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Research Article
Effect of Drying and Distillation Techniques on the Oil Ingredients of Mint (*Mentha* sp.)

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Abstract
Background and Objective: The essential oil (EO) of mint used in food and pharmaceutical industries. Drying and distillation techniques play an important role in the EO production from mint. The aim of this investigation was to evaluate the EO composition of mint plants under various drying and distillation techniques. **Materials and Methods:** The fresh herb of *Mentha longifolia* (L.) Huds. ssp. *schimperi* Briq and *Mentha longifolia* (L.) Huds. ssp. *Longifolia* were subjected to different drying techniques such as shad, sun and oven drying (40°C) compared with fresh herb. On the other hand, dried herb of *Mentha piperita* L. and *Mentha citrate* (Ehrh.) was subjected to various distillation techniques (hydro and stem). The EO content and its constituents were evaluated under drying and distillation techniques. The averages data were statistically analyzed using 2-way analysis of variance (ANOVA-2) with 0.05 level of significance. **Results:** The greatest amounts of EO and its major constituents were produced from fresh plants, followed by the plants treated with shade, sun and oven techniques respectively. Higher values were detected in EO and major components under hydro distillation than steam distillation. **Conclusion:** Separation of EO from the fresh mint is the best way to obtain the high quantity and quality of peppermint EO, however, in the case of peppermint EO separation in remote places, the drying technique can be used in the shade to reduce the size and avoid disease. Isolation of EO with hydro distillation technique is requiring for increasing the quantity and quality of mint EO.

Key words: Mint plants, essential oil, steam distillation, fresh herb, air drying, hydro distillation, monoterpenes, sesquiterpenes

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Essential oil (EO) is a secondary product formed by aromatic plants, it used in food and pharmaceutical industries, it has various chemo preventive properties against liver, lung, colon and gastric cancer[1]. The genus *Mentha* belongs to the family Lamiaceae. The EO isolated from mint reported as anti-inflammatory, carminative, antiemetic, diaphoretic, antispasmodic, analgesic, stimulant, emmenagogue, anticatarrhal, fungicide and antioxidant[2].

Scientific research into various techniques to increase the aromatic crops productivity must increase as demand for food and natural pharmaceutical row materials production increases. The techniques of drying and distillation represent tow ways of research that has the potential to increase aromatic crops productivity[3].

The drying of various fresh parts of aromatic plants such as leaves, stems, roots, flowers, seeds and fruits is necessary to reduce weight, volume, fungal and molds attacks, cost of transportation, space of storage and increase the shelf life[4]. Drying techniques (DRTECHs) play important roles in the EO production from aromatic plants[5]. The effects of DRTECHs such as air, sun and oven on the *Artemisia afra* EO were investigated by Asekun *et al.*[6] and they reported that the EO yield and major constituents (thujone, camphor, 1,8-cineole and borneol) were differed according to the DRTECH. *Laurus nobilis* leaves were exposed to different drying temperature, significant changes were occurred in EO yield and EO constituents due to the temperature of drying[7]. Leaves of lemongrass were subjected to three DRTECHs (sun, shade and oven), significant differences were obtained in the EO content and its constituents under various DRTECHs[8]. Different variations were found in the active constituents of *Nardostachys jatamansi* DC EO due to the various DRTECHs and using low temperature (22-34°C) caused a significant reduction in deterioration in the EO composition[9]. The DRTECHs had a significant variation in the quantity and quality of EOs extracted from *Cupressus macrocarpa*, *Eucalyptus spathulata*, *Basil* (*Ocimum basilicum* L.) and *Warionia saharae* plants[10-13]. *Kelussia odoratissima* Mozaff plants treated with shade drying resulted in higher yield of EO, (Z)-ligustilide component and accepted quality of color than those treated with sun, oven, microwave and freeze DRTECHs[14]. The influence of natural and artificial DRTECHs on the EO extracted from *Tanucetum parthenium* cv. Zardband, citronella and *Myrtus communis* were investigated[15-18] and obtained results reported that DRTECHs had a positive effect on the proportion and volatile composition. Saeidi *et al.*[19] indicated that oven and shade DRTECHs were recommended for achieving high EO yield and percentages of major and some minor components of the EO isolated from *Mentha longifolia* (L.) Hudson.

