EFFECT OF CONVENTIONAL AND MICROWAVE DRYING TECHNIQUES ON FLAT AND CURLY PARSLEY QUALITY CULTIVATED IN EGYPT

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Abstract

This study performed out during seasons 2016 and 2017 at special farm near Cairo-Alex Desert Road, Egypt, to investigate the effect of dehydration by sun, oven, hot air, oven under vacuum and microwave treatments on some bioactive compounds and their activities in flat (*Petrosilinum crispum* var. *neapolitanum)* and curly (*Petroselinum crispum* var. *crispum*) parsley varieties cultivated in Egypt. The results showed that yield, ash and acid insoluble ash were the highest in flat parsley than curly, while curly parsley was the highest in total hydrolysable carbohydrates and dietary fiber. The results from bioactive compounds showed that the gradually decrease cosntents of chlorophyll a and b, carotenoids, β-carotene, flavonoids, polyphenols, vitamin C and volatile oil percentage in commercial techniques (sun, oven and hot air dried) and controlling techniques (oven dried 55°C under vacuum and microwave 400W and 800W in either flat or curly parsley. Those results reflected to free radical scavenging activity and total antioxidants activity. Total identified volatile oil components in flat parsley in different dehydration techniques ranged from 11 to 28 items while, in curly parsley ranged from 13 to 28 items. The percentage of total identified components were higher in two parsley cultivars treated by microwave 800W/6 min (66.99 and 66.77%) and 800W/12 min (63.08 and 64.18%) followed by microwave 400W/12 min (58.70 and 56.50%) and 400W/24 min (47.37 and 48.79%) than other treatments either in flat or curly parsley, respectively. the major components of curly leaves essential oil were Myristicin (15.05%), 2-Allyl-4-methyl phenol (10.15%), Isolongipholene (8.59%) and β-Caryophyllene (6.43%).While, volatile oil of flat parsley, the highest compounds were Myristicin (12.65%), 2-Allyl-4-methyl phenol (10.77%), Apiol (9.5%) and Isolongipholene (9.45%). From the obviously results it could be recommended that the best dehydration methods were microwave 800W/6min. > microwave 400W/12min.> oven under vacuum > sun dried > microwave 800W/12min> oven dryer> hot air dried. Finally, through this study, it could be clearly concluded that, it is technical and economical to utilize microwave as a new untraditional dehydration technique in producing flat and curly parsley, rather than traditional dehydration techniques in Egypt, Thus improving the quality specifications of dried parsley which increases the opportunity of exporting.

Key words: Parsley flat, Parsley curly, Dehydration techniques, Microwave, Oven dryer, Hot air dried, Sun dried, Antioxidant contents, Volatile oils.

INTRODUCTION

The common varieties of parsley, the curly leave variety (*Petrosilinum. crispum var. crispum*) which often used as a garnish, while the flat leave or Italian variety (*P. crispum var. neapolitanum*) used in tabbouleh and other Mediterranean dishes; and root parsley (*P. crispum* var. *tuberosum*), which grown as a root vegetable (Craft and Setzer, 2017). *Petroselinum* is the genus name of the plants commonly known as parsley commonly used for cooking and in medicinal folk remedies. Parsley is a member of the Apiaceae family of plants which native to Europe and Western Asia. It is widely used in both fresh and dry to enhance the flavor of many foods and also in perfume manufacturing (Simon and Quinn, 1988). Drying is widely used not only as a way to preserve foods but also to reduce weight of the product. The quality of the dried product can be affected by high temperatures resulting in off-odors, change of color or loss of nutrients (Mangkoltriluk *et al*., 2005). But, drying is the most traditional methods for preservation of agricultural post-harvest products and preventing activities of enzymes and microorganisms (Ebadi *et al*., 2010). Oven dry method has the disadvantage of entailing a time consuming process. In contact with oxygen the product becomes exposed to high temperatures for a long time which reduces the content of some valuable components (Nawirska *et al*., 2009). Microwave drying, fluidized bed dries and hot air drying systems offer opportunities as less drying time, uniform energy and high thermal conductivity with high quality of dried product (Ozkan *et al*., 2007). Microwave drying method under vacuum is a modern and efficient method for food preservation. The advantages of microwave treatments, the microwave assisted procedure available high throughput, repeatable drying of multiple samples, in a manner easily adaptable for drying a wide array of biological samples. Depending on the tolerance for sample heating, the drying time can be altered by changing the power level of the microwave unit (Cellemme *et al*., 2013). Also, the total aerobe bacteria count was reduce with microwave drying in comparison with convective drying alone, especially in herbs and spices dehydration (Heindl and Müller, 2007). Kamel (2013) found that parsley leaf had higher total phenolic, chlorophyll, carotenoids and antioxidants scavenging activity (1031.4 mg/100g, 32.47 mg/kg, 40.0 mg/kg and 40.1%, respectively). The effect on the volatiles by different drying treatments in parsley (*Petroselinum crispum* L.) was studied. Air drying at room temperature (25±5ºC) resulted in decrease losses in volatile compounds compared with the fresh herb, whereas oven drying at 45 °C and freeze-drying caused a reduction in the concentrations of the most volatile components, especially those with the considerable impact on parsley aroma: ρ-mentha-1,3,8-triene and apiole (Díaz-Maroto *et al.,* 2002).The time/temperature required for drying Coleus leaves by hot air drying revealed that the lowest reduction in the quality characteristics of leaves at 60°C (Dwivedy *et al.*, 2012). While, time/temperature required by microwave drying can be successfully used to dry Coleus leaves with maximum preservation of aroma. In absence of the availability of commercial microwave drying, hot air drying may be adopted for large scale drying of leaves. However, the same author reported that selection of drying method depended on the use of end product and the economic consideration. Thus, the aim of this study is to compare other conventional drying techniques and microwave drying technique, as a hot drying systems offer opportunities as less drying time, uniform energy and high thermal conductivity with high quality of dried product.

