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# Research Article
# Effect of Drying Methods on the Chemical Composition and Biological Activity of Parsley Herb Essential Oil

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## Abstract

**Background and Objective:** This study was used to identify the effect of different drying methods on chemical composition and biochemical activities of parsley herb. The main objective was to study the benefits and harms of drying process for aromatic herbs that some factories perform to increase the yield of essential oil from each distillation batch. **Materials and Methods:** Fresh parsley herb was dried by one of two methods: an electric oven or a solar drying unit. The essential oil separated from dried herb was inspected for the changes that occurred in its chemical composition using by GC/MS technique. Moreover, the antioxidant and antimicrobial activities of parsley oil were determined using DPPH assay and the agar-well diffusion method, respectively. **Results:** The results indicated that, solar drying (sd) of parsley herb led to slight increment of oil yield, while oven drying (od) slightly decreased oil yield. The concentration of p-Mentha-1,3,8-triene (the major) was changed by decrease or increase after sd or od, respectively. The oil of sd had the highest antioxidants activity compared to that of od. The antimicrobial activity of parsley oil of od was significantly higher than that of sd. **Conclusion:** It is better to separate parsley oil by distillation from fresh herb without drying, which causes undesirable changes in the structure and properties of the oil.

Key words: Parsley, steam distillation, antioxidant activity, antimicrobial activity, agar-well diffusion method, aromatic plants

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

## INTRODUCTION

Herbs and spices play a pivotal role in the day-to-day life of mankind as important flavoring agents in foods, beverages and pharmaceuticals, also as ingredients in perfumes and cosmetics. The manufacturers of foods, beverages, cosmetics and pharmaceuticals are responding to the growing wave of consumer resistance and legislative limitations set for products containing chemical additives. Spices as sources of natural colors and flavors present welcome opportunities in the international market. The nutritional, antioxidant, antimicrobial and medicinal properties of spices also have widespread applications[1].

Parsley is a very rich source of vitamins C, E, b-carotene, thiamin and organic minerals[2,3]. Because of its high water content (78-82%, w/w), parsley is ordinarily dried for market, in order to inhibit micro-organism growth and prevent degradation due to the biochemical reactions. Also, drying brings about substantial reduction in weight and volume, minimizing packaging, storage and transportation costs[4].

Drying is the most common and also the simplest method of preserving fresh plant materials. This process greatly extends the life of the product by the removal of water, which decreases the rate of chemical and enzymatic reactions or even inhibits them. The drying step can cause a change in appearance, taste, color and consistency, as well as reduce the quantity of essential oils, poly phenols, pigments and vitamins. These changes can be significantly reduced by using suitable drying techniques, depending on the material. The choice of the technique should be based on knowledge of the biological, physical and chemical characteristics of the raw material[5].

The chemical constitutes of parsley essential oil were Myristicin 44.88%, limonene 11.72%, α-Pinene (%), 11.35%, Cosmene 9.86%, β-Pinene (%), 5.38%, 1-Butyin-3-one 3.49%, β-Phellandrene (%), 2.00%, Elemicin (%), 1.96%, α-terpinolene 1.71%, carvyl acetate 0.62% and 1.3.8-p-Menthatriene 0.36%[6].

Parsley leaves contain a number of different antioxidants among which flavones (apigenin and luteolin), xanthophylls (lutein and zeaxanthin) as well as some components of its essential oil, such as apiol and myristicin can be distinguished[7].

Using essential oil of parsley as antimicrobial additives in food may be useful and alternative medical therapy for micro-organisms which may resist customary treatment. This will suggestion a great help in facing the appearance spread of bacteria[8].

The aim of this study was to identify the benefits and harms of drying aromatic herbs before distilling their oil in order to increase the output of the oil in each batch. Therefore, the effect of two different drying methods on the content and chemical components of parsley leaves essential oil, beside the antimicrobial and antioxidant activities of the oil were investigated.

## MATERIALS AND METHODS

The study was carried out at Food Science Department, Faculty of Agriculture, Cairo University, Quality Control Lab. and Microbiology Lab., Egypt from March, 2017-June, 2019.

### Materials

**Plant material:** Fifty kilogram of fresh parsley herb (*Petroselinum crispum*) was purchased from Medicinal and Aromatic Plants Research Department, Horticulture Research Institute, Horticultural Research Center, Giza, Egypt.