The EO is basically isolated from aromatic plants by distillation techniques (DISTECHs) such as hydro (or water) distillation (HD) and steam distillation (SD), DISTECHs can produce significant changes in the yield and constituents of EO such isomerization, saponification or polymerization of the more labile components[20]. The effect of DISTECHs on *Satureja hortensis* EO was investigated[21], obtained results indicated that HD gave higher value in EO yield (0.9%) than SD (0.3%). *Eucalyptus spathulata* plants treated with HD technique produced the highest values of EO yield and major component (1,8-cineole)[10]. The highest EO yields of lemon balm and apple geranium were produced under HD technique, the highest amount of methyl eugenol was obtained with HD technique while SD technique resulted in the greatest amount of limonene. Different variations were found in oxygenated and hydrocarbon components under both of HD and SD techniques[22]. Significant variations were found in the major components (%) of summer savory EO due to different DISTECHS[23].

The techniques of drying and distillation play very important roles in EO productions, so, this study included two trials: The first trial was to evaluate the EO composition of two subspecies of *Mentha longifolia* (L.) Huds. [*Mentha longifolia* (L.) Huds. ssp*. schimperi* Briq and *Mentha longifolia* (L.) Huds. ssp. *Longifolia*] under various DRTECHs (shade, sun and oven drying). The second one was to investigate the effect of different DISTECHs (HD and SD) on the EO composition of two mint species [*Mentha piperita* L. and *Mentha citrate* (Ehrh)].

MATERIALS AND METHODS

Experimental: Pot experiments were conducted in the greenhouse of National Research Centre (NRC), Dokki, Cairo, Egypt, during two seasons, 2017 and 2018. Seedlings of mint [*Mentha longifolia* (L.) Huds. ssp*. schimperi* Briq, *Mentha longifolia* (L.) Huds. ssp. *Longifolia, Mentha piperita* L. and *Mentha citrate* (Ehrh.)] were obtained from the Institute of Medicinal and Aromatic Plants, Egypt. Uniform seedlings (15 cm height) were transplanted into clay pots (30 cm diameter and 50 cm height), each pot contains 3 seedlings. In the 1st week of February during both seasons, the pots were adjusted to natural conditions. Each pot was filled with 10 kg of air-dried clay soil. All agricultural practices such as fertilization and weed control were conducted according to the main recommendations by the Ministry of Agriculture, Egypt.

Harvesting: All mint plants were harvested twice (first and second harvest) during both seasons, by cutting the plants 5 cm above the soil surface (after 12 and 20 weeks from transplanting, respectively), total fresh and dry masses (g plant^{-1}) were recorded.

Essential oil isolation: The fresh herbs (aerial parts) of the *Mentha longifolia* (L.) Huds. ssp. *schimperi* Briq and *Mentha longifolia* (L.) Huds. ssp. *Longifolia* were collected and then dried by different DRTECHs [(Shad, sun and oven (40°C)] compared with fresh status (as control), 200g from each replicate (4 replicates) of all status were subjected to hydro-distillation (HD) for 3 h using a Clevenger-type apparatus[24]. On the other hand, the fresh aerial parts of the *Mentha piperita* L. and *Mentha citrate* (Ehrh.) were collected and then air dried, 200 g from each replicate (4 replicates) were subjected to two different DISTECHs (HD and SD) for 3 h using a Clevenger-type apparatus[24]. The EOs (%) and mL plant^{-1} were calculated according to the dry weight.