MATERIALS AND METHODS

Materials:

Flat (*Petrosilinum crispum* var. *neapolitanum, Danert*) and Curly (*Petroselinum crispum* var. *crispum*) parsley were planted and collected at special farm near Cairo-Alex Desert Road. The part of collected samples was used fresh. Other samples were solar dried, dried at hot air 100°C pumped in oven dryer and continuous mixing. Also, Sample was dehydrated by mechanical commercial technique 135°C/h followed by 60-70°C/h then ventilated one hour. Meanwhile, another sample was dried in oven under vacuum at 55°C. Furthermore, samples were dried by microwave 400W at 12, 24 and 36 min and 800W at 6, 12 and 24 min, respectively. The dried samples were crushed by crusher then packaged in paper inner polyliner bags.

Methods:

The chemical analyses such as, moisture, ash, acid insoluble ash, ether extract, dietary fiber and crude protein were determined according the procedures described in AOAC, (2012), While, total hydrolysable carbohydrates were calculated by difference according to Mathew *et al.*, (2014).

Total polyphenol components were determined using Folin–Ciocalteu method as described by Boligon *et al.*, (2009). The content of flavonoids was determined by a Pharmacopeia method (1989).

Chlorophyll-A, chlorophyll-B and total carotenoids were extracted from fresh, dehydrated parsley according to the methods of Schopfer, (1989). Then samples were measured in a UV-spectrophotometer at 480 nm and 510 nm for carotenoids and at 644nm and 662nm for chlorophyll. β-carotene was determination as described by Nagata and Yamashita, (1992). The absorbance was measured at 453, 505, 645 and 663 nm. β- carotene (mg/g) = 0.216 A663 – (0.304 A505 + 0.452 A453). While, ascorbic acid was analyzed as described by Klein and Perry, (1982).

The free radical scavenging activity of the extracts was examined using DPPH radical according to the method of Shimada *et al.*, (1992) with slight modification. 1.0 ml of various concentrations of extracts (2-10 mg/ml) was mixed with 1.0 ml of 0.8 mM DPPH solution. The mixture was shaken vigorously and left to stand for 30 min and the absorbance was measured at 517 nm against a reagent blank. Gallic acid and BHT were used as standards. The inhibition percentage for scavenging DPPH radical was calculated according to the equation: % Decolorization = [1-(ABS sample/ABS control] x 100.

The total antioxidant capacity was determined as described by Prieto *et al.*, (1999). At different ethanol extracts which were prepared in their respective solvents and combined in a tube with 1ml of reagent solution (0.6M H_2SO_4, 28mM sodium phosphate, 4mM ammonium molybdate mixture). The tubes were incubated for 90min at 95ºC. The mixture was cooled to room temperature (25± 5ºC) and the absorbance was read at 695nm against blank. Ascorbic acid equivalents were calculated using standard graph of ascorbic acid. The experiment was conducted in triplicates and values are expressed as equivalents of ascorbic acid in µg per g. Also, volatile oils were determined according to ISO Method 6571 (2009). Samples were analyzed using DsChrom 6200 Gas Liquid Chromatography equipped with a flame ionization detector for separation of volatile oil constituents.

The GC analysis of the essential oil samples was performed using gas chromatography-mass spectrometry instrument stands at the Department of Medicinal and Aromatic Plants Research, Horticultural Institute, Agricultural Research Center, Egypt with the following specifications:

The chromatograph apparatus was fitted with capillary column BPX-5, 5% phenyle(equiv.) polysillphenylene-siloxane 30m X 0.25 mm ID X 0.25µm film. Temperature program ramp increase with a rate of 10°C/ min from 70º to 200º C. Flow rates of gases were nitrogen at 1 ml / min, hydrogen at 30 ml/ min and 330 ml / min for air. Detector and injector temperatures were 300ºC and 250ºC, respectively. The obtained chromatogram and report of GC analysis for each sample were analyzed to calculate the percentage of main components of volatile oil (British Pharmacopoeia, 1963).

Statistical analysis:

All data were analyzed by SPSS 19.0 Program (2000). Means and standard deviations were determined using descriptive statistics. Statistical analysis was performed using one way analysis of variance (ANOVA) followed by Duncan's multiple range test with $P \leq 0.05$ being considered statistically significant.

RESULTS AND DISCUSSIONS

Yield and chemical composition of parsley varieties

Data in table 1 indicated that yield in flat parsley was higher (6.50 and 7.00 Ton /Fadden) than in curly parsley (4.00 and 4.50 Ton /Fadden) at first and second year. Furthermore, the yield of parsley after dehydration in commercial technique was 11 ton in fresh flat parsley given 1 ton dry, while 9 ton fresh curly given 1 ton dry.

Table 1. Flat and curly parsley Productivity in fresh and after dehydration in 2 years.

Items	Flat (Italian) Parsley		Curly (French) parsley	
	First year 2016	Second Year 2017	First year 2016	Second year 2017
Ton /Fadden/cut	$6.50^{a} \pm 0.60$	$7.00^{a} \pm 1.00$	$4.00^{b} \pm 0.95$	$4.50^{b} \pm 0.50$
Moisture (%)	$90.20^{a} \pm 1.84$	$89.85^{a} \pm 1.71$	$80.13^{b} \pm 1.90$	$78.99^{b} \pm 1.54$
After dehydration	11 ton fresh given 1 ton dry weight		9 ton fresh given 1 ton dry weight	

Means ± SD, means having the same letter within column are not significantly different at p<0.05.Data were mean of three determinations (n=3).

