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Effects of different drying methods on the volatile components of selected spices

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Abstract
This study investigated the effect of different drying methods on the volatile components of parsley, sage, basil, rosemary, ginger, and thyme. Volatiles were extracted using a Soxhlet extractor and analyzed by gas chromatography with mass detection. The findings showed that oven-drying at 45 °C increased the concentration of certain volatile compounds in parsley, rosemary, ginger, basil, and thyme, compared to air-drying or commercial samples. For example, parsley dried at 45 °C contained 93.64% apiol, significantly higher than other methods. In rosemary, eucalyptol was the most abundant compound, with concentrations varying across drying methods. Sage, ginger, basil, and thyme exhibited similar trends, with specific volatile compounds being more prevalent depending on the drying method. Overall, the study concluded that oven-drying at 45 °C is ideal for preserving or enhancing the volatile components in ginger, basil, and thyme, while room temperature drying is more suitable for parsley.

Keywords: Drying, essential oil, GC/MS, oven-drying, air-drying, spices

Introduction
A spice is a plant or herb's dried seed, fruit, root, bark, or flower that is used in tiny quantities for flavour, colour, or as a preservative (Sachan *et al*. 2018) [14]. The International Organization for Standardization defines spices and condiments as "natural plant or vegetable products or mixtures thereof in whole or ground form that are used for adding flavour, smell, and piquancy to and flavouring meals" (Padakatti & Meti 2020) [10]. Spices have an important role in the diet as flavouring, colouring, or preservation agents, and they are utilised all around the globe (Arvind *et al*. 2016) [3]. Spices are essential components of our daily diet, even if we only take a little quantity of them (Khanum *et al*. 2001) [8]. Spices have long played an important part in both ancient and contemporary culinary preparations (Balasasirekha 2014) [4]. The bulk of the key components of spice ingredients are carbohydrates, protein, and trace minerals. Tannins, resins, pigments, volatile, essential, and fixed oils are present in trace levels and account for just a tiny part of the dry matter (Ugwuona 2014) [16]. Commercial spices include red pepper, onions, sage, ginger, nutmeg, clove, cinnamon, mustard, curry, turmeric, rosemary, and garlic. Spices provide flavour, savour, and pungency to meals. The majority of spices are fragrant, aromatic, and pleasurable. Spices in food can offer additional advantages such as lowering salt and sugar levels, preventing spoilage, and improving texture (Ravindran *et al*. 2002) [12]. Spices are known to fight cancer and a variety of heart diseases owing to the phytochemicals they contain. Spices are employed as culinary components as well as in a range of pharmaceuticals, fragrances, cosmetics, and natural colours. Many spices have been used in traditional medicine for a long time. Many regional cuisines are well-known for their reliance on exotic spices. Turmeric is utilised in Italian food, basil, garlic, and oregano in Italian and Greek cuisine, and lemon grass, ginger, and chilli peppers in Thai cuisine (Satia-Abouta *et al*. 2002) [14]. Meanwhile, since spices have a weak internal structure and are very perishable, an efficient technique of preservation is required to lengthen shelf life and increase value (Majumder *et al*. 2021) [9].
Drying is universally acknowledged as the best technique for preserving fruits, vegetables, and herbs since it reduces their volume and weight, saving packing, storage, and transportation costs.

Furthermore, flavour and texture characteristics are adjusted, resulting in a new generation of things such as snacks that may be a healthy alternative to other commercial products such as sweets (Sehrawat *et al*. 2018) [15]. Furthermore, eliminating water reduces microbe development and harmful chemical reactions, resulting in longer storage duration (Amit *et al*. 2017) [1]. When the water activity is less than 3%, this is commonly performed. Thus, there are various types of drying methods based on the technique of removing water, such as thermal drying, which is further subdivided into air-drying, low air environment drying, and modified atmosphere drying; osmotic dehydration, which uses a solution to remove the water; and mechanical dewatering, which uses physical force to dry (Rahman 2020) [11]. Traditional thermal and non-thermal drying processes are used to dry spices. Because of its simplicity and low cost, direct solar or open sun drying (OS) has been the most popular in tropical areas from ancient times. However, it is weather dependent, the product is prone to contamination, and drying parameters are sometimes difficult to control. In order to overcome the limits of OS, indirect sun drying and greenhouse drying (GH) may be used. In addition to solar energy, biomass and geothermal energy are used as heat sources to power the drying medium (Ananno *et al*. 2020) [2]. Environmental conditions have an impact on the volatile components of spices, particularly EOs (humidity, temperature, and velocity). The drying temperature is the most important factor in keeping the active components of volatile oil in gland cells, which are very sensitive to temperature rises. After harvest, the surface area of gland hairs declines in lockstep with cell death, possibly leading in considerable water loss. Drying accelerates water loss from the whole tissue, including gland hairs (Karami *et al*. 2017) [7]. In general, high temperatures alter the quantity and quality of essential oils in spices not only during drying, but also during storage. Because drying decreases the weight and volume of the plant, which benefits transport and storage, it may also assist to ensure a steady supply and facilitate the marketing of spices (Majumder *et al*. 2021) [9]. As a consequence, appropriate drying techniques are necessary, including the use of temperature and humidity values for drying air to permit a speedy decrease in moisture content without affecting the quality of the active compounds in the spices. The aim of this study is to investigate the effect of drying temperature on the chemical composition of the extract of selected spices.