GC and GC-MS: GC analyses[25] were performed using a Shimadzu GC-9 gas chromatograph equipped with a DB-5 (dimethylsiloxane, 5% phenyl) fused silica column (J and W Scientific Corporation) (60 m, 0.25 mm i.d., film thickness 0.25 µm). Oven temperature was held at 50°C for 5 min and then programmed to rise to 240°C at a rate of 3°C min^{-1}. The flame ionization detector (FID) temperature was 265°C and injector temperature was 250°C. Helium was used as carrier gas with a linear velocity of 32 cm sec^{-1}. The percentages of compounds were calculated by the area normalization method, without considering response factors. GC-MS analyses[25] were carried out in a Varian 3400 GC-MS system equipped with a DB-5 fused silica column (30 m, 0.25 mm i.d., film thickness 0.25 mL), oven temperature was 50-240°C at a rate of 4°C min^{-1}, transfer line temperature 260°C, carrier gas, helium, with a linear velocity of 31.5 cm sec^{-1}, split ratio 1:60, ionization energy 70 eV, scan time 1 sec and mass range 40-300 amu.

Identification of volatile components: The components of the oils were identified by comparison of their mass spectra with those of a computer library or with authentic compounds and confirmed by comparison of their retention indices, either with those of authentic compounds or with data published in the literature[25]. Mass spectra from the literature were also compared[24]. Further identification was made by comparison of their mass spectra on both columns with those stored in NIST-98 and Wiley-5 Libraries. The retention indices were calculated for all volatile constituents using a homologous series of n-alkanes.

Statistical analysis: In this experiment, two factors were considered: DRTECHs or DISTECHs×2 subspecies of *Mentha longifolia* (or 2 species of *Mentha*). For each factor there were 4 replicates, the experimental design followed a complete random block design. The averages data of both seasons were statistically analyzed using 2-way analysis of variance (ANOVA-2)[26]. Significant values determined according to LSD at 0.05. The applications of that technique were according to the STAT-ITCF program version 10 Statsoft[27].

RESULTS

Effect of DRTECHs on EO composition: Various DRTECHs (shade, sun and oven drying) and/or different subspecies of *M. longifolia* (*Schimperi* Briq and *Longifolia*) affected the EO contents (Percentage and mL Plant^{-1}) of first, second and total of two harvests (Table 1). Thus, different DRTECHs resulted various reduces in EO contents compared with the fresh status. Higher values were found in the DRTECHs extracted from *Longifolia* ssp. than *Schimperi* Briq. Greatest EO contents were recorded with the fresh status for the subspecies of *Longifolia* with values of 3.2% and 3.0 mL plant^{-1}, 2.9% and 2.4 mL plant^{-1}, 3.1% and 5.4 mL plant^{-1} during first, second and total of two harvests, respectively. The changes in EO contents were significant for *M. longifolia* ssp., DRTECHs and their interactions (Table 1). Twenty one constituents were identified by GC-MS analysis in the EO isolated from *M. longifolia* (L.) Huds. ssp. *schimperi* Briq under different DRTECHs and fresh status (Table 2). Carvone and limonene were detected as the major compounds that produced the highest amounts of EO. All DRTECHs resulted in a decrease in the major compounds compared with control. The highest values of major components (64.5 and 14.9%) were obtained from untreated plants (fresh) followed by shade technique (63.5 and 13.9%), sun technique (62.5 and 13.1%) and oven technique (58.2 and 12.9%). Various identified constituents divided into three chemical classes, monoterpene hydrocarbons (MTH), oxygenated monoterpenes (OMT) and sesquiterpenes hydrocarbons (STH). The OMT and MTH were the major classes while STH formed the minor class. Fresh plants and sun technique produced the highest amounts of MTH and OMT with the values of 19.4 and 78.2%, respectively, while the

Table 1: Effect of DRTECH on the EO content of *M. longifolia* ssp.