Data in table 2 showed that leaves percentage in curly parsley was higher than flat parsley (79.38 and 42.10%), respectively, whereas the yield of leaves in curly parsley was the highest.

Table 2. Percentage of leaves and stem in fresh flat and curly parsley after dehydration in 2 years.

constituents	Flat (Italian) Parsley		Curly (French) parsley	
	First year 2016	Second year 2017	First year 2016	Second year 2017
Leaves	$42.10^{b} \pm 5.36$	$40.25^{b} \pm 3.98$	$79.38^{a} \pm 7.34$	$81.24^{a} \pm 8.23$
Stems	$47.37^{a} \pm 6.55$	$43.22^{a} \pm 5.68$	$20.63^{b} \pm 2.60$	$21.33^{b} \pm 2.58$

Means ± SD, means having the same letter within column are not significantly different at p<0.05.Data were mean of three determinations (n=3).

Crude protein and oil extract contents in flat and curly parsley ranged from 24.40 to 24.85% and from 6.28 to 6.72% at first and second year (Table 3). While, curly parsley was higher in total hydrolysable carbohydrates and dietary fiber (57.27, 57.70 and 31.55, 32.00%) than in flat parsley (55.56, 55.47 and 30.41 and 30.55%) in the two years, respectively. In contrast, ash and acid insoluble ash were higher contents in flat parsley than in curly parsley. Ayyobi *et al*., (2014) found that increasing oven temperature led to reduction of essential oil yield. Minimum and maximum essential oil were obtained when dill and peppermint were oven dried at 75°C (20.11 ml) and dried in shading (28.44 ml), respectively.

Table 3. Chemical analyses in dried flat and curly parsley (g/100g on dry weight basis).

Components	Flat (Italian) Parsley		Curly (French) parsley	
	First year	Second year	First year	Second year
Crude protein	24.40[a] ± 1.88	24.85[a] ± 1.35	24.59[a] ± 0.90	24.88[a] ± 1.01
Oil extract	6.72[a] ± 0.12	6.28[a] ± 0.23	6.34[a] ± 0.88	6.50[a] ± 1.02
Total hydrolysable carbohydrates	55.56[b] ± 1.78	55.47[b] ± 2.01	57.27 [a]± 3.21	57.70[a] ± 3.04
Dietary fiber	30.41[b] ± 1.23	30.55[b]± 1.45	31.55[a] ± 1.10	32.00[a] ± 0.99
Ash	13.32[a] ± 0.54	13.40[a] ± 0.62	11.80[b] ± 0.63	10.92[b] ± 0.40
Acid insoluble ash	0.82[a] ± 0.11	0.77[a] ± 0.08	0.42[b] ± 0.02	0.45[b] ± 0.04

Means ± SD, means having the same letter within column are not significantly different at $p<0.05$.Data were mean of three determinations (n=3).

Bioactive compounds of dehydrated parsley varieties:

Chlorophyll a, b, carotenoids, β-carotene have higher content in fresh curly parsley than in flat parsley. While, flavonoids and vitamin C were the nearest contents in either flat (294.94 and 47.94 mg/100g) or curly (296.53 and 47.70 mg/100g) parsley, respectively. Furthermore, fresh flat parsley was higher content in polyphenols and volatile oil (88.89 mg/100g and 0.34 %) than in fresh curly parsley (77.91 mg/100g and 0.05 %), respectively. Also, free radical scavenging activity and total antioxidant activity in flat parsley (82.61% and 454.11mg/100g) were higher than in curly parsley (78.86% and 324.89 mg/100g), respectively. In general, microwave technique seems to be the most suitable drying method in terms of preservation of pigments, this result agree with Droštinová *et al.* (2015) who showed higher content of pigments in *Melissa officinalis* when microwave drying procedure was applied compared to the oven dried samples and the sun dried samples.

Data in Table (4 and 5) indicated that gradually decrease contents of chlorophyll a and b, carotenoids, b-carotene, flavonoids, polyphenols, vitamin C and essential oil in commercial techniques (sun, oven and hot air dried) and controlling techniques (oven dried 55°C under vacuum and microwave 400W and 800W in either flat or curly parsley. These results reflected to free radical scavenging activity (FRSC) and total antioxidants activity (TAC). Also, the antioxidant contents and its activity were decrease as follows: microwave 800W/6min. > microwave 400W/12min.> oven under vacuum > sun dried > microwave 800W/24min> oven dryer> hot air dried.

The contents of antioxidants and their activities in controlling techniques were higher than in commercial techniques. While, microwave technique were the best controlling techniques compared to other techniques. This observation is agreed with those reported by Ayyobi *et al.*, (2014); Kouřimská *et al.* (2013); and Priecina and Karlina (2013).

Table 4. Antioxidant contents and its activity in fresh, oven dried and microwave treatments in Flat parsley.

