Science Letters ISSN 2345-5463

Research article
2020 | Volume 8 | Issue 1 | Pages 36-42

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# Impact of Drying Methods on the Functional Properties of Peppermint (*Mentha piperita* L.) Leaves

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ARTICLE INFO

**Received**
January 01, 2020
**Revised**
March 08, 2020
**Accepted**
March 10, 2020
**Published**
April 10, 2020

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**Keywords**
Hot-air oven drying
Microwave oven drying
Total polyphenol content
Total flavonoid content
Antioxidant potential

**How to Cite**
Hayat K. Impact of drying methods on the functional properties of peppermint (*Mentha piperita* L.) leaves. Sci Lett 2020; 8(1):36-42

## Abstract

The microbes and enzymes responsible for the degradation of food materials are only active in the presence of suitable water content. Therefore, drying is a commonly used method to prolong the shelf life of food materials, especially the herbs and spices. In this study, the effect of hot-air oven drying and microwave oven drying was evaluated on the weight loss, total polyphenol content (TPC), total flavonoid content (TFC) and antioxidant activity of peppermint leaves. The maximum weight loss (87.1%) was found in peppermint leaves dried at 80°C for 180 min in the hot-air oven followed by the sample dried in the microwave oven at 900W for 3 min. Microwave oven drying at 900W yielded the highest TPC [406.7 mg GAE/100 g fresh weight (FW)] in peppermint leaves. While the lowest TPC (183.5 mg GAE/100 g FW) was found in the leaf sample dried in the hot-air oven at 80°C and it was even lower than that of the fresh leaf sample (229 mg GAE/100 g FW). Microwave oven drying at 900W showed the highest TFC (247 mg CE/100 g FW) of peppermint leaves followed by the hot-air oven drying at 50°C (181 mg CE/100 g FW). The least DPPH scavenging capacity (34%) was exhibited by the samples dried in the hot-air oven at 80°C followed by the fresh leaf sample (39.9%). While the highest DPPH scavenging capacity (86.8%) was obtained for the peppermint leaves dried in the microwave oven at 900W. In the present study, microwave drying yielded better results in a shorter time. Thus, the microwave drying could be a promising technique to enhance the shelf life and functional properties of peppermint leaves.

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## Introduction

In recent years, natural antioxidants have received an increased interest by human beings [1]. This interest is reflected by the surge in the consumption of plant extracts for medicinal purposes and health effects. Many herbs and spices commonly used to flavor dishes are good sources of bioactive components with excellent antioxidant capacity. Medicinal plants, herbs, and their preparations are being extensively used by mankind all over the world [2, 3]. Peppermint (*Mentha piperita* L.) is one of the most common and fragrant herbs [4, 5]. It can be utilized as a medicinal herb and helps in fighting colds, flu, poor digestion, flatulence, motion sickness, food poisoning, and throat and sinus diseases. Its leaves are used for spices, tea infusions and flavorings [6, 7]. Mint leaves are part of various dishes such as vegetable curry, mint chutney, salad dressings, soups, desserts, juices, and confectionery products [8, 9].

Food drying is the most commonly employed technique for food preservation as well as for the preparation of certain foods. Drying not only alters the water activity of the product, but also affects other physical, chemical, and biological characteristics such as the enzymatic activity of food, microbial decay, hardness, aroma, and taste [7, 8]. Due to the high water content (78-85%, w/w), peppermint is generally dried in order to prevent the growth of microorganisms and avoid decomposition due to biochemical reactions [10]. Drying also significantly reduces weight and volume, decreasing the cost of packaging, storage and transportation [11, 12]. The drying parameters must be optimized to minimize losses and preserve the product.

Alternatives to the conventional drying procedures such as sun drying are the conventional oven drying and also the use of microwaves, a faster drying / heating technique, which can prevent / minimize some of the thermal damages of antioxidant components and improve the antioxidant activity of the plant materials [3, 13, 14]. However, there is inadequate information on the variations in total phenols and antioxidant potential of peppermint dried by these methods. Therefore, the aim of this study was to evaluate the impact of the hot-air oven and microwave oven drying methods on peppermint leaves. We used two treatment levels for both dying methods and evaluated their impact on the total polyphenol content, total flavonoid content, and the antioxidant potential of peppermint leaves.