		Essential oil					
		1st harvest		2nd harvest		Total	
Mentha longifolia Subspecies	DRTECH	Percentage	Yield (mL plant^{-1})	Percentage	Yield (mL plant^{-1})	Percentage	Yield (mL plant^{-1})
Schimperi Briq	Fresh	2.5	2.1	2.2	1.5	2.4	3.6
	Shad	2.1	1.7	2.0	1.4	2.1	3.1
	Sun	1.9	1.6	1.8	1.2	1.9	2.8
	Oven	1.7	1.4	1.6	1.1	1.7	2.5
Overall *Schimperi* Briq		2.1	1.7	1.9	1.3	2.0	3.0
Longifolia	Fresh	3.2	3.0	2.9	2.4	3.1	5.4
	Shad	2.9	2.7	2.1	1.7	2.5	4.4
	Sun	2.7	2.5	1.9	1.6	2.3	4.1
	Oven	2.1	2.0	1.7	1.4	1.9	3.4
Overall *Longifolia*		2.7	2.6	2.2	1.8	2.5	3.3
Overall	Fresh	2.9	2.6	2.6	2.0	2.8	4.5
DRTECH	Shad	2.5	2.2	2.1	1.6	2.3	3.8
	Sun	2.3	2.1	1.9	1.4	2.1	3.5
	Oven	1.9	1.7	1.7	1.3	1.8	3.0
LSD: 0.05							
DRTECH		0.2	0.3	0.2	0.1	0.2	0.3
Subspecies		0.3	0.4	0.2	0.2	0.3	0.2
DRTECH×Subspecies		0.2	0.2	0.1	0.1	0.1	0.2

DRTECH: Drying techniques

Table 2: Effect of DRTECH on the EO components of *M. longifolia* (L.) Huds. ssp. *schimperi* Briq

			DRTECH			
Compounds (%)	RI	Class	Fresh	Shade	Sun	Oven
α-Pinene	939	MTH	1.2	1.3	1.4	1.8
Sabinene	976	MTH	1.4	1.1	1.2	1.6
β-Pinene	980	MTH	0.3	0.2	0.9	0.7
Myrcene	991	MTH	0.2	0.4	0.4	0.7
p-Cymene	1026	MTH	1.1	0.8	0.9	0.4
Limonene	1031	MTH	14.6	13.9	13.1	12.9
Cis-β-Ocimene	1040	MTH	0.6	0.5	0.5	0.9
Cis-Sabinene hydrate	1097	OMT	0.3	0.5	0.8	1.9
Linalool	1098	OMT	2.6	2.4	2.6	2.8
Menthone	1154	OMT	3.4	3.1	3.4	3.7
Isomenthone	1164	OMT	0.7	0.6	0.7	1.5
Terpinen-4-0l	1177	OMT	0.7	0.6	1.7	1.9
α-terpineol	1189	OMT	0.4	0.5	0.8	0.7
Dihydrocarveol	1192	OMT	2.9	2.8	2.9	2.7
Trans-Carveol	1217	OMT	0.5	0.5	1.7	1.7
2 Hydroxy-1,8-cineole	1219	OMT	0.2	0.5	0.7	0.8
Carvone	1242	OMT	64.5	63.5	62.5	58.2
Thymol	1290	OMT	0.7	0.6	0.4	1.2
β-Caryophyllene	1418	STH	0.6	0.5	0.6	1.3
Germacrene D	1480	STH	1.7	1.6	1.6	1.5
Bicyclogermacrene	1494	STH	0.8	0.7	0.8	0.9
MTH			19.4	18.2	18.4	19.0
OMT			76.9	75.6	78.2	77.1
STH			3.1	2.8	3.0	3.7
Total identified			99.4	99.6	99.6	99.8

DRTECH: Drying techniques, EO: Essential oil, MTH: Monoterpene hydrocarbons, OMT: Oxygenated monoterpenes, STH: Sesquiterpenes hydrocarbons

highest value of STH (3.7%) was recorded with oven DRTECH. The EO isolated from *M. longifolia* (L.) Huds. ssp. *Longifolia* were analyzed by GC-MS (Table 3) and 19 compounds were detected. The main components were piperitone, limonene, trans-piperitol and cis-piperitol which decreased due to different DRTECHs. Fresh status resulted in the greatest

Table 3: Effect of DRTECH on the EO components of *M. longifolia* (L.) Huds. ssp. *Longifolia*