Constituents	Chlo. A	Chlo. B	Carotenoids	β-carotene	Flavonoids	Polyphenols	Vitamin C	Volatile oil *	FRSC**	TAC***
Fresh****	97.87^{h}	18.78^{h}	45.52^{g}	17.37^{h}	296.53^{g}	88.89^{i}	47.70^{b}	0.34^{f}	81.61^{b}	454.11^{i}
Commercial (traditional) Techniques										
Sun dried	210.81^{c}	73.32^{d}	160.0^{c}	74.37^{c}	617.19^{c}	277.69^{c}	96.63^{a}	0.77^{ab}	86.24^{ab}	2492.00^{c}
Oven dried	162.32^{e}	20.78^{g}	98.93^{e}	61.14^{f}	583.75^{e}	173.80^{g}	95.25^{a}	0.39^{e}	82.86^{b}	899.56^{g}
Hot air dried	143.71^{g}	19.91^{g}	75.83^{f}	49.21^{g}	332.94^{f}	127.55^{h}	47.94^{b}	0.10^{f}	82.79^{b}	780.44^{h}
Controlling Techniques										
Oven under vacuum	233.02^{b}	89.92^{c}	183.49^{b}	125.22^{c}	619.30^{c}	291.07^{bc}	96.65^{a}	0.80^{b}	87.37^{ab}	2492.00^{c}
Microwave										
400W 12 min	290.01^{a}	95.07^{b}	202.19^{a}	129.84^{b}	626.73^{b}	301.76^{b}	96.67^{a}	1.27^{a}	89.07^{a}	4906.67^{b}
24 min	168.95^{e}	47.31^{f}	109.89^{d}	65.55^{e}	602.41^{d}	237.15^{e}	95.64^{a}	0.67^{c}	83.56^{b}	1175.56^{f}
36 min	151.76^{f}	22.39^{g}	103.03^{de}	65.08^{e}	592.13^{de}	214.28^{f}	95.25^{a}	0.49^{d}	83.49^{b}	1400.44^{e}
Microwave										
800W 6 min	297.68^{a}	141.90^{a}	207.22^{a}	147.17^{a}	641.53^{a}	342.85^{a}	97.00^{a}	1.35^{a}	89.37^{a}	6634.67^{a}
12 min	204.57^{d}	68.05^{e}	117.25^{d}	71.99^{d}	617.00^{c}	262.39^{d}	96.03^{a}	0.75^{b}	86.01^{ab}	1956.44^{d}
18 min	199.87^{d}	50.54^{f}	111.45^{de}	65.75^{e}	610.16^{cd}	259.20^{d}	95.75^{a}	0.59^{cd}	85.29^{ab}	1424.43^{e}
LSD (5%)	1.02	0.34	4.44	16.51	4.80	2.01	0.11	0.03	0.25	23.38

% **FRSC Free radical scavenging activity ***TAC total antioxidant activity µg ascorbic acid/g * mg/100g fresh weight**

Means ± SD, means having the same letter within column are not significantly different at p<0.05.Data were mean of three determinations (n=3).

Table 5. Antioxidant contents and its activity in fresh, oven dried and microwave treatments in Curly parsley.

Constituents	Chlo. A	Chlo.B	Carotenoids	β-carotene	Flavonoids	Polyphenols	Vitamin C	Volatile oil *	FRSC**	TAC***
Fresh****	125.29^{g}	25.16^{h}	75.73^{g}	33.40^{h}	294.94^{h}	77.91^{j}	47.54^{b}	0.05^{j}	78.86^{d}	324.89^{j}
Commercial (traditional) techniques										
Sun dry	236.94^{c}	65.08^{c}	172.35^{bc}	105.36^{b}	632.95^{c}	264.89^{b}	96.27^{a}	0.57^{d}	85.40^{b}	1152.0^{c}
Oven dryer	165.47^{f}	39.59^{f}	96.93^{f}	39.64^{g}	573.29^{f}	147.59^{h}	95.62^{a}	0.13^{i}	82.61^{c}	704.67^{h}
Hot air dried	127.79^{g}	32.49^{g}	93.51^{f}	38.82^{g}	328.15^{g}	65.53^{i}	47.79^{b}	0.10^{i}	81.71^{c}	670.44^{i}
Controlling techniques										
Oven under vacuum	288.79^{b}	73.95^{b}	176.71^{b}	109.34^{b}	632.85^{c}	265.97^{c}	96.42^{a}	0.62^{c}	84.45^{b}	1311.56^{b}
Microwave 400 W 12 min	297.68^{ab}	84.92^{a}	177.67^{b}	132.73^{a}	644.58^{b}	266.75^{b}	96.49^{a}	0.86^{b}	87.46^{a}	1398.67^{b}
24 min	176.75^{e}	47.05^{e}	121.70^{e}	64.66^{d}	581.47^{e}	224.03^{f}	95.89^{a}	0.37^{f}	82.92^{c}	939.55^{f}
36 min	159.43^{f}	44.42^{e}	118.39^{e}	45.83^{f}	580.66^{e}	206.33^{g}	95.86^{a}	0.21^{h}	82.61^{c}	820.89^{g}
Microwave 800 W 6 min	315.17^{a}	84.41^{a}	194.20^{a}	139.29^{a}	697.74^{a}	284.93^{a}	96.51^{a}	1.25^{a}	88.57^{a}	1785.96^{a}
12 min	234.89^{c}	54.43^{d}	160.70^{c}	75.80^{c}	632.21^{c}	243.51^{d}	96.17^{a}	0.46^{e}	85.37^{b}	989.78^{d}
18 min	198.27^{d}	54.01^{d}	147.92^{d}	72.67^{c}	623.62^{d}	234.32^{e}	96.01^{a}	0.30^{g}	85.02^{b}	975.11^{d}
LSD	2.65	0.99	5.27	7.66	1.46	1.33	0.03	0.08	0.50	11.96

***%   **FRSC Free radical scavenging activity   ***TAC total antioxidant activity µg ascorbic acid/g   ****mg/100g fresh weight**

Means ± SD, means having the same letter within column are not significantly different at p<0.05.Data were mean of three determinations (n=3).