**Microbial cultures:** The following bacterial strains were obtained from ATCC, American Type Culture Collection Rockville, Maryland, USA: *Listeria monocytogenes* 7644, *Staphylococcus aureus* 2593, *Salmonella typhimurium* 140228, *Bacillus cereus* 33018, *Escherichia coli* 3521. Moreover, the yeast; *Candida albicans* 10231 and the mold; *Aspergillus niger* 326 were obtained from NRRL, Northern Regional Research Laboratories, Peoria, IL, USA.

**Media:** Plate Count Agar (PCA) medium and Brain Heart Infusion (BHI) medium were purchased from Oxoid Company, Hampshire, England.

### Methods

**Drying methods of parsley herb:** Parsley herbs were divided into two batches, which immediately dried by using one of the following drying methods:

- The first batch 25 kg was washed well and dried in a solar dryer at 39±2.8°C and humidity of 41±3.2% for 4 days
- The second batch 25 kg of parsley herb was washed well then dried in a drying oven at 45°C for 2 days.

**Isolation of essential oil:** Essential oil of dried parsley herb was separated by steam distillation. One hundred gram of dried parsley leaves were extracted by steam-distilled for 3 h using a Clevenger type apparatus. The collected oil was dried over anhydrous sodium sulfate. The oil was stored in a sealed glass bottle at -18°C until subsequent tests. Steam distillation was carried out in triplicates and the mean values of the obtained result were recorded by the method of Vokk *et al.*[9]. Oil yield was calculated according to Guenther[10]:

$$\text{Oil yield (\%, v/w)} = \frac{\text{Volume of extracted oil (mL)}}{\text{Weight plant material (g)}} \times 100$$

## Analysis of essential oil

**Gas Chromatography-Mass Spectrometry (GC-MS) Analysis:** The essential oil of dried parsley herb was analyzed using the GC/MS (Gas Chromatography/Mass Spectrometry) technique. The GC-MS system (Agilent technologies) was equipped with gas chromatograph (7890B) and mass spectrometer detector (5977A) at Central Laboratories Network, National Research Centre, Cairo, Egypt. Samples were diluted with hexane (1:19, v/v). A GC apparatus equipped with HP-5MS column (30 m × 0.25 mm internal diameter and 0.25 µm film thickness) was used. Analysis was carried out using helium as a carrier gas at flow rate of 1.0 mL $min^{-1}$ at a split ratio of 1:30, injection volume of 1 µL and the following temperature program: 40°C for 1 min; rising at 4°C/min to 150°C and held for 6 min, rising at 4°C/min to 210°C and held for 1 min. The injector and detector were held at 280 and 220°C, respectively. Mass spectra were obtained by Electron Ionization (EI) at 70 eV using a spectral range of m/z 50-550 and solvent delay 3 min. Identification of different constituents was determined by comparing the spectrum fragmentation pattern with those stored in Wiley and NIST Mass Spectral Library data.

**Antioxidant activity of essential oil:** The antioxidant potential of parsley essential oil was determined by using DPPH method, 2,2-diphenyl-1-picrylhydrazyl (DPPH). The odd electron in the DPPH free radical gives a strong absorption maximum at 517 nm and is purple in color as described by Choi *et al.*[11]. The DPPH analysis was measured as mentioned by Brand-Williams *et al.*[12]. Each sample was prepared by adding 25, 50, 100, 150 µL of the essential oil in a test tube followed by addition 2.8 mL of 0.4 g $L^{-1}$ DPPH solution (0.02±0.0001 g DPPH in 50 mL methanol as a solvent). The solution was vigorously shaken for 10 sec and subsequently preserved in darkness for 30 min at room temperature. Afterword the absorbance was recorded at 517 nm against methanol in a UV-vis Spectrophotometer UNICO model (UV 2000, USA). The initial absorbance of the DPPH solution was 0.966. The BHT solution was considered the reference in concentrations of 25, 50, 100, 150 and 200 ppm. The radical scavenging activity was expressed as the percentage quenching of the DPPH radical, calculated according to Hinneburg *et al.*[13]:

$$\text{Inhibition of DPPH (\%)} = \frac{A_{blank} - A_{sample}}{A_{blank}} \times 100$$

where, A is absorbance.