			DRTECH			
Compounds (%)	RI	Class	Fresh	Shade	Sun	Oven
α-Pinene	939	MTH	0.6	0.7	0.8	0.7
β-Pinene	980	MTH	0.8	0.5	0.4	1.6
Sabinene	976	MTH	0.5	0.6	0.6	0.8
Myrcene	991	MTH	0.9	1.1	0.6	0.8
Limonene	1031	MTH	14.8	14.2	13.9	13.6
Linalool	1098	OMT	0.7	0.6	0.7	0.9
Menthone	1154	OMT	0.7	1.4	0.1	1.8
Menthol	1173	OMT	0.9	0.8	0.9	1.7
Terpinen-4-0l	1177	OMT	0.4	0.7	0.8	1.7
cis-Piperitol	1193	OMT	8.9	8.5	8.6	8.5
trans-Piperitol	1205	OMT	12.9	12.8	12.6	12.3
trans-Carveol	1217	OMT	0.7	1.4	0.2	1.3
Piperitone	1282	OMT	48.8	48.5	48.1	47.4
Piperitenone	1342	OMT	2.6	2.4	0.1	0.6
β-Elemene	1375	STH	0.7	0.6	0.5	0.7
β-Caryophyllene	1418	STH	0.3	0.6	0.7	1.6
β-Humulene	1440	STH	0.5	0.7	0.9	1.8
Germacrene D	1480	STH	3.3	3.1	1.2	1.1
Bicyclogermacrene	1494	STH	0.7	0.6	0.5	0.8
MTH			17.6	17.1	16.3	17.5
OMT			76.6	77.1	79.3	76.2
STH			5.5	5.6	3.8	6.0
Total identified			99.7	99.8	99.4	99.7

DRTECH: Drying techniques, EO: Essential oil, MTH: Monoterpene hydrocarbons, OMT: Oxygenated monoterpenes, STH: Sesquiterpenes hydrocarbons

Table 4: Effect of DISTECH on the EO content of mint species

		Essential oil					
		1st harvest		2nd harvest		Total	
Mint species	DRTECH	Percentage	Yield (mL plant^{-1})	Percentage	Yield (mL plant^{-1})	Percentage	Yield (mL plant^{-1})
Piperita	HD	0.4	0.6	0.3	0.2	0.4	0.8
	SD	0.2	0.3	0.2	0.1	0.2	0.4
Overall Piperita		0.3	0.5	0.3	0.2	0.3	0.6
Citrate	HD	0.3	0.3	0.2	0.2	0.3	0.5
	SD	0.2	0.2	0.1	0.1	0.2	0.3
Overall Citrate		0.3	0.3	0.2	0.2	0.3	0.4
Overall							
DISTECH	HD	0.4	0.5	0.3	0.2	0.4	0.7
	SD	0.2	0.3	0.2	0.1	0.2	0.4
LSD: 0.05							
DISTECH		0.1	0.1	0.1	0.1	0.1	0.2
Species	NS	0.1	0.1	0.1	NS	0.1	
DISTECH x Species		0.1	0.1	0.1	0.1	0.1	0.2

DISTECH: Distillation techniques, HD: Hydro distillation, SD: Steam distillation

amounts of the main components (48.8, 14.8, 12.8 and 8.9%) followed by shade drying technique (48.5, 14.2, 12.8 and 8.5%), sun drying (48.1, 13.9, 12.6 and 8.6%) and oven technique (47.4, 13.9, 12.3 and 8.5%). The major chemical classes were OMT and MTH while the minor class was STH. The highest values of OMT (79.3%), MTH (17.6%) and STH (6.0%) were recorded with fresh (none drying), sun drying and oven drying, respectively.

Effect of DISTECHs on EO composition: The values of the contents of EO (% and mL plant^{-1}) isolated from *M. piperita* and *M. citrate* were affected by different DISTECHs i.e., HD and SD (Table 4). The DISTECHs caused various changes in the EO contents of both mint species during first, second and total of two harvests. The *M. piperita* and HD technique produced higher values in EO content than *M. citrate* or SD technique especially in the total values of the two harvests. The greatest