## Materials and Methods

### Raw materials

Peppermint was procured from a local market in Riyadh, Saudi Arabia. The leaves were selected uniformly. Peppermint leaves for drying experiments were processed instantly while the fresh sample was stored in plastic bags at 4$^o$C until analysis.

### Drying methods

Drying of the peppermint samples was performed in a household microwave oven (MWL311, Kenwood, China; 900 W and 2450 MHz) and a hot-air conventional oven (ED56, Binder, Tuttlingen, Germany) in our laboratory. Samples (70 g) were separately dried at 450W and 900W in a microwave oven (MWO) and at 50$^o$C and 80$^o$C in hot-air oven (HAO), respectively. According to the microwave power and oven temperature used, the samples were termed as MWO 450, MWO 900, and HAO 50, HAO 80, respectively. The drying was performed till the constant weight was attained for each sample, which was monitored by weighing the samples at specific intervals. The dried samples were kept in air-tight containers till further analysis. Drying for each sample was done in triplicate.

### Weight loss and moisture content

The weight of each sample at the start and the end of the drying procedure was recorded and weight loss was calculated. The moisture level of the dried samples was measured by an AOAC method 934.06 using an oven at 105$^o$C till the constant weight [15].

### Extraction of leaf samples

Two grams of crushed samples were extracted with 20 ml of 70% ethanol (v/v) in an ultrasonic device (Wisdom, WUC-D10H, 665 W, 60 Hz, Daihan Scientific Co., Ltd., Wonju-si, Gangwon-do, Korea) for 60 min at 23$^o$C. The mixture was then centrifuged at 3000×g for 10 min at room temperature and filtered using Whatman filter paper number 2. The obtained extracts were stored at 4$^o$C and used for analyses.

### Total polyphenol content (TPC)

The method of Hayat et al. [16] was adopted to determine the polyphenol content of peppermint leaves. The extract (25 µl) was mixed with distilled water (1500 µl) and then the mixture was added with an undiluted Folin Ciocalteau reagent (125 µl). After 1 min, 20% sodium carbonate (375 µl) and distilled water (475 µl) were added, respectively. After incubating the mixture at room temperature for 30 min, the absorbance was measured at 760 nm. Total polyphenol content was measured as gallic acid equivalent per hundred-gram fresh weight (mg GAE/ 100 g FW).

### Total flavonoid content (TFC)

The total flavonoid content was assessed according to the method of Hayat et al. [16]. Peppermint leaf extract (250 µl) was mixed with distilled water (1000 µl) and then sodium nitrite (75 µl) and aluminum chloride (75 µl) were added to the mixture, respectively. After standing the mixture for 5 min at 23ºC, sodium hydroxide (1 M, 500 µl) and distilled water (600 µl) were added and the absorbance was measured at 510 nm. Total flavonoid content was measured as catechin equivalent per hundred-gram of fresh weight (mg CE/100 g FW).

### DPPH scavenging

The DPPH free radical scavenging potential of the peppermint leaf extract was recorded according to the method of Noreen et al. [17]. The mixture of extract (130 µl) and DPPH solution (0.1 mM, 2000 µl) was left in the dark for 30 min at 23ºC and then absorbance was recorded at 517 nm. Control was prepared without extract and the scavenging percentage was determined as:

DPPH scavenging % = absorbance of control – absorbance of sample/absorbance of control × 100

### Reducing power

The method of Hayat et al. [14] was employed to measure the reducing power of peppermint leaves. Briefly, 500 µl of the extract was mixed with 1250 µl of phosphate buffer saline (0.2 M, pH 6.6) and 1250 µl of potassium ferricyanide. After incubating the mixture at 50ºC for 20 min, 1250 µl of trichloroacetic acid were added and then centrifugation was performed at 3000×g for 10 min at 23ºC. An aliquot was taken from the supernatant (1250 µl), to which distilled water (1250 µl) and ferric chloride (250 µl) were added, respectively, and the absorbance was noted at 700 nm against a blank (without extract).

### Statistical analysis

Each experiment was executed in triplicate. The results were expressed as means ± SD (standard deviation). The one-way analysis of variance (ANOVA) was applied for the grouping and significant differences among the parameters were determined using Duncan's multiple range test by SAS (Version 9.2, 2000-2008; SAS Institute Inc., Cary, NC, USA).