Materials and Methods

The experiment was conducted at the Food processing technologies Laboratory as well as Laboratory of ethnobotany and ethnopharmacology, Faculty of Tropical Agrisciences, Czech University of Life Science, Prague.

Experimental materials

A total of six (6) different spices were used for this experiment which include parsley, sage, basil, rosemary, ginger, and thyme. The fresh herbs were bought from a local market. Basil was grown from Kenya, rosemary from Morocco, while parsley, sage, ginger and thyme are from Czech Republic. The studied herbs were also purchased in dried form (Petržel, Šalvěj, Bazalka, Rozmarýn, Zázvor, Tymián - Kotányi, S.R.O.), these samples are marked as “commercial”.

Equipment and reagents

The equipment used for the purpose of the experiment include Series Automatic Soxhlet Extractor SER 158 – Velp Scientifica, sensitive weighing balance, petri dishes, spatula, tubes, round bottom flask, mill (RETSCH Knife Mill Grindomix GM 100), drying oven (Memmert Oven UN110m plus, Merci S.R.O.), 500 microlitres pipettes, vacuum rotary evaporator (Heidolph Hei-VAP Core rotary evaporator – VERKON S.R.O.) and Gas chromatography/Mass spectrometry analyser (Agilent Technologies 5977A MSD equipped with a 38 HP-5 column (5%-phenyl)-methylpolysiloxane, 30 m length, 250 µm internal diameter, 0.25 µm film thickness). All reagents and chemicals used were of analytical grade; they include: n-Hexane (Penta S.R.O.).

Extraction and GC/MS analysis

The methodology was modified according to the ‘Effect of different drying methods on thevolatile components of parsley (Petroselinum crispum L.) M.C. Díaz-Maroto, M.S. Pérez-Coello & M.D. Cabezudo.

GC/MS analysis was conducted by the method described by Farouk *et al*. (2017) [6]. The collected fresh samples were divided into two parts, and different drying methods were applied. Room temperature drying was carried out in a partly closed place protected from sunlight (average temperature was 22 °C) by using trays; the duration was 7 days. After the drying process, a constant weight was achieved. The rest of the plant material was dried in the oven in Petri dishes plates at a temperature 45 °C to constant weight (10-15 hrs, depending on the type of spice). After drying, the leaves were removed from the stems for further analysis.

A modified AOAC 2003.06 extraction was used for extraction. 7 g of the dried sample was placed in an extraction thimble with 130 ml of hexane. After extraction, the solvent was evaporated on a vacuum rotate evaporator. The sample was then diluted with hexane to a concentration of 10 µl/ml.

Each sample (commercial, room temperature, 45 °C) was analysed in triplicates. Overall, there were fifty-four measurements. GC/MS analysis was employed. The injections were performed using an autosampler immediately after extraction. Injection volume was 1 µl.

The inlet GC injection port temperature was maintained at, 220 °C, the split mode was setto 1:10. The optimized GC oven temperature program was 50 °C (3 mins) to 120 °C (rate 3 °C/min) to 250 °C (rate 5 °C/min), hold time 5 min, to 280 °C (rate 15 °C/min) hold 5 min. Carrier gas helium was used at a flow rate of 1 mL/min. The MSD transfer line temperature was maintained at, 250 °C with the electron energy of 70 eV. Mass spectra were acquired in the mass range from m/z 30 to 600, using a scan time of 1 s. Data was obtained through MassHunter Workstation Software Qualitative Analysis Version B.07.00.

Percentage composition was obtained from electronic integration measurements. The representation of the individual components is presented as the average value from three repeated measurements. Identification of constituents was based on a comparison of their retention indices (RI) and spectra with the National Institute of Standards and Technology Library ver. 2.2.f (NIST, USA), as well as with authentic standards and literature. The RI were calculated using the retention times of n-alkanes series

ranging from C7 to C40 (Sigma-Aldrich, Prague, CZ). Not all substances could be verified by comparison of RI, because some retention indexes were not available.

Results

Volatile compounds of parsley EO

Table 1 shows the volatile compound composition of parsley essential oil as affected by drying method. A total of thirteen volatile compounds were identified in commercial parsley EO, twelve were identified in parsley EO air-dried at room temperature and four were identified in oven-dried parsley EO. Apiol was identified as the most abundant compound in parsley. The result revealed that commercial parsley contained 76.48% apiol while parsley dried at room temperature and 45 °C oven-drying contained 65.45% and 93.64% apiol, respectively. More so, small amounts of p-Mentha-1(7),8-diene, Caryophyllene, and Phytol were found in commercial parsley, air-dried parsley and parsley oven-dried at 45 °C.

The result also revealed that α-Pinene, β-Myrcene, o-Cymene, Terpinolene, 1,3-Dimethyl-2-vinylbenzene, γ-Elemene, and Germacrene D were found in little proportions in parsley dried at room temperature but were not found in commercial parsley and parsley dried at 45 °C oven-drying. However, Linalool, (-)-Carvone, Anethole, α-Terpinyl acetate, α-Guaiene, 1,3-Benzodioxole 4-methoxy-6-(2-propenyl), and Caryophyllene oxide were found in little proportions in commercial parsley but were not identified in air-dried parsley and oven-dried parsley

Volatile compounds of rosemary EO

Volatile compounds identified in rosemary essential oil as affected by the drying method are presented in Table 2. A total of 14 volatile compounds were identified in commercial rosemary EO, 22 volatile compounds were identified in air-dried sample and 23 volatile compounds were identified in oven-dried sample. The analysis identified Eucalyptol as the most abundant volatile compound in commercial rosemary (47.73%), air-dried rosemary (22.95%) and oven-dried rosemary (19.28%). The result also revealed that Camphor was also abundant in commercial rosemary (20.47%), air-dried rosemary (18.15%) and oven- dried rosemary (12.82%). Another abundant volatile compound identified in rosemary is α-Pinene. This study recorded 9.40% of α-Pinene in commercial rosemary, 7.41% in air-dried rosemary and 18.25% in oven-dried rosemary.

Furthermore, Caryophyllene, Camphene, β-Pinene, α-Terpinene, Linalool, Endo-borneol, Terpinen-4-ol, α-Terpineol, (-)-Bornyl acetate, Humulene, and Caryophyllene oxide were found in little proportions in commercial rosemary, air-dried rosemary and oven-dried rosemary. However, Tricyclene, Dehydrosabinene, β-Myrcene, α-Phellandrene, γ-Terpinene, E-Sabinene hydrate, Terpinolene, 2-Pinen-4-one, and Methyleugenol were found in rosemary dried at room temperature and oven-dried rosemary but absent in commercial rosemary.

Volatile compounds of sage EO

The volatile compounds identified in sage essential oil as affected by the drying method are presented in Table 3. A total of 21 volatile compounds were identified in commercial sage EO, 18 volatile compounds were identified in air-dried sample and 16 volatile compounds were identified in oven-dried sample. The analysis identified 2-Bornanone, Eucalyptol and Epimanool as abundant volatile compounds in sage. The study found 21.99% 2-Bornanone in commercial sage, 18.04% in air-dried sage and 27.02% in oven-dried sage. The result also identified 9.94% Eucalyptol in commercial sage, 20.55% in air-dried sage and 20.24% in oven-dried sage. The result also shows that commercial sage contained 9.41% Epimanool, air-dried sage contained 14.50%, and oven-dried sage contained 28.42%.

Furthermore, Camphene, Terpinolene, γ-Terpinene, β-Thujone, Endo-borneol, L-α- Terpineol, L-α-Bornyl acetate, (+)-Ledene and Viridiflorol were found in small proportions in commercial sage, air-dried sage and oven-dried sage. However, 2-Thujene, β-Pinene, β-Myrcene, and E-Sabinene hydrate were found in sage dried at room temperature and oven dried sage but absent in commercial sage.

Volatile compounds of ginger EO

Table 4 presents the volatile compounds of essential oil identified in ginger as affected by the drying method. This study identifies a total of 22 volatile compounds in commercial ginger EO, 22 volatile compounds were identified in air-dried sample and 27 volatile compounds were identified in oven-dried sample. The analysis identified Curcumene, β-Bisabolene, and β-Sesquiphellandrene as abundant volatile compounds in commercial and air-dried ginger. The study found 37.25% Curcumene in commercial ginger, 11.01% in air-dried ginger and 27.02% in oven-dried ginger. The result also identified 10.06% β-Bisabolene in commercial ginger, 21.55% in air-dried ginger and 0.79% in oven-dried ginger. The result also shows that commercial ginger contained 26.31% β- Sesquiphellandrene, air-dried ginger contained 20.05% and oven-dried ginger contained 1.00%. The study found β-Elemene, Epi-β-Caryophyllene, and alfa-Copaene as abundant volatile compounds in oven-dried ginger. The result showed that oven-dried ginger contained 17.16% β-Elemene, 14.07% Epi-β-Caryophyllene, and 11.51% α -Copaene.

Furthermore, α-Pinene, Camphene, β-Myrcene, Decane, Octanal, Z-Sabinene hydrate were absent in commercial ginger and air-dried ginger, but they were available in small proportions in oven-dried ginger. However, Eucalyptol, Melonal, Linalool, 6-Octenal, endo-Borneol, α-Terpineol, Decanal, β-Citral, Geraniol, α-Citral, 2-Undecanone, and Cyclosativene were found in commercial ginger, air-dried ginger at room temperature and oven-dried ginger.

Volatile compounds of basil EO

The volatile compounds identified in basil essential oil as affected by the drying method are presented in Table 5. This study identifies a total of 24 volatile compounds were identified in commercial basil EO, 15 volatile compounds were identified in air-dried sample and 22 volatile compounds were identified in oven-dried sample. The result identified Eugenol, α- Bergamotene, and Linalool as abundant volatile compounds in commercial, air-dried, and oven-dried basil. The study found 3.77% Eugenol in commercial basil, 59.78% in air-dried basil and 37.35% in oven-dried basil. The result also identified 10.16% α-Bergamotene in commercial basil, 12.51% in air-dried basil and 16.50% in oven-dried basil. The result also shows that commercial basil contained 10.28% Linalool, air-dried basil contained 6.38%, and oven-dried basil contained 16.36%. The study found Estragole (16.24%), and 2-Propenoic acid

3-phenyl- methyl ester (25.43%) as abundant volatile compounds in commercial basil.

Volatile compounds of thyme EO

Table 6 shows the volatile compound composition of Thyme EO as affected by the drying method. A total of 9 volatile compounds were identified in commercial thymus EO, 11 volatile compounds were identified in air-dried sample and 13 volatile compounds were identified in oven-dried sample. Thymol, γ-Terpinene and m-Cymene were identified as the abundant compounds in Thyme. The result revealed that commercial thyme contained 71.01% Thymol while thyme dried at room temperature and 45 °C oven-drying contained 58.70% and 59.98% Thymol, respectively. The result also showed that 18.55% γ-Terpinene was contained in commercial thyme while air-dried commercial thyme contained 16.65% and oven-dried commercial thyme contained 14.59%. Similarly, commercial thyme contained, 2.88% m-Cymene while air-dried thyme contained 13.14% and oven-dried thyme contained 11.74%.

Furthermore, small amounts of E-Sabinene hydrate, Linalool, Endo-Borneol, Methyl thymyl ether, Methyl carvacrol and Caryophyllene were found in commercial, air-dried and Thyme oven-dried at 45 °C. The result also revealed that, 2-Thujene and Terpinolene were found in small proportions in thyme dried at room temperature and thyme oven-dried at 45 °C but were not found in commercial thyme. α-Pinene and β-Myrcene were found in minor amount in thyme oven-dried at 45 °C but were not identified in air-dried thyme and commercial thyme.

Discussion

This study identified apiol as the most abundant volatile compound in parsley, whereby the highest relative content of apiol was recorded in extract oven-dried at 45 °C, which was greater than apiol content recorded in air-dried parsley and commercial parsley. According to Zhang *et al*. (2006), antioxidant activity in parsley essential oil is due to apiol, which is described as the major contributor to the antioxidant activity of this oil. Apiol has also been explored as a conceivable abortifacient. Hence, pregnant women ought to be mindful so as not to eat a lot of parsley (Ajmera *et al*. 2019). The result also showed that drying method affected the quantity of volatile compounds recorded in parsley, especially apiol, in favour of oven-drying at 45 °C.

However, the relative content of other more volatile compounds decreased at the expense of the higher content of Apiol during oven-drying at 45 °C compared to drying at room temperature. This means that oven-drying at 45 °C negatively affected the chemical composition of the essential oil. These results are in agreement with those obtained by Badee *et al*. (2020), who reported that oven-drying at 45 °C caused the greatest losses in the volatiles. Kandil *et al*. (2016) mentioned that the oil content of dried parsley was strongly affected by drying methods. These findings are similar to Díaz-Maroto *et al*. (2002), who also found apiol to be the most abundant volatile compound in parsley. Macleod *et al*. (1985) also reported 45 volatile compounds from parsley leaves and identified apiol as one of the most abundant volatile components of parsley.

This study identified Eucalyptol, Camphor and α-Pinene as the abundant volatile compounds in rosemary. Oven-drying of rosemary at 45 °C caused a great reduction in the proportion of Eucalyptol and Camphor but however increased the proportion of α-Pinene in rosemary EO. Anh *et al*. (2019) also reported Eucalyptol, Camphor and α-Pinene as abundant compounds in rosemary essential oil in Vietnam. Eucalyptol, 2-Bornanone and Epimanool were identified as abundant volatile compounds in sage by this study. Oven-drying at 45 °C did not reduce the proportions of these compounds compared to air-drying at room temperature.

However, some compounds such as α-Pinene, Terpinen-4-ol and Caryophyllene disappeared during oven-drying. The results of the tests of essential oil content conducted on sage by Sellami *et al*. (2012) indicated losses from 0.3% to 0.26% during convection-drying method at 45 °C compared to naturally drying at approximately 22 °C, which is comparable to the values presented in this study. Pirbalouti *et al*. (2013) observed the lowest oil losses in green and red basil dried naturally in the shade. This method of conservation, though the least expensive, is linked to the risk of adverse atmospheric conditions and prolonged time of drying, during which enzymatic decomposition and the development of unwanted microbiota may occur. Eucalyptol, Camphor and α-Pinene have been reported to possess antimicrobial activity against a range of bacteria such as E. coli, S. aureus and Bacillus species (Zengin & Baysal 2014).

The result of this study reveals that drying ginger at 45 °C increased the concentration of α- Copaene (11.51%), β-Elemene (17.16%) and Epi-β-Caryophyllene (14.07%) compared to drying at room temperature and commercial ginger. Oven-drying of ginger at 45 °C also favoured the availability of α-Pinene, Camphene, β-Myrcene, Decane, Octanal and Z- Sabinene hydrate that were absent in ginger air-dried at room temperature. However, oven- drying lead to the decrease of β-Bisabolene, Curcumene, and β-Sesquiphellandrene which have been reported to be dominant compounds in ginger. The EOs of ginger rhizomes are used for preserving various foods against autoxidation and microbial spoilage because of their antioxidant and antimicrobial properties (Bellik 2014). Many *in vitro* studies demonstrated the antimicrobial potential of Zingiber plant extracts against both Gram-positive (*Bacillus cereus*, *Staphylococcus aureus*) and Gram-negative (*Escherichia coli*, *Salmonella typhi*, *Pseudomonas aeruginosa*, *Klebsiella pneumonia*) bacteria (Kumar *et al*. 2011). The EOs also exhibited significant antifungal activity against *Candida glabrata*, *C. albicans* and *Aspergillus niger* (Ghosh *et al*. 2011). These results suggest that EO of Zingiber plant could be used in the treatment of many bacterial and fungal diseases as well as in food preservation as natural preservatives. These results of this study are in agreement with the findings of Huang *et al*. (2012), who studied the effects of oven-drying, microwave drying, and silica gel drying methods on the degree of dehydration and volatile components of ginger. Sixty compounds were identified by GC/MS.

This study found increasing abundanceof Linalool (16.36%) and α-Bergamotene (16.50%) in oven-dried basil compared to air-dried basil and commercial basil. Meanwhile, air-drying of basil at room temperature resulted in higher retention of Eugenol (59.78%), which was lost in oven-dried basil. Linalool has a variety of biological properties, including anxiolytic, sedative, anti-inflammatory, anticonvulsant, and analgesic effects. The results obtained from the present experiment and reports of other scientists

show that there was a contradictory viewpoint on the effects of different drying methods on the essential oil profile of basil. Drying conditions meaningfully influenced the essential oil composition of Calendula officinalis, and the predominant constituents of the oil were monoterpenoid components. Furthermore, consistent with this study, oven-drying led to the destruction and/or absence of some major components. Contrarily, Sefidkon *et al*. (2006) reported that drying methods had no significant effect on essential oil composition of spices. This study shows that there is no significant difference in thyme dried at room temperature and 45 °C. However, during oven-drying, essential compound such as γ-Terpinene was lost. γ-Terpinene has been reported by several researchers to possess antimicrobial, antifungal and antiviral properties. Similarly, Calín-Sánchez *et al*. (2013) evaluated the effects of different methodologies and temperatures in the chemical composition of thyme essential oils, which presented high levels of thymol after oven-drying. The authors found that oven-drying promoted an increase in the levels of thymol, which corroborate with the results of this study.

Table 1: Chemical composition of parsley essential oil

RT (min)	Compound	Relative content (%)				
		Pub.	Obs.	Comm.	R. temp.	45 ºC
12.14	α-Pinene	939	920	0.00	0.75	0.00
15.02	β-Myrcene	981	978	0.00	2.61	0.00
16.74	o-Cymene	1011	1012	0.00	4.75	0.00
16.91	p-Mentha-1(7), 8-diene	1004	1015	0.58	7.45	1.47
19.91	Terpinolene	1088	1073	0.00	1.35	0.00
20.11	1,3-Dimethyl-2-vinylbenzene	1074	1077	0.00	4.03	0.00
20.76	Linalool	1098	1089	0.87	0.00	0.00
27.71	(-)-Carvone	1242	1231	4.44	0.00	0.00
29.72	Anethole	1289	1275	1.22	0.00	0.00
32.00	α-Terpinyl acetate	1352	1331	1.43	0.00	0.00
34.45	Caryophyllene	1428	1399	4.31	2.93	1.92
34.84	γ-Elemene	1430	1411	0.00	1.01	0.00
36.37	Germacrene D	1480	1462	0.00	1.42	0.00
36.55	α-Guaiene	1439	1468	2.95	0.00	0.00
37.54	β-Sesquiphellandrene	1519	1500	0.51	2.49	0.00
37.97	1,3-Benzodioxole 4-methoxy-6-(-propenyl)	1520	1516	1.15	0.00	0.00
39.28	Caryophyllene oxide	1573	1565	0.69	0.00	0.00
39.68	Carotol	1594	1580	2.38	0.00	0.00
41.76	Apiol	1680	1663	76.48	65.45	93.64
50.44	Phytol	2135	2170	2.99	5.76	2.97

RT = retention time, min = minutes, Pub = Published, Obs. = Observed, Comm. = commercial, R. temp. = room temperature.

Table 2: Chemical composition of rosemary essential oil

RT	Compound	Retention Index		Relative content (%)		
		Pub.	Obs.	Comm.	R. temp.	45 ºC
11.56	Tricyclene	926	909	0.00	0.00	0.27
12.15	α-Pinene	937	920	9.4	7.41	18.25
12.85	Camphene	953	934	3.01	3.69	6.44
13.17	Dehydrosabinene	960	941	0.00	0.27	0.33
14.23	β-Pinene	980	962	1.01	1.98	2.88
15.03	β-Myrcene	991	978	0.00	0.48	1.14
15.68	α-Phellandrene	1005	991	0.00	2.05	1.78
16.31	α-Terpinene	1018	1003	0.50	1.16	0.97
17.13	Eucalyptol	1033	1019	47.73	22.95	19.28
18.46	γ-Terpinene	1062	1045	0.00	1.59	1.15
19.06	Z-Sabinene hydrate	1069	1056	0.00	0.45	0.37
19.92	Terpinolene	1088	1073	0.00	0.74	0.59
20.76	Linalool	1112	1089	1.07	0.64	1.3
22.89	Camphor	1143	1132	20.47	18.15	12.82
24.14	endo-Borneol	1165	1156	5.22	4.33	4.55
24.55	Terpinen-4-ol	1177	1165	0.68	0.68	0.68
25.36	α-Terpineol	1189	1181	4.41	2.98	1.96
26.16	2-Pinen-4-one	1205	1197	0.00	4.98	7.08
29.44	(-)-Bornyl acetate	1285	1269	0.83	11.67	9.13
34.04	Methyleugenol	1401	1387	0.00	0.43	0.24
34.48	Caryophyllene	1428	1399	4.27	10.52	6.71
35.54	Humulene	1440	1434	0.59	1.64	1.06
39.28	Caryophyllene oxide	1581	1565	0.83	1.19	1.02

RT = retention time, min = minutes, Pub = Published, Obs. = Observed, Comm. = commercial, R. temp. = room temperature.

Table 3: Chemical composition of sage essential oil

RT	Compound	Retention Index		Relative content (%)		
		Pub.	Obs.	Comm.	R. temp.	45 ºC
11.98	2-Thujene	931	917	0.00	1.56	0.85
12.24	α-Pinene	937	922	2.07	2.47	0.00
12.87	Camphene	953	935	2.62	3.88	2.93
14.27	β-Pinene	980	963	0.00	4.44	2.79
15.23	β-Myrcene	991	982	0.00	5.99	2.43
16.46	Terpinolene	1088	1006	0.52	1.17	1.12
17.04	Eucalyptol	1033	1017	9.94	20.55	20.24
18.47	γ-Terpinene	1062	1045	0.3	1.71	1.56
19.26	E-Sabinene hydrate	1070	1060	0.00	0.00	0.43
21.48	β-Thujone	1102	1103	2.92	6.33	6.48
23	2-Bornanone	1145	1134	21.99	18.04	27.02
24.18	endo-Borneol	1165	1157	4.02	0.93	1.41
24.58	Terpinen-4-ol	1177	1165	0.40	0.00	0.00
25.34	L-α-Terpineol	1189	1180	0.35	0.45	0.5
27.72	Carvone	1242	1231	0.36	0.00	0.00
29.51	L-α-bornyl acetate	1285	1270	4.24	1.14	1.56
29.78	Thujyl acetate	1290	1276	0.55	0.00	0.00
34.55	Caryophyllene	1428	1402	6.45	7.18	0.00
35.67	Humulene	1440	1439	10.79	0.00	1.54
36.65	β-Eudesmene	1485	1471	0.00	0.00	0.00
36.81	(+)-Ledene	1490	1476	2.04	1.67	0.3
39.3	Caryophyllene oxide	1581	1566	0.58	0.00	0.00
39.75	Viridiflorol	1590	1583	17.34	7.44	0.4
40.04	Humulene epoxide	1607	1593	1.61	0.00	0.00
40.07	Epiglobulol	1588	1594	0.00	0.53	0.00
41.28	Isoaromadendrene epoxide	1612	1643	1.5	0.00	0.00
49.9	Epimanool	2056	2142	9.41	14.5	28.42

RT = retention time, min = minutes, Pub = Published, Obs. = Observed, Comm. = commercial, R. temp. = room temperature.

Table 4: Characteristics composition of ginger essential oil

RT	Compound	Retention Index		Relative content (%)		
		Pub.	Obs.	Comm.	R. temp.	45 ºC
12.08	α-Pinene	920	919	0.00	0.00	1.46
12.78	Camphene	934	933	0.00	0.00	2.85
14.98	β-Myrcene	981	977	0.00	0.00	1.94
15.35	Decane	999	984	0.00	0.00	0.56
15.62	Octanal	1001	990	0.00	0.00	1.02
16.87	Z-Sabinene hydrate	1089	1014	0.00	0.00	3.25
16.9	Eucalyptol	1019	1015	1.85	4.66	4.24
18.18	Melonal	1056	1039	0.46	0.00	0.42
20.69	Linalool	1089	1088	1.25	0.88	0.47
23.16	6-Octenal	1153	1137	0.00	0.57	1.15
24.05	endo-Borneol	1156	1155	2.54	1.02	2.33
25.26	α-Terpineol	1189	1179	1.58	1.14	4.18
25.72	Decanal	1204	1188	1.1	0.59	2.33
27.59	β-Citral	1218	1228	0.00	7.43	1.76
28.25	Geraniol	1255	1242	0.64	0.00	0.57
29.12	α-Citral	1271	1262	0.00	17.46	4.37
29.79	2-Undecanone	1291	1276	0.00	0.64	0.64
32.55	Cyclosativene	1368	1346	0.55	0.36	3.2
32.91	α -Copaene	1376	1356	1.22	1.11	11.51
33.49	β-Elemene	1375	1372	1.62	1.79	17.16
33.88	7-epi-Sesquithujene	0.00	1383	0.75	0.00	3.12
34.39	epi-β-Caryophyllene	0.00	1397	0.74	0.74	14.07
34.83	Elixene	1445	1411	1.59	1.67	0.81
35.5	E-β-Farnesene	1458	1433	2.17	1.26	4.14
36.21	γ-Muurolene	1477	1456	1.89	1.86	3.01
36.51	Curcumene	1486	1466	37.25	11.01	2.47
37.21	β-Bisabolene	1509	1489	10.06	21.55	0.79
37.7	β-Sesquiphellandrene	1519	1506	26.31	20.05	1.00
38.39	Elemol	1547	1532	1.34	1.41	1.86
38.61	E-Nerolidol	1564	1540	1.46	0.85	1.12
39.98	Zingiberenol	1626	1591	1.68	0.81	1.66
40.46	Globulol	1576	1610	1.96	1.14	0.56

RT = retention time, min = minutes, Pub = Published, Obs. = Observed, Comm. = commercial, R. temp. = room temperature.