Quantitative and identification of volatile oil composition in two parsley varieties.

The results of the GLC analysis of the volatile oils of flat and curly parsley are shown in Tables (6 and 7). Total identified volatile oil components in flat parsley in different dehydration techniques ranged from 11 to 28 items. The better flat parsley treatments were microwave 800W/6 min, 800W/12 min and 400W/12min then 400W/24 min, while the lowest number of identified items in sun dried flat parsley (11 items). On the other hand, the number of identified components in curly parsley ranged from 13 to 24 items. The best treatments in curly parsley were microwave 400W/24 min (24 items) followed by microwave 800W/12 min and 400W/12 min are the same item numbers (22 items). The percentage of total identified components were higher in two parsley species treated by microwave 800W/6 min (66.99 and 66.77%) and 800W/12 (63.08 and 64.18%) min followed by microwave 400W/12 min (58.70 and 56.50%) and 400W/24 min (47.37 and 48.79%) than other treatments either in flat or curly. The main constituents in fresh flat and curly parsley leaves volatile oil were Myristicin (12.65 and 15.05%), 2-Allyl-4-methyl phenol (10.77 and 10.15%) and Isolongipholene (9.45 and 8.59%), respectively.

Results showed that α-Pinene was present only in two treatments (oven dryer under vacuum and sun dried) in the flat and curly parsley, in addition to microwave 800W/6 min treatment in curly parsley only (table 7). Also, β-Pinene was present in fresh flat and curly parsley, sun dried and oven dryer under vacuum treatments only [(2.95 and 0.80), (1.92 and 0.55) and (0.43 and 0.30%)], respectively in addition to microwave 800W/6 min treatment in curly parsley only, it recorded (4.25%).

Table 6. Volatile oil composition in fresh and treated leaves of flat parsley (%).

Peak No.	Components	Retention time (min)	1	2	3	4	5	6	7
1	α-pinene	7.40	------	------	-----	-----	------	1.00	4.38
2	β-pinene	7.71	1.92	----	-----	----	----	0.43	2.95
3	limonene	8.80	4.12	5.06	0.44	3.56	0.30	6.68	12.64
4	2-Allyl-4-methyl phenol	9.615	10.77	1.72	3.33	3.14	1.03	-----	-----
5	Myrtenal	9.80	1.93	4.97	1.35	3.72	----	-------	------
6	Pulegone	10.10	3.40	3.05	1.46	3.05	----	--------	------
7	γ-terpineol	10.826	3.62	0.87	4.88	3.57	2.12	------	------
8	β-citronellol	13.154	3.46	0.32	0.19	0.15	2.22	1.39	0.46
9	Methyl cinnamate	13.72	0.28	0.83	0.16	0.46	0.42	4.24	-----
10	2,5Dimethyl-p-cymene	13.80	1.68	----	-----	-----	-----	-----	-----
11	Myristicin	13.922	12.65	0.13	0.31	0.17	0.27	1.11	----
12	2,5Dimethoxy-p-cymene	14.076	2.44	1.02	0.44	1.05	0.45	------	-----
13	α-Himachalene	14.17	3.09	0.99	0.18	0.5	0.23	0.81	0.36
14	β-Elemene	14.287	0.11	0.54	0.47	0.65	0.25	5.79	-----
15	β-Caryophyllene	14.42	4.62	----	-----	-----	0.61	-----	-----
16	α-Copaene	14.49	3.51	0.48	0.19	0.14	2.85	3.27	-----
17	α-Elemene	14.55	0.67	4.75	6.45	3.19	7.57	6.92	12.76
18	β-Sesquiphellandrene	14.75	0.21	-------	-----	-----	----	-------	------
19	α-Ylangene	14.82	2.87	4.14	3.47	4.41	0.38	0.79	0.45
20	δ-Cadinene	14.983	2.57	3.51	2.11	2.96	1.27	0.35	-----
21	Isoledene	15.67	0.42	---	----	----	----	-----	------
22	2-Methyl-4-[2,6,6-trimethylcyclohex-1-en-1-ol]	15.77	0.19	4.74	4.98	4.37	1.7	0.81	------
23	Cedren-13ol,8	16.10	3.51	2.33	5.15	2.16	1.62	0.27	0.36
24	Isolongipholene	16.363	9.45	9.28	10.12	8.57	4.38	3.25	2.42
25	Apiol	16.63	9.5	----	----	-----	----	-----	-----
26	Isocalamendiol	16.683	5.89	3.18	4.32	2.47	1.83	1.40	0.63
27	10,13-Octadecadilynoic acid, methyl ester	16.788	2.52	2.84	1.53	1.99	1.05	------	-----
28	Phytol	17.273	0.12	11.94	10.00	8.28	15.69	16.24	2.18
29	Phytol, acetate	17.92	0.41	0.30	1.55	0.14	1.13	3.38	-----
Total Identified components No.			**28**	**22**	**22**	**22**	**21**	**18**	**11**
Identified components (%)			**95.93**	**66.99**	**63.08**	**58.70**	**47.37**	**58.13**	**39.59**
Unidentified components (%)			**4.07**	**33.01**	**36.92**	**41.3**	**52.63**	**41.87**	**60.41**

1-Fresh 2- 800W/6min 3- 800W/12min 4- 400W/12min
5- 400W/24min 6- Oven dryer under vacuum 7- Sun dried

Four volatile oil components only appeared in fresh flat and curly parsley (2,5-Dimethyl-ρ-cymene, β-Sesquiphellandrene, Isolendene and Apiol (1.68, 4.13; 0.21, 0.28; 0.42, 0.36 and 9.50, 2.26%, respectively). Also, β-Caryophyllene component was present only in fresh flat parsley and flat leaves treated by microwave 400W/24 min (4.62 and 0.71%, respectively), but β-Caryophyllene component was present only in fresh curly parsley (6.43%). Therefore, the dehydration treatments either commercial or controlling may affect the type's volatile oil components.

This result is in line with Díaz-Maroto *et al*., (2002); Mangkoltriluk *et al*., (2005) and Petropoulos *et al*., (2010) who stated that when fresh herbs, including parsley, are dried the aromatic and nutritional constituents may be altered or reduced depending on the drying conditions.

Limonene contents was the highest in flat parsley sun dried (12.64%) followed by oven dryer under vacuum (6.68%) then microwave 800W/6min (5.06%) and 400W/12min (3.56%) compared to fresh flat parsley (4.12%). Also, limonene content was higher content in flat than curly parsley.

Flat parsley dehydrated by microwave 800W/ 12min and 400W/12min treatments has higher content in 2-Allyl-4-methyl phenol (3.33 and 3.14%, respectively) than either microwave 800W/6 min or microwave 400W/24 min treatments (1.72 and 1.03%, respectively). In parallel for curly parsley, the same component contents in microwave treatment 400W/12 min, 400W/24 min and microwave treatment 800/12 min were (3.99, 3.43 and 1.34%), respectively compared to fresh curly parsley (10.15%).

As for microwave technique at 800W/6min and 400W/12min, they appeared with high content of Myrtenal in flat parsley (4.97 and 3.72%), respectively, also the content of Pulegone in flat or curly parsley was the same results (3.05%). In addition, Myrtenal and Pulegone content in curly parsley recorded (3.58, 3.05; 3.39, 3.03 and 1.54 and 2.57%) for microwave 400W/24 min, microwave 800W/ 12 min and 400W/12 min, respectively.

Flat and curly parsley revealed (4.88, 0.52; 3.57, 1.74 and 2.12, 3.91%) from γ-Terpineol content when treated by microwave 800W/12min, 400W/12min and 400/24min, respectively compared to fresh flat and curly parsley (3.62 and 4.07%).While, the two types of parsley have no γ-Terpineol when treated by oven dryer under vacuum and sun dried.

The results found that, microwave 400/24 min was the best treatment followed by oven dryer under vacuum in β-Citronellol contents (2.22 and 1.39%), respectively compared to fresh flat parsley (3.46%). Furthermore, curly parsley was rich in β-Citronellol contents when treated by sun dried and microwave 800W/12 min treatments (2.71 and 1.36), respectively.

Concerning to Methyl cinnamate, it has higher contents in flat parsley treated by oven under vacuum (4.24%) than other treatments, while the same components was the highest in curly parsley treated by microwave 800W/12 min and 400W/12 min (0.61 and 0.62%, respectively).

Table 7. Volatile oil composition in fresh and treated leaves of curly parsley (%).

Peak No.	components	Retention time (min)	1	2	3	4	5	6	7
1	α-pinene	7.40	------	3.13	------	------	------	0.28	0.38
2	β-pinene	7.71	4.25	0.55	---	-----	-----	0.30	0.80
3	limonene	8.80	3.89	5.36	3.53	2.07	2.05	0.72	2.07
4	2-Allyl-4-methyl phenol	9.615	10.15	-----	1.34	3.99	3.43	-----	-----
5	Myrtenal	9.80	2.75	-----	3.39	1.54	3.58	------	-----
6	Pulegone	10.10	2.64	-----	3.03	2.57	3.05	------	------
7	γ-terpineol	10.826	4.07	-----	0.52	1.74	3.91	------	------
8	β-citronellol	13.154	3.63	0.49	1.36	0.11	0.53	0.27	2.71
9	Methyl cinnamate	13.72	0.28	-----	0.61	0.62	0.26	0.28	0.40
10	2,5Dimethyl-p-cymene	13.8	4.13	-----	----	----	-----	-----	-------
11	Myristicin	13.922	15.05	-----	0.16	0.27	0.15	0.29	0.37
12	2,5Dimethoxy-p-cymene	14.076	0.15	------	1.26	0.87	0.53	0.27	---------
13	α-Himachalene	14.17	2.29	0.94	0.60	0.36	0.40	-----	0.65
14	β-Elemene	14.287	0.43	-----	0.56	0.54	0.17	0.28	1.51
15	β-Caryophyllene	14.42	6.43	-----	-----	----	-----	-----	-----
16	α-Copaene	14.49	0.21	-----	0.92	0.24	0.55	3.33	6.7
17	α-Elemene	14.55	0.43	47.78	5.11	5.04	2.83	7.1	4.03
18	β-Sesquiphellandrene	14.75	0.28	------	-----	----	------	-----	-------
19	α-Ylangene	14.82	2.8	0.51	4.39	4.27	3.13	1.18	3.22
20	δ-Cadinene	14.983	3.37	0.64	3.90	3.23	2.17	0.26	1.12
21	Isoledene	15.67	0.36	-----	----	----	-----	-----	-------
22	2-Methyl-4-[2,6,6-trimethylcyclohex-1-en-1-ol]	15.77	0.32	------	6.00	4.93	4.45	-----	---------
23	Cedren-13ol,8	16.10	3.53	0.55	2.52	1.02	2.61	0.63	1.55
24	Isolongipholene	16.363	8.59	2.71	8.8	7.39	9.22	9.9	1.47
25	Apiol	16.63	2.26	------	----	----	-----	-----	-----
26	Isocalamendiol	16.683	4.08	0.77	3.11	3.46	0.79	2.60	0.54
27	10,13-Octadecadilynoic acid, methyl ester	16.788	2.36		2.92	3.21	0.67	------	-----
28	Phytol	17.273	0.33	3.34	9.58	8.21	3.73	9.76	7.76
29	Phytol, acetate	17.92	0.42	-----	0.57	0.82	0.58	0.80	0.59
Total Identified Components No.			**28**	**13**	**22**	**22**	**24**	**17**	**17**
Identified components (%)			**89.48**	**66.77**	**64.18**	**56.5**	**48.79**	**38.25**	**35.87**
Unidentified components (%)			**10.52**	**33.23**	**35.82**	**43.5**	**51.21**	**61.75**	**64.13**

1-Fresh 2- microwave 800W/6min 3- microwave 800W/12min
4-micorwave 400W/12min 5- microwave W400/24 min 6- Oven dryer under vacuum 7- Sun dry

Meanwhile, 2,5 Dimethoxy-ρ-cymene was present only in fresh flat parsley (1.78%), while this component was higher content in curly parsley treated by microwave 400W/12 min and 400W/24 min (0.87 and 0.53%), respectively.

While, Myristin and β-Elemene content were the highest in flat parsley dried in oven dryer under vacuum (4.24, 1.11 and 5.79%), respectively, also the content of Myristin and β-Elemene were higher in sun dried curly parsley (0.37 and 1.51%) than other treatments. As for α- Himachalene, it has higher content either in flat or in curly in fresh or microwave 800W/6 min treatments (3.09, 2.29 and 0.99, 0.94), respectively.

The data revealed that, the highest content of α-Copaene was in flat parsley treated by microwave 400W/24 min followed by oven dryer under vacuum (2.85 and 3.27%), respectively compared to fresh flat parsley (3.51%). Also, α-Copaene was the highest content in curly parsley treated by oven dryer under vacuum (3.33%).

Concerning α-Elemene content, it was found to have lower contents in fresh flat parsley (0.67%) than in other different treatments, while it has the highest contents when treated by sun dried (12.76%) followed by microwave 400W/24 min, oven dryer under vacuum and microwave 800W/12 min (7.57, 6.92 and 645%), respectively. In the contrast, it was the highest content in curly parsley treated by microwave 800W/6 min (47.78% from 66.77% total identified components). The changes in the aromatic profile of the dried product vary with the genotype drying (Petropoulos *et al.*, 2010).

As for α-Ylangene, it was the highest in flat parsley treated by microwave 400W/12 min (4.41%) followed by microwave 800W/6 min (4.14%) then microwave 800W/12 min treatment (3.47%) compared to fresh flat parsley (2.87%). While, δ-Cadinene ranged from 1.2 to 3.51% in microwave treatments compared to fresh flat parsley (2.57%). Also, flat parsley had 2-Methyl-4-[2,6,6-trimethylcyclohexa-1-en-ol] contained (4.74, 4.98 and 4.37%) treated by microwave treatments(800W/6, 800W/12 and 400W/12 min), respectively.

Also, α-Ylangene, δ-Cadinene and 2-Methyl-4-[2,6,6-trimethylcyclohexa-1-en-ol] were higher in curly parsley treated by microwave 800W/12 min, 400W/12 min and 400W/24 min (4.39, 3.90, 6.00; 4.27, 3.23, 4.93 and 3.13, 2.17 and 4.45%), respectively compared to other treatments.

Cedren-13-ol,8 was the highest in flat parsley treated by microwave 800W/12min (5.15%) followed by 800W/6 min (2.33 %), 400W/12 min (2.16%), respectively and 400W/24 min (1.62%) treatment. Also, Cedren-13-ol,8 was higher in curly parsley treated by microwave 400W/24 min and 800W/12 min (2.61 and 2.52%), respectively than other treatments.

Furthermore, Isolongipholene and Isocalamendiol contents were the highest contents in flat parsley treated by 800W/12 min (10.12 and 4.32%), respectively followed by 800W/6 min and 400W/12min (9.28, 3.18 and 8.57, 2.42%), respectively, in the contrast the lowest Isolongipholene and Isocalamendiol contents in flat parsley treated by oven dryer under vacuum then sun dry treatments (3.25, 1.40 and 2.42, 0.63%), respectively. Also, Isolongipholene recorded (9.90, 9.22, 8.80, and 7.39 %) in curly parsley treated by oven under vacuum, microwave 400W/24 min, microwave 800W/6 min and 400W/12 min, respectively. Meanwhile, Isocalamendiol component was higher in curly parsley treated by microwave 400W/12 min, microwave 800W/12 min and oven dryer under vacuum (3.46, 3.11 and 2.60), respectively than other treatments.

10,13-Octadecadilynoic acid methyl ester component was higher content in flat parsley treated by microwave 800W/6 min and 400W/12 min (2.84 and 1.99%), respectively than which treated by microwave 800W/12 min and 400W/24 min (1.55 and 1.05%), respectively compared to fresh flat parsley.

According to phytol component, it was the highest content in flat and curly parsley treated by oven dryer under vacuum (16.24 and 9.76%), respectively followed by flat parsley treated by microwave 800W/6 min, 800W/12 min (1.94 and 10.00%), respectively then which treated by microwave 400W/12 min and 400W/24 min (8.28 and 15.69%), respectively also, phytol in curly parsley treated by microwave 800W/12min, 400W/12 min and sun dried (9.58, 8.21 and 7.76%), respectively were higher than other treatments. While, sun dry flat parsley leaves had the lowest phytol content (2.18%).