## Results and Discussion

### Impact of drying methods on weight loss and moisture content of peppermint leaves

Table 1 shows the processing time, weight loss, and the moisture level of fresh and dried peppermint samples. All the samples were dried until the constant weight was achieved and the drying time for each treatment was recorded. It was noticed that the drying time of peppermint leaves was reduced substantially in the microwave oven as compared to the hot-air oven. For instance, the hot-air oven dried the sample in 720 min at 50ºC, while the microwave oven dried the sample to a constant weight in only 3 min at 900W. Therdthai and Zhou [18] found similar results that microwave vacuum drying was much faster for drying the peppermint as compared to the hot-air drying. In another study, microwave processing took less time to dry the coriander leaves as compared to the conventional oven drying [19]. Microwave energy reduces the drying time by providing uniform heating with high thermal conductivity, which offers energy saving and cost reduction of the process [7].

**Table 1** Drying time, weight loss and moisture content of peppermint leaves treated with different drying methods.

| Sample | Drying time (min) | Weight loss (%) | Moisture content (%) |
|---|---|---|---|
| Fresh | 0 | $0^{d}$ | $89.94 \pm 0.39^{a}$ |
| HAO 50 | 720 | $86.66 \pm 0.12^{bc}$ | $3.72 \pm 0.20^{b}$ |
| HAO 80 | 180 | $87.12 \pm 0.07^{a}$ | $3.24 \pm 0.11^{c}$ |
| MWO 450 | 10 | $86.37 \pm 0.29^{c}$ | $4.03 \pm 0.14^{b}$ |
| MWO 900 | 3 | $86.85 \pm 0.19^{ab}$ | $3.62 \pm 0.15^{bc}$ |

The different superscripts in a column denote that means significantly differ from each other ($P<0.05$).
HCO = hot-air oven; MWO = microwave oven

The polyphenol-oxidase causes the enzymatic oxidation of the polyphenolic compounds in the presence of water leading to their degradation, while the drying process protects the bioactive compounds by eliminating the water from the sample [19]. The maximum weight loss (87.1%) was shown by the peppermint leaves sample dried at 80ºC for 180 min in the hot-air conventional oven, followed by the sample dried in the microwave oven at 900W for 3 min. While the least weight loss (86.4%) was exhibited by the sample dried in the microwave oven at 450W for 10 min. The highest moisture content of 89.9% was recorded in the fresh peppermint leaves while the lowest moisture content (3.2%) was found in the sample dried in the hot-air conventional oven at 80$^{o}$C for 180 min.

**Impact of drying methods on total polyphenol content of peppermint leaves**

The TPC of peppermint leaves as influenced by drying techniques are shown in Fig. 1. The drying methods showed a significant impact ($P$<0.05) on the TPC of peppermint leaves. Microwave oven drying at 900W yielded the highest TPC (406.7 mg GAE/100 g FW) of the sample as compared to the hot-air oven drying. While concerning the hot-air oven drying, the highest TPC (334.6 mg GAE/100 g FW) was recorded for the sample dried at 50$^{o}$C but it was significantly lower ($P$<0.05) than that obtained by drying the sample at 900W in the microwave oven. Hihat et al. [19] reported that the highest TPC was obtained for the coriander leaves dried by microwave heating than conventional oven heating, and among them, the mid-range microwave power (500W) yielded the best results. Inchuen et al. [20] dried the Thai red curry pastes into powder by microwave drying at 180, 360 and 540W, and by hot-air drying at 60, 70 and 80$^{o}$C. It was found that all the microwave dried red curry powders exhibited higher TPC than those dried by the hot-air method. This effect was explained by the fact that microwave intense heating caused the increase of vapor pressure and temperature inside the plant tissue causing the disruption of the cell wall of the plant, resulting in more extraction of phenolics. The lowest TPC (183.5 mg GAE/100 g FW) was found in the samples dried by hot-air oven at 80$^{o}$C and it was even lower than that of the fresh sample (229 mg GAE/100 g FW). These findings revealed a harmony with the study of Hihat et al. [19] who reported a higher TPC (26.64 mg GAE/g) of coriander leaves dried at 60$^{o}$C than those (11.5 m GAE/g) dried at 100$^{o}$C using the conventional oven. Vega-Gálvez et al. [21] also reported similar effects for the total polyphenol content of hot-air dried red pepper (*Capsicum annum* L). They found the highest TPC for the sample dried at 60$^{o}$C, which was then decreased after heating at higher temