-ethyl	90	0.009	0.007	0.008	0.008	0.001	0.125

Melissopalynological which is the traditional method to find the botanical origin of honey, relies on examination of its pollen. This analysis requires a high skill and does not ensure reliable identification if the honey concerned contains little or no pollen. Characterization of monofloral lavender honeys requires a percentage of pollen ranging from 10 to 20%.[32] *L. latifolia* pollen needed to characterize Lavender honey as monofloral is 15% as the minimum quantity That is the typical quantity for all other species of the family Labiatae.

The analysis of aromatic components is a useful tool to authenticate unifloral honeys as aroma in honey characterize as the principal factor on it.[33] Lavender honey has been identified in terms of its nerolidol oxide, heptanal, hexanal, and coumarin contents (Bouseta, Collins, & Dufour, 1992; Bouseta, Scheirman, & Collin, 1996; Castro-Vázquez, Díaz-Maroto, Gonzalez-Viñas, & Pérez-Coello, 2009; Guyot-Declerck, Renson, Bouseta, & Collin, 2002; Radovic et al., 2001; Shimoda, Wu, & Osajima, 1996) cited in.[34] Furthermore, for authenticating French lavender honey which has high contents in the same aroma compounds, heptanal, hexanal, and coumarin besides phenylacetaldehyde.[35,36] Also, in agreement with previous findings, C. Guyot-Declerck et al., 2002, reported that French *L. angustifolia* markers are hexanol, n-hexanal, n-heptanal, and phenylacetaldehyde.[34] The results of this study confirm that hexanal, heptanal, and coumarin are present in Tasmanian Lavender honey. The high contents of Methyl syringate followed by 2-Furancarboxaldehyde, 5-(hydroxymethyl), which were identified for the first time in this study as components of Tasmanian Lavender honey, are proposed as a marker for its authenticating.

Conclusion

S. aureus is a major cause of wound infection all over the world and the prevalence of *S. aureus* MRSA demands innovative interventions. Moreover, secondary infection with gram negative bacteria causes considerable morbidity and occasional mortality in burn patients. These results suggest that lavender honey and *E. oil* could be used as a topical antimicrobial agent for skin infections caused by *S. aureus, P. aeruginosa* and *E. coli*. Moreover, the results of the honey volatile compounds confirmed that HS-SPME could be used as a new and faster method suitable for the routine analysis of honey origin, and for assessing multiple samples in a short time. could be used as an alternative to melissopalynology in the estimation of the origin of unifloral honey.

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Conflicts of Interest

There are no conflicts of interest.

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References

1. Jamshidi-Kia F, Lorigooini Z, Amini-Khoei H. Medicinal plants: Past history and future perspective. Journal of Herbmed Pharmacology. 2018;7(1):1–7.
2. Hammer KA, Carson CF, Riley TV. Antimicrobial activity of essential oils and other plant extracts. J Appl Microbiol. 1999;86(6):985–990.
3. Joshi B, Sah GP, Basnet BB, et al. Phytochemical extraction and antimicrobial properties of different medicinal plants: Ocimum sanctum (Tulsi), Eugenia caryophyllata (Clove), Achyranthes bidentata (Datiwan) and Azadirachta indica (Neem). 2011;3(1):1–7.
4. Bassolé IHN, Juliani HR. Essential Oils in Combination and Their Antimicrobial Properties. Molecules. 2012;17(4):3989–4006.
5. Ouibrahim A, Tlili-Ait-kaki Y, Bennadja S, et al. Evaluation of antibacterial activity of Laurus nobilis L., Rosmarinus officinalis L. and Ocimum basilicum L. from Northeast of Algeria. African Journal of Microbiology Research. 2013;7(42):4968–4973.
6. Bais HP, Walker TS, Schweizer HP, et al. Root specific elicitation and antimicrobial activity of rosmarinic acid in hairy root cultures of Ocimum basilicum. Plant Physiology and Biochemistry. 2002;40(11):983–995.
7. Mandalari G, Bennett R, Bisignano G, et al. Antimicrobial activity of flavonoids extracted from bergamot (Citrus bergamia Risso) peel, a byproduct of the essential oil industry. J Appl Microbiol. 2007;103(6):2056–2064.
8. Kaya I, Yigit N, Benli MJAJoT, Complementary, et al. Antimicrobial activity of various extracts of Ocimum basilicum L. and observation of the inhibition effect on bacterial cells by use of scanning electron microscopy. Afr J Tradit Complement Altern Med. 2008;5(4):363–369.
9. Basch E, Boon H, Heerema TD, et al. Boswellia: An evidence-based systematic review by the natural standard research collaboration. Journal of herbal pharmacotherapy 2004;4(3):63–83.
10. Renata P, Krzysztof B. Composition, biological properties and therapeutic effects of lavender L). A review. Herba Polonica. 2014; 60(2):56–66, doi:10.2478/hepo-2014-0010.
11. Ciocarlan A, Lupascu L, Aricu A, et al. Chemical composition and assessment of antimicrobial activity of lavender essential oil and some by-products. Plants. 2021;10(9):1829.
12. Henriques AF, Jenkins RE, Burton NF, et al. The effect of manuka honey on the structure of Pseudomonas aeruginosa. Eur J Clin Microbiol Infect Dis. 2011 Feb;30(2):167-71.
13. Molan PC. The antibacterial activity of honey: 2. Variation in the potency of the antibacterial activity. Bee World. 1992;73(2):59–76.
14. Ohashi K, Natori S, Kubo T. Expression of amylase and glucose oxidase in the hypopharyngeal gland with an age-dependent role change of the worker honeybee (Apis mellifera L.). European Journal of Biochemistry. 1999;265(1):127–133, doi:10.1046/j.1432-1327.1999.00696.x.
15. Mandal MD, Mandal S. Honey: its medicinal property and antibacterial activity. Asian Pacific Journal of Tropical Biomedicine. 2011;1(2):154–160.
16. Brudzynski K, Abubaker K, Miotto D. Unraveling a mechanism of honey antibacterial action: Polyphenol/H 2O 2-induced oxidative effect on bacterial cell growth and on DNA degradation. Food Chemistry. 2012;133(2):329–336, doi:10.1016/j.foodchem.2012.01.035.
17. Kwakman PH, Zaat SA. Antibacterial components of honey. IUBMB life. 2012;64(1):48–55.
18. Stanimirova I, Üstün B, Cajka T, et al. Tracing the geographical origin of honeys based on volatile compounds profiles assessment using pattern recognition techniques. Food Chemistry. 2010;118(1):171–176, doi:10.1016/j.foodchem.2009.04.079.
19. Yamani H. Production of bioactive honey from medicinal plants using alternative and conventional production methods. RMIT University: Melbourne; 2015.
20. Yamani HA, Pang EC, Mantri N, et al. Antimicrobial activity of Tulsi (*Ocimum tenuiflorum*) essential oil and their major constituents against three species of bacteria. Frontiers in Microbiology. 2016;7:681, doi:https://doi.org/10.3389/fmicb.2016.00681.
21. Da Porto C, Decorti D. Analysis of the volatile compounds of flowers and essential oils from Lavandula angustifolia cultivated in Northeastern Italy by headspace solid-phase microextraction coupled to gas chromatography-mass spectrometry. Planta Medica. 2008;74(02):182–187.
22. Mandal S, DebMandal M, Pal NK, et al. Synergistic anti–Staphylococcus aureus activity of amoxicillin in combination with Emblica officinalis and