The $IC_{50}$ (50% of inhibition) was calculated from a graph plotting percentage inhibition against each volatile oil concentration. Butylated Hydroxy Toluene (BHT) was used as a positive control.

## Antimicrobial activity

**Renewal of microbial cultures:** Pathogens bacteria were maintained on Brain Heart Infusion (BHI, Oxoid) medium at 37°C and transferred monthly.

**Preparation of essential oil emulsion:** Thirty percent (w/w) of essential oils emulsion was prepared using Tween-80 as emulsifying agent. The resultant emulsion was sterilized by filtration through 0.45 mm hydrophilic membrane filter and stored at 4°C in a well closed sterile container[14].

**Determination of antimicrobial activity by the agar-well diffusion method:** The antibacterial activity was measured with the agar-well diffusion method. Fifty milliliter portions of the melted sterile PCA, maintained at 50°C were inoculated with 100 mL of properly diluted inoculums and mixed well. The inoculated medium was poured into sterile Petri dish (15 cm) and allowed to solidify. Wells, each 6 mm were cut through the agar using sterile cork borer and the agar removed leaving empty wells which was filled with the original oil (100% w/w) or the oil emulsion (30% w/w). Maintain the plates at room temperature for about 2 h and then incubate at 37°C for 24 and 48 h in case of bacteria and yeast, respectively. The resultant inhibition zones were measured (mm) and the average values were taken[14].

**Statistical analysis:** Data were statistically analyzed by analysis of variance[15], ANOVA. Data were presented as means of 3 experiments±SD. All microbial data were transformed to logarithm before analysis.

## RESULTS

**Essential oil content in fresh and dried plant material of parsley:** Data in Table 1 showed the content of essential oil of fresh and dried parsley herb. This data indicated that a

Table 1: Essential oil content in fresh and dried plant material of parsley

| Materials | Time required for drying (days) | Volatile oil yield on dry weight basis (%) |
|---|---|---|
| Fresh herb | - | 0.26±0.11 |
| Herb dried by oven at 45°C | 2-3 | 0.24±0.02 |
| Herb dried at 39±2.8°C by solar drying | 4-5 | 0.29±0.01 |

Table 2: Effect of drying methods on chemical constituents of parsley essential oil