Table 5: Effect of DISTECH on the EO constituents of *M. piperita*

			DRTECH	
Compounds (%)	RI	Class	HD	SD
α-Pinene	939	MTH	0.3	1.6
Camphene	953	MTH	0.1	1.1
Verbenene	967	MTH	0.3	1.6
β-Pinene	980	MTH	0.2	0.9
Myrcene	991	MTH	0.5	1.6
α-Phellandrene	1005	MTH	0.5	0.8
Limonene	1031	MTH	2.7	2.6
γ-Terpinene	1062	OMT	0.7	2.5
α-Terpinolene	1088	MTH	0.3	1.6
Linalool	1098	OMT	0.8	1.9
Isopulegol	1145	OMT	0.8	0.5
Menthone	1154	OMT	0.7	0.6
Menthofuran	1164	OMT	43.6	39.6
Borneol	1165	OMT	0.1	0.7
Menthol	1173	OMT	8.7	6.4
Terpinen-4-0l	1177	OMT	0.2	0.4
α-Terpineol	1189	OMT	0.3	0.6
2 Hydroxy-1,8-cineole	1219	OMT	0.7	0.7
Pulegone	1237	OMT	32.8	28.9
Piperitone	1282	OMT	0.5	0.8
α-Cubebene	1351	STH	0.1	1.3
β-Caryophyllene	1418	STH	0.2	0.7
Germacrene D	1480	STH	0.5	0.9
Spathulenol	1576	OST	0.6	0.4
Caryophyllene oxide	1581	OST	3.2	0.8
MTH			4.9	11.8
OMT			89.9	83.6
STH			0.8	2.9
OST			3.8	1.2
Total identified			99.4	99.5

DISTECH: Distillation techniques, EO: Essential oil, HD: Hydro distillation, SD: Steam distillation, MTH: Monoterpene hydrocarbons, OMT: Oxygenated monoterpenes, STH: Sesquiterpenes hydrocarbons, OST: Oxygenated sesquiterpenes

contents of EO (0.8 mL plant^{-1}) were recorded with *M. piperita* under DISTECHs (as total values of the two harvests). Significant variations were found in EO contents for DISTECHs, mint species and their interactions except the changes the EO percentages at the first and total of two harvests were insignificant for mint species. The EO isolated from *M. piperita* resulted in 25 components by GC-MS analysis under different DISTECHs (Table 5). The major constituents were menthofuran, pulegone and menthol which produced more than 70% from the total components, higher values of the major constituents were found under HD (43.6, 32.8 and 8.7%) than SD (39.6, 28.9 and 6.4%). All constituents were classified to four chemical classes, the OMT was the major one while the MTH, STH and oxygenated sesquiterpenes (OST) were formed the minor classes. The greatest values of MTH (11.8%) and STH (2.9%) were recorded with SD techniques while the HD techniques resulted in the highest amounts of OMT (89.9%) and OST (3.8%). Fourteen constituents were detected in *M. citrate* EO by GC-MS analysis under various DISTECHs (Table 6). Linalyl acetate and linalool were isolated as the main compounds with the DISTECHs. On the other hand, OMT was the major class but MTH and STH were the minor classes. The highest amount of linalyl acetate, linalool and OMT were obtained with HD technique with values of 70.9, 22.7 and 95.5% respectively. The highest values of MTH (6.8%) and STH (0.6%) were recorded with SD technique.

DISCUSSION

Obtained results reported that DRTECHs brought about different decreases in the values of EO contents, major and some minor constituents in EO compared with the fresh status. This may be due to some chemical transformations during the drying process[28,29]. The variations in the values of the EO and its components during drying depend on different factors, such as the DRTECH and the classification of plant. Mint belongs to Lamiaceae family which is known to store their EO on or near the leaf surfaces[5]. This might account for the loss of EO and its major constituents in mint under different DRTECHs[5]. The effect of DRTECH on *M. longifolia* (L.)