Furthermore, phytol acetate content was the highest content in flat parsley treated by oven dryer under vacuum (3.38%) followed by microwave 800W/12 min treatment, then microwave 400W/24 min (1.55 and 1.13%), respectively. While, the same components was higher in curly parsley leaves treated by microwave 400W/12 min and oven dryer under vacuum (0.82 and 0.80%), respectively than other treatments.

Ten volatile oil components were absent in flat parsley, while 13 components were absent in curly parsley treated by oven dryer under vacuum and sun dry. Although, flat parsley sun dried has high contents in α-Pinene (4.38%), β-Pinene (2.95%), Limonine (12.64%) and α-Elemene (12.76%). Curly (var. *crispum*) had plentiful in Myristicin, but contain much less essential oil than (var. *latifolium*) (Mangkoltriluk *et al.,* 2005).

CONCLUSION

Total polyphenol contents, flavonoids and volatile oil components were achieved using different microwave treatment and oven dryer under vacuum on either flat or curly parsley. Also, controlling drying processes has positive effect on antiradical activity and may be considered as useful tool in improving nutritional and phytochemical properties of flat and curly parsley. Based on the aforementioned results, it could be concluded that parsley has effected dehydration is still a valuable commodity on the basis of its essential oil content and composition. This is important because although parsley is frequently dehydrated and sold as a dry condiment, the aromatic constituents of the dry product may be seriously reduced and altered.

RECOMMENDATION

From the obviously results it could be recommended that the best dehydration techniques were microwave 800W/6min., microwave 400W/12min. and oven under vacuum more than other traditional dehydration techniques (sun dried, oven dryer or hot air dried).

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تأثير تقنيات التجفيف التقليدية و الميكروويف علي جودة البقدونس المسطح و المجعد المنزرع في مصر

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أجريت هذه الدراسة خلال موسم 2016–2017 فى مزرعة خاصة بطريق القاهرة الأسكندريه الصحراوى–مصر بهدف البحث فى تأثير التجفيف الشمسى و بالأفران و الهواء الساخن والأفران تحت تفريغ والتجفيف بمعاملات الميكروويف على بعض المركبات الحيوية و نشاطها فى صنفين من البقدونس المسطح (*Petrosilinum crispum* var. *neapolitanum, flate*) و المجعد المنزرع فى مصر (*Petroselinum crispum* var. *Crispum*, Curly). و أوضحت النتائج أن إنتاجية المحصول و الرماد و الرماد غير الذائب في الأحماض هى الأعلى فى البقدونس المسطح عن المجعد بينما الصنف المجعد تميز بزيادة الكربوهيدرات الكلية الذائبة و الألياف الغذائية. و قد أوضحت النتائج المتحصل عليها أن المحتوي من المركبات الحيوية النشطة (كلوروفيل أ و كلوروفيل ب وكاروتينات و بيتا كاروتين و فلافونيدات و بولى فينول و فيتامين ج و النسبة المئوية للزيت الطيار تقل تدريجيا بإستخدام التقنيات التجارية (التجفبف الشمسى – الفرن – الهواء الساخن) و التقنيات المتحكم فيها [الأفران تحت تفريغ (55°م) و الميكروويف (400–800 وات)] فى كلٍ من البقدونس المسطح و المجعد. وهذه النتائج تعكس أهمية نشاط الشقوق الحرة و نشاط مضادات الأكسدة الكلية. أظهرت النتائج المتحصل عليها أن الزيوت الطيارة التى تم تعريفها قى البقدونس المسطح تتراوح من 11–28 مركب و فى البقدونس المجعد من 13–28 مركب. النسبة المئوية للمركبات التى تم تعريفها فى البقدونس المسطح و المجعد كانت أعلى بإستخدام الميكروويف 800 وات لمدة 6 دقائق (66.77–66.99%) و الميكرويف 800 وات لمدة 12 دقيقة (63.08–64.18%) ثم الميكروويف 400 وات لمدة 12 دقيقة (56.50–58.70%) و الميكرويف 400 وات لمدة 24 دقيقة (47.37–48.79%) على التوالى بالنسبة لإستخدام الطرق الاخرى. فقد وجد أن المركبات الأساسية للزيت فى البقدونس المجعد هى (ميرستسين بنسبة (15.05%) ،2–آليل 4–ميثايل فينول (10.15%)، آيزولونجفولين (8.59%) و بيتاكاريوفلين (6.43%). أما الزيت الطيارة للبقدونس المسطح فكانت أهم المكونات (ميرستسين بنسبة 12.65%) و (2 – آليل 4 – ميثايل فينول 10.77%) و أبيول (9.5%) وآيزولونجفولين (9.45%). من النتائج الواضحة يمكننا أن نوصى بأن أفضل الطرق المستخدمة للتجفيف هى إستخدام الميكروويف 800 وات لمدة 6 دقائق > الميكروويف 400 وات لمدة 12 دقيقة> الأفران تحت تفريغ > التجفبف الشمسى > الميكروويف 800وات لمدة 12 دقيقة > الفرن > التجفيف بالهواء الساخن. من خلال تلك الدراسة ، يمكن إستخدام الميكروويف كتقنية جديدة غير تقليدية و إقتصادية لتجفف البقدونس المسطح و المجعد بدلاً من تقنيات التجفيف التقليدية في مصر وبالتالي تحسين مواصفات جودة البقدونس المجفف مما يزيد من فرصة تصديرة.