| Compounds | Area (%) | | |
|---|---|---|---|
| | OF fresh | OSD solar | OOD oven |
| α-Thujene | 0.15 | - | - |
| Camphene | 0.11 | - | - |
| Sabinene | 0.60 | - | - |
| Benzene, 1-methyl-3-(1-methylethenyl)- | 0.41 | - | - |
| d-Limonene | 10.35 | - | - |
| γ–Terpinene | 0.44 | - | - |
| p-Mentha-1,5,8-triene | 12.69 | - | - |
| α-Pinene (-)- | 12.59 | 0.94 | 1.59 |
| Cyclohexanone, 5-methyl-2-(1-methylethyl)-, cis- | 0.06 | - | - |
| Carveol | 0.05 | - | - |
| Benzenemethanol, α ,α,4-trimethyl- | 0.06 | - | - |
| (1R)-(-)-Myrtenal | 0.14 | - | - |
| Citronellol | 0.21 | - | - |
| (-)-β-Pinene | 8.59 | 0.64 | 1.24 |
| 3,9-Epoxy-p-mentha-1,8(10)-diene | 0.08 | - | - |
| 6-Octen-1-ol, 3,7-dimethyl-, formate | 0.15 | - | - |
| β-Myrcene | 5.46 | 4.12 | 2.94 |
| α-Phellandrene | 0.61 | 0.32 | 0.55 |
| 4-Terpinenyl acetate | 0.03 | - | - |
| α-Bourbonene | 0.03 | - | - |
| Caryophyllene | 0.09 | - | - |
| γ-Elemene | 0.09 | - | - |
| α-Terpinolene | 0.05 | 0.61 | 1.66 |
| Germacrene D | 0.07 | - | - |
| β-Selinene | 0.04 | - | - |
| Benzene, 1-methyl-4-(1-methylethenyl) | 4.64 | 1.72 | 4.49 |
| Benzene, 1,2,3-trimethoxy-5-(2-propenyl) | 0.24 | - | - |
| γ-eudesmol | 0.14 | - | - |
| β-Phellandrene | - | 5.67 | 7.49 |
| Apiol | 5.03 | - | - |
| 2-Pentadecanone, 6,10,14-trimethyl | 0.14 | - | - |
| Unknown | 0.34 | - | - |
| Unknown | 0.81 | - | - |
| Spiro[(tricyclo[6.2.2.0(2,7)]dodeca-5,9-diene)-4,1'-cyclobutane]-12,2'-dione, 3,3,5,8,11,11-hexamethyl | 0.79 | - | - |
| m-Camphorene | 0.45 | - | - |
| Spiro[(tricyclo[6.2.2.0(2,7)]dodeca-5,9-diene)-4,1'-cyclobutane]-11,2'-dione, 1,3,3,5,12,12-hexamethyl | 1.55 | - | - |
| 1,3,8-p-Menthatriene | 19.95 | 12.63 | 21.67 |
| Unknown | 1.75 | - | - |
| Benzene, 1,2,3,5-tetramethyl | 5.87 | - | - |
| Unknown | 0.45 | - | - |
| 1,8,15,22-Tricosatetrayne | 0.24 | - | - |
| Unknown | 0.96 | - | - |
| α,α,4-trimethyl benzyl carbanilate | - | - | 0.51 |
| Estragole | - | 1.67 | - |
| 2,4,6-Trimethyl benzyl alcohol | - | 0.80 | - |
| Myristicin | 3.51 | 36.32 | 50.86 |
| Methyl 4,6-tetradecadiynoate | - | 1.08 | 1.08 |
| Eugenol | - | 7.29 | - |
| α-Copaene | - | 0.38 | - |
| (-)-β-Bourbonene | - | 0.63 | - |
| α-ylangene | - | 1.30 | - |
| cis-β-Farnesene | - | 3.15 | 1.12 |
| β-Cubebene | - | 4.43 | 0.90 |
| Phenol, 2-methoxy-4-(2-propenyl)-, acetate | - | 1.66 | - |
| γ-Gurjunene | - | 2.25 | 1.32 |
| Acetic acid (1,2,3,4,5,6,7,8-octahydro-3,8,8-trimethylnaphth-2-yl)methyl ester | - | 0.58 | - |
| Neophytadiene | - | 9.13 | 2.58 |
| 2-Hexadecen-1-ol, 3,7,11,15-tetramethyl | - | 2.69 | - |
| Number of identified compounds | 37 | 23.00 | 15 |
| Number of unknown compounds | 5 | - | - |
| Total non-oxygenated compounds (%) | 87.76 | 84.23 | 98.41 |
| Total oxygenated compounds (%) | 7.94 | 15.77 | 1.59 |
| Total unknown compounds | 4.31 | - | - |

OSD: Oil extracted from parsley dried at 39±2.8°C by solar drying, OOD: Oil extracted from parsley dried at 45°C by oven drying, OF: Oil extracted from fresh parsley

Table 3: Effect of drying methods on the antioxidant activity of parsley herb essential oil (DPPH radical-scavenging activity %)

| Samples | $IC_{50}$ (μg $mL^{-1}$) |
|---|---|
| Oil of parsley dried at 45°C (oven drying) | 104.47 |
| Oil of parsley dried at 39±2.8°C (solar drying) | 98.30 |
| BHT | 92.98 |

$IC_{50}$ is the concentration (μ $mL^{-1}$) for a 50% inhibition, BHT was used as a control sample

Table 4: Effect of drying methods on antimicrobial activity of parsley leaves oil (by agar well diffusion method)

| | Treatments | | | |
|---|---|---|---|---|
| Pathogens bacteria | T1 | T2 | T3 | T4 |
| *Listeria monocytogenes* ATCC 7644 | $14.33\pm0.58^{Db}$ | $12.33\pm0.58^{Bc}$ | $17.67\pm0.58^{Ba}$ | $11.67\pm0.58^{BCc}$ |
| *Staphylococcus aureus* ATCC 2593 | $12.33\pm0.58^{Eb}$ | $7.67\pm0.58^{Cc}$ | $14.67\pm0.58^{Ca}$ | $12.67\pm0.58^{Ab}$ |
| *Salmonella typhimurium* ATCC 140228 | $8.33\pm0.58^{Gb}$ | 0.00 | $10.67\pm0.58^{Da}$ | 0.00 |
| *Bacillus cereus* ATCC 33018 | $16.33\pm0.58^{Cab}$ | $15.33\pm0.58^{Ab}$ | $17.33\pm0.58^{Ba}$ | $12.33\pm0.58^{ABc}$ |
| *Escherichia coli* ATCC 35218 | $9.67\pm0.58^{Fa}$ | 0.00 | $8.67\pm0.58^{Ea}$ | 0.00 |
| *Aspergillus niger* NRRL 326 | $20.67\pm0.58^{Ba}$ | $12.33\pm0.58^{Bb}$ | $20.33\pm0.58^{Aa}$ | $11.33\pm0.58^{Cb}$ |
| *Candida albicans* ATCC 10231 | $22.33\pm0.58^{Aa}$ | 0.00 | $20.67\pm0.58^{Ab}$ | 0.00 |