Table 6: Effect of DISTECH on the EO constituents of *M. citrate*

			DRTECH	
Compounds (%)	RI	Class	HD	SD
α-Pinene	939	MTH	0.6	0.7
β-Pinene	980	MTH	0.5	2.7
Myrcene	991	MTH	0.8	1.7
Limonene	1031	MTH	0.9	1.7
Linalool	1098	OMT	22.7	18.9
α-Terpineol	1189	OMT	0.2	1.3
2 Hydroxy-1,8-cineole	1219	OMT	0.5	1.8
Nerol	1228	OMT	0.5	1.2
Carvone	1242	OMT	0.3	0.9
Geraniol	1255	OMT	0.4	0.5
Linalyl acetate	1261	OMT	70.9	65.8
Neryl acetate	1365	OMT	0.6	0.8
Geranyl acetate	1383	OMT	0.4	0.8
Caryophyllene oxide	1581	STH	0.5	0.6
MTH			2.8	6.8
OMT			95.5	92.0
STH			0.5	0.6
Total identified			99.8	99.4

DISTECH: Distillation techniques, EO: Essential oil, HD: Hydro distillation, SD: Steam distillation, MTH: Monoterpene hydrocarbons, OMT: Oxygenated monoterpenes, STH: Sesquiterpenes hydrocarbons

Huds. ssp. *schimperi* Briq and *M. longifolia* (L.) Huds. ssp. *Longifolia* has not been studied before but similar investigations were found on different species or varieties of mint with some previous literature. The herbs of *M. spicata* var. Viridis were treated with different drying methods [shade, sun, forced air oven (60-80°C)], shade drying resulted in significant increases of EO content[30]. Shade drying caused higher values in *M. piperita* EO than sun drying[31]. The fresh leaves of pineapple mint (*Mentha rotundifolia 'variegata'*) were dried by air-drying at ambient temperature (22°C) and oven-drying at 60°C. The results indicated that the yields of the EO were significantly affected by the various drying methods. Higher EO yields by air-drying at 22°C was found when compared with oven-drying (0.63 and 0.31%, respectively), while the effect of drying methods on the chemical components of the essential oils were not significantly[32]. Mint leaves (*Mentha spicata* L.) were subjected to hot air, shade and microwave drying[33]. Appreciable losses were found in EO contents under various drying methods compared with fresh leaves. Drying methods (shade and sun) as well as drying duration resulted in different changes in the essential oil composition of spearmint (*Mentha spicata* L.)[34]. Similarly, oven-drying of rosemary at 45°C resulted in 7.3% loss in volatile constitutes, while microwave-drying produced losses of 61.5% in the same plant[35]. However, rosemary, dried at ambient temperature was similar in EO yield to the fresh plant[20]. Significant changes were found in EO and its constituents of *Tanucetum parthenium*, citronella, lemon balm and *Myrtus communis*[10-13]. Saeidi *et al.*[19] reported that various DRTECH caused a significant reduction in the EO yield and major constituents of *Mentha longifolia*. The increase in EO contents and major constituents under HD technique may be due to the fact that parameters such as material of plants as well as modes of combination, charging grade of insulation which play an important role in HD technique[36]. The significant effect of HD technique was confirmed by some previous investigation on EO extracted from *Satureja rechingeri* lemon balm and apple geranium[20,22]. The highest amounts EO extracted from rose-scented geranium were produced under HD and the lowest obtained SD[36]. Different variations were recorded in the EO constituents of geranium and *Nigella sativa* due to different DISTECHs[36,37]. The DISTECHs resulted in significant differences in the EO and major components of summer savory[23]. The EO contents and constituents were changed according to species and subspecies of mint which may be due to genetic differences between the species or sub species. Also these results may be due to the changes in herb weight per plant[22].

CONCLUSION

It can be concluded that DRTECH and DISTECH resulted in different changes in the EO extracted from subspecies or species of mint. The DRTECH caused different decreases in the EO contents and major constituents of *M. longifolia* (L.) Huds. ssp. *schimperi* Briq and *M. longifolia* (L.) Huds. ssp. *Longifolia.* The HD resulted in higher values in EO contents and major component of *M. piperita* and *M. citrate* than SD.

SIGNIFICANT STATEMENTS

This study discovered that the greatest EO content and major constituents were recorded with fresh plants, followed by shade, sun and oven drying. So the producers can use the fresh herb of mint to extract the EO from mint and if necessary to conduct the drying process as in the case of transport to remote places can be used the shade drying technique because its results are closer to use fresh status. Higher amounts of EO and major constituents were observed by using HD of mint EO than those obtained by SD. Thus the farmers or producers can select the HD technique for produce the EO from mint.

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