Nymphae odorata extracts. Asian Pacific Journal of Tropical Medicine. 2010;3(9):711–714.
23. Mandal S, DebMandal M, Pal NK, et al. Antibacterial activity of honey against clinical isolates of Escherichia coli, Pseudomonas aeruginosa and Salmonella enterica serovar Typhi. Asian Pacific Journal of Tropical Medicine. 2010;3(12):961–964.
24. Cavanagh HMA, Wilkinson JM. Biological activities of lavender essential oil. Phytotherapy Research. 2002;16(4):301–308.
25. Lis-Balchin M, Deans SG, Eaglesham E. Relationship between bioactivity and chemical composition of commercial essential oils. Flavour and Fragrance Journal. 1998;13(2):98–104.
26. Pattnaik S, Subramanyam VR, Bapaji M, et al. Antibacterial and antifungal activity of aromatic constituents of essential oils. Microbios. 1997;89(358):39–46.
27. Willix DJ, Molan PC, Harfoot CG. A comparison of the sensitivity of wound-infecting species of bacteria to the antibacterial activity of manuka honey and other honey. Journal of Applied Bacteriology. 1992;73(5):388–394.
28. Molan PC. Potential of honey in the treatment of wounds and burns. American Journal of Clinical Dermatology. 2001;2(1):13–19.
29. Bogdanov S. Nature and Origin of the Antibacterial Substances in Honey. LWT - Food Science and Technology. 1997;30(7):748–753, doi:http://dx.doi.org/10.1006/fstl.1997.0259.
30. Adams CJ, Boult CH, Deadman BJ, et al. Isolation by HPLC and characterisation of the bioactive fraction of New Zealand manuka (Leptospermum scoparium) honey. Carbohydrate Research. 2008;343(4):651–9, doi:10.1016/j.carres.2007.12.011.
31. Henriques AF, Jenkins RE, Burton NF, et al. The effect of manuka honey on the structure of Pseudomonas aeruginosa. European Journal of Clinical Microbiology & Infectious Diseases. 2011;30(2):167–171, doi:10.1007/s10096-010-1065-1.
32. Louveaux J, Maurizio A, Vorwohl G. Methods of melissopalynology. Bee world. 1978;59(4):139–157.
33. Castro-Vázquez, V. Leon-Ruiz, M.E. Alañon, M.S. Pérez-Coello, A.V. González-Porto, Floral origin markers for authenticating Lavandin honey (*Lavandula angustifolia x latifolia*). Discrimination from Lavender honey (*Lavandula latifolia*), Food Control, V. 37, 2014, P: 362–370, https://doi.org/10.1016/j.foodcont.2013.09.003.
34. Guyot-Declerck C, Renson S, Bouseta A, et al. Floral quality and discrimination of Lavandula stoechas, Lavandula angustifolia, and Lavandula angustifolia— latifolia honeys. Food Chemistry. 2002;79(4):453–459.
35. Bouseta A, Collin S, Dufour J-P. Characteristic aroma profiles of unifloral honeys obtained with a dynamic headspace GC-MS system. Journal of Apicultural Research. 1992;31(2):96–109.
36. Bouseta A, Scheirman V, Collin S. Flavor and free amino acid composition of lavender and eucalyptus honeys. Journal of Food Science. 1996;61(4):683–687.