Any two means within the same column have different capital letters and any two means within the same row have different small letters are significantly different, at $p<0.05$, SD: Standard deviation of group means, T1: Original oil from solar drying, T2: Oil 30% from solar drying, T3: Original oil from oven drying, T4: Oil 30% from oven drying. The diameter of the antibiotic well (6 mm) is included. No inhibition (<6 mm diameter)

considerable amount of parsley essential oil was lost during drying processes especially with higher temperatures (dried by oven at 45°C).

**Volatile components of parsley essential oil:** Results in Table 2 showed the chemical components of fresh and dried parsley essential oils (obtained with solar or oven drying of fresh herb) as identified by GC-MS.

Thirty seven components were identified in fresh parsley oil. The main compound of the oil of fresh herb was 1,3,8-p-menthatriene. Same data indicated considerable changes in parsley oil after solar and oven drying of its herb. The major identified compounds in parsley oil which dried by solar drying were Myristicin, 1,3,8-p-Menthatriene and Neophytadiene, while Myristicin, 1,3,8-p-Menthatriene and β-Phellandrene were the major identified compounds in parsley oil which dried by oven drying.

**Antioxidant activity of parsley oil:** The results presented in Table 3 demonstrated the DPPH (%) scavenging activity of parsley herb essential oil. Oil isolated from parsley dried by solar drying had the highest antioxidants activity compared to the oil isolated from parsley dried by oven drying, while the antioxidants activity of BHT recorded the lowest activity.

**Antimicrobial activity of parsley oil:** The results in Table 4 indicated that the original oil extracted from parsley herb which dried by oven drying have the higher significantly inhibition zone against *Listeria monocytogenes* followed by *Bacillus cereus* when compared with original oil which extracted from parsley herb dried by solar drying. On the other hand, original oil from solar drying have high significantly inhibition zone against *Candida albicans*, but not significantly for *Aspergillus niger.* The results also indicated that the original oil (T3) was more effective against the standard bacterial strains of *Listeria monocytogenes*, *Staphylococcus aureus, Salmonella typhimurium and Bacillus cereus* when compared with T1. Zones of growth inhibition (mm, Mean±SD) showing antibacterial activity of parsley oil extracted from dried leaf by solar and oven drying including the disk diameter 6.0 mm.

## DISCUSSION

Data in Table 1 showed that the content of essential oil of fresh parsley herb was 0.26±0.11%, on dry weight basis, while unlike expected, it decreased by 0.02% after oven drying of parsley herb at 45°C. On the other hand, oil content of the solar dried parsley herb at 39±2.8°C increased by 0.03%. These data indicated that a considerable amount of parsley essential oil was lost during drying especially with higher temperatures, consequently oven drying showed higher loss of oil while the increase of oil content after solar drying represent the difference between lose by heat and the apparent increase due to water loss. Hinneburg et al.[13] and Vokk et al.[9] reported that the essential oil yield of dried aromatic plants grown in winter time was 0.24% of dry weight for parsley 0.56% for dill, 0.29 and 0.65% for plants, grown in summer, respectively.

On the other hand, Kandil *et al.*[16] mentioned the oil content of dried parsley was strongly affected by drying methods. Although air drying (at room temperature) is one of the most time-consuming drying methods it produced dried parsley materials contain higher amounts of essential oil (0.43%) when compared to other drying methods. Also, oven drying (40°C) exhibited high levels of essential oils in parsley (0.40%) and solar tunnel (35%).

Farouk *et al.*[17] reported that the hydrodistillation of the fresh green parts of parsley (*P. crispum*) provided a yellow liquid ranging from 0.28±0.08% of the Egyptian essential oil to 0.21±0.05% of the Madinah essential oil.

The data indicated that the content of the main component of fresh parsley herb namely, 1,3,8-p-menthatriene showed a decreasing percentage of 36.69% after solar drying while the percentage was 8.62% after oven drying. Moreover, 2 of the major components the oil of fresh herb namely, p-Mentha-1,5,8-triene and d-Limonene were completely disappeared after solar and sun drying. The decreasing percentages of the third major component α-Pinene were 92.53 and 87.37% for oils of solar and oven drying samples, respectively. After solar and oven drying of parsley herb 3 of the minor components of the oil of fresh herb were completely disappeared.

Generally, essential oils are highly rich in lipophilic compounds that could dissolve in the bio-membrane of micro-organisms and interact with membrane lipids and proteins, which lead to cell disruption as reported by Khalil *et al.*[14]. Moreover, Vokk *et al.*[9] reported that 34 essential oil components were identified in parsley leaves essential oil (≥96%) with the major constituents Myristicin (30.7-42.7%), B-phellandrene (21.8-35.9%).

These findings are confirmed with those obtained with Mulugeta *et al.*[18] who reported that the essential oil of parsley (*Petroselinum crispum* (mill) Fuss) obtained by hydro-distillation was characterized by its physicochemical properties, phytochemical screening and Gas Chromatography-Mass Spectrometry (GC-MS) profiles. The major components of the essential oil were 1,3,8-para-menthatriene, 1-methyl, 4-isopropenyl benzene and 4, 7-dimethoxy-5-prop-2-enyl-1,3-benzodioxole.

Moreover, Nemeš *et al.*[19] reported that the main components of the essential oils obtained from parsley leaves were 1,3,8-menthatriene (22.8-50.9%), myristicin (12.8-36.8%), β-phellandrene (14.1-29.0%) and β-myrcene (1.4-12.7%).

The data also showed that oil isolated from parsley leaf dried by solar drying have high content from oxygenated compounds (15.77%), compared with oil isolated from parsley leaf dried by oven which have low content (1.59%). This means that oven drying at 45°C had a bad effect on chemical composition of the oil (9 components found in the oil of the herb dried by solar were disappeared). These results are in agreement with those obtained by Díaz-Maroto *et al.*[20] and Nitz *et al.*[21] who reported that oven drying at 45°C and freeze-drying caused the greatest losses in the volatiles. Moreover, Aziz *et al.*[22] found that plants sown in December and harvested in April showed a higher concentration of Apiol compared with plants sown in September and harvested in either December or January. Thus, seasonal variation had a profound effect on chemistry of parsley leaf oil.

Also Mangkoltriluk *et al.*[23] reported that geographical location plays a key factor in parsley leaf oil composition. In general, although, the major constituent in parsley essential oil was 1,3,8-p-menthatriene followed by β-phellandrene, myristicin, Apiol and myrcene detected by Simon *et al.*[24] and Zhang *et al.*[25] did not found 1,3,8-p-menthatriene and myrcene in crude parsley oil from china. This may be due to the plant genetic and development and environmental condition.

The results indicated that the difference in the antioxidant activity of the essential oil of parsley is related to the drying method and consequently the temperature, which affects the active oil components affecting the antioxidant activity. Marín *et al.*[26] reported that parsley (*Petroselium crispum*) obtained from organic grown plants cultivated in Spain presented the best antioxidant profile, given its highest percentage of inhibition of DPPH radical (64.28%). Regarding $IC_{50}$ (g $L^{-1}$) (EO concentration to inhibit 50% of the radicals) for Egyptian organic fennel, the order was as follows: BHT (0.53)>parsley EO (12.91)>lavender EO (31.30)>fennel EO (45.49)

Hinneburg *et al.*[13] reported that $IC_{50}$ values of parsley oil was 12.0±0.10 mg $mL^{-1}$ and BHT showed 50% inhibition at 0.21±0.01 mg $mL^{-1}$. Meanwhile, Teixeira *et al.*[27] reported that $IC_{50}$ values of parsley oil was 7.23±0.16 mg $mL^{-1}$ and BHT was 0.02±0.00 mg $mL^{-1}$.

The $IC_{50}$ value of the crude Parsley Oil (PO) dissolved in methanol was about 5.12 mg $mL^{-1}$, though this antioxidant activity was much weaker than that of 0.01 mg $mL^{-1}$ of BHT and α-tocopherol[25]. The model system of scavenging DPPH free radicals is a simple method to evaluate the antioxidative activity of antioxidants. The PO exhibited the $IC_{50}$ of DPPH free radical scavenging activity at the concentration of 80.21 mg $mL^{-1}$. This value is much weaker than those of BHT and α-tocopherol at 0.58 and 0.10 mg $mL^{-1}$, respectively[25].

The results showed that there were significant differences in favor of the effect of parsley oil obtained from dried herb in the oven on oil produced from dried herb powered by solar energy (against *Listeria monocytogenes, Staphylococcus aureus, Salmonella typhimurium* and *Bacillus cereus*) and the opposite is true, as the superiority was significant in favor of oil obtained from sun-dried herb (against *Escherichia coli, Aspergillus niger* and *Candida albicans*). Our findings are compatible with García-Díez *et al.*[6], who found that parsley herb oil made inhibition zone just against *Listeria monocytogenes* by the Disk Diffusion Assay (DDA).

Karimi *et al.*[8] tested the antimicrobial effect of parsley and observed its effect against *S. aureus* and *E. coli*, which were nearly equal to the effect of antibiotics currently used against these micro-organisms without any side effects. Also, Seyyednejad *et al.*[28] reported that parsley extract had antimicrobial effect at 0.1-0.4 g $mL^{-1}$ against Gram-negative *E. coli* and Gram-positive bacteria, in addition, it has a better effect against *Salmonella typhimurium* when 0.4 g $mL^{-1}$ extract was used.

Elsharawy[29] reported that parsley extract was more effective against *E. coli* then dill and have the same inhibition (%) against *salmonella* spp. In parsley burger treated, parsley recorded lower inhibition (%) than dill on *Shigella* spp. Meanwhile, Busatta *et al.*[30], Dostalova *et al.*[31] and Farah *et al.*[32] reported that parsley contains antimicrobial compounds effects against *Salmonella, Shigella, S. aureus* and *E. coli* such as oleic, linoleic, palmitic and other fatty acid.

Wahba *et al.*[33] clarified the antibacterial of parsley extract effect against *S. aureus* while, Farah *et al.*[32] indicated that parsley oil has more antibacterial effect against *S. aureus* which reached to 18% while dill green extract against *S. aureus* was 9% lower. On the contrary, Seyyednejad *et al.*[28] reported that parsley extract had not any antimicrobial effect at different concentration (0.1 to 0.4 g $mL^{-1}$) against *S. aureus*.

Generally, phenolic compounds in herbs extracts has decrease bacterial activity through its effect on bacterial enzymes specially energy producing enzymes which may leading to protein denaturation[34].

Also, Tajkarimi *et al.*[35] reported that dill and parsley grown during the summer season contained essential oils with significantly higher antimicrobial properties. The most active constituents are aromatic phenolic compounds with a wide spectrum of antimicrobial activity.

Khalil *et al.*[14] reported that agar-well diffusion method revealed that the maximum inhibition zones were obtained with cumin, coriander and caraway oils against the standard bacterial strains *Escherichia coli* and *Bordetella bronchiseptica* followed by *Staphylococcus aureus*. On the other hand, the remaining essential oils as celery, dill, parsley, anise and fennel showed much smaller inhibition zones or no inhibition at all as red and yellow carrot. All tested oils had no inhibitory effect on *Candida albicans.*

From the foregoing it becomes clear the importance of using fresh parsley herb oil or oil obtained from solar energy dried herb, in preserving foods such as processed meat due to its strong properties as a broad-spectrum antioxidant and antimicrobial. Additional studies are also needed to identify the effect of the active oil ingredients.

## CONCLUSION

Our study showed the presence of biological and chemical activities of the essential oil of parsley herb and the efficiency of oil in this field decreases as the herb is dried at high temperatures. So, it is preferable to separate the oil directly from the fresh herb, with the recommendation to conduct additional studies to specify the role of the active ingredients in the oil.

## SIGNIFICANCE STATEMENT

This study discovers that the process of drying parsley herb with the aim of increasing the amount of oil obtained from distillation in each batch, which some factories were conducting is a process that is useless and even harms the properties and quality of the oil. Thus, it is preferable to get parsley herb oil by distillation directly from the fresh herb.

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