Table 5: Chemical composition of basil essential oil

RT	Compound	Retention Index		Relative content (%)		
		Pub.	Obs.	Comm.	R. temp.	45 ºC
17.04	Eucalyptol	1033	1017	0.63	1.15	2.17
20.9	Linalool	1098	1092	10.28	6.38	16.36
24.23	Isoborneol	1156	1158	0.3	0.00	0.24
25.36	L-α-Terpineol	1189	1181	0.00	0.68	1.41
25.41	Terpinen-4-ol	1182	1182	0.78	0.00	0.00
25.69	Estragole	1195	1187	16.24	0.00	0.00
29.51	Bornyl acetate	1285	1270	0.54	0.82	1.35
29.77	Anethole	1289	1276	0.45	0.00	0.00
31.51	γ-Elemene	1433	1433	0.00	0.91	0.58
32.74	Eugenol	1356	1352	3.77	59.78	37.35
33.56	β-Elemen	1375	1374	0.00	2.54	2.76
34.16	Methyleugenol	1401	1391	7.74	0.00	0.27
34.44	β-Ylangene	1421	1398	0.00	0.65	0.91
34.51	Caryophyllene	1418	1400	2.05	0.00	0.28
34.98	α-Bergamotene	1436	1416	10.16	12.51	16.5
35.53	E-β-Farnesene	1458	1434	0.72	3.03	3.47
35.6	Humulene	1440	1436	0.38	0.00	0.8
35.88	E-Muurola-4(15),5-diene	1463	1446	0.78	0.86	0.76
36.44	Isogermacrene D	1448	1464	1.81	3.53	4.02
36.6	β-Eudesmene	1472	1469	0.67	0.00	0.00
36.84	Bicyclogermacren	1494	1477	0.00	0.98	1.46
36.85	γ-Eudesmol	1472	1478	0.82	0.00	0.00
37.02	α-Bulnesene	1505	1485	0.00	0.00	1.46
37.41	γ-Cadinene	1513	1496	6.07	3.57	4.26
38.67	1,6,10-Dodecatrien-3-ol-3,7,11-trimethyl-	1566	1542	0.29	0.00	0.00
39.27	Spathulenol	1575	1565	1.08	0.00	0.75
39.34	Caryophyllene oxide	1575	1567	0.72	0.00	0.00
40.03	Humulene epoxide,	2	1607	1593	0.56	0.00
50.47	Phytol	2114	2171	3.85	2.59	2.48

RT = retention time, min = minutes, Pub = Published, Obs. = Observed, Comm. = commercial, R. temp. = room temperature.

Table 6: Chemical composition of thyme essential oil

RT	Compound	Retention Index		Relative content (%)		
		Pub.	Obs.	Comm.	R. temp.	45 ºC
11.8	2-Thujene	931	913	0.00	1.14	1.56
12.13	α-Pinene	920	920	0.00	0.00	0.76
15.01	β-Myrcene	981	977	0.00	0.00	1.89
16.25	Terpinolene	1088	1002	0.00	1.93	2.04
16.69	m-Cymene	1023	1011	2.88	13.14	11.74
18.52	γ-Terpinene	1045	1046	18.55	16.65	14.59
19	E-Sabinene hydrate	1056	1055	1.19	1.15	0.95
20.69	Linalool	1089	1088	1.19	2.25	1.49
24.08	endo-Borneol	1156	1155	0.72	0.81	1.33
27.12	Methyl thymyl ether	1232	1218	1.04	0.95	0.6
27.56	Methyl carvacrol	1244	1227	1.07	0.97	0.76
30.87	Thymol	1290	1300	71.01	58.7	59.98
34.44	Caryophyllene	1428	1398	2.34	2.32	2.30

RT = retention time, min = minutes, Pub = Published, Obs. = Observed, Comm. = commercial, R. temp. = room temperature.

Conclusion

This study explored the effect of drying methods on volatile compounds of six spices, namely parsley, rosemary, sage, ginger, basil and thyme. The study concludes that apiol is the most abundant volatile compound in parsley and oven-drying at 45 °C increased the availability of apiol in parsley. However, most of the parsley essential oil components decreased during oven-drying at 45 °C compared to room temperature drying. This study also identified Eucalyptol, Camphor and α-Pinene as the abundant volatile compounds in rosemary. Oven- drying of rosemary at 45 °C caused a great reduction in the proportion of Eucalyptol and Camphor but increased the relative content of α-Pinene in rosemary. Furthermore, oven-drying at 45 °C did not affect the presence of Eucalyptol, 2-Bornanone and Epimanol in the sage extract compared to air-drying at room temperature. Oven-drying of ginger at 45 °C also favoured the availability of α-Pinene, Camphene, β-Myrcene, Decane, Octanal and Z-Sabinene hydrate that were absent in ginger air-dried at room temperature.

However, oven-drying lead to the decrease of β-Bisabolene, Curcumene, and β- Sesquiphellandrene which have been reported to be dominant compounds in ginger. Oven- dried basil also contained higher concentration of Linalool (16.36%) and α-Bergamotene compared to air-dried samples.

Disclosure of Interest

The author reports there are no competing interests to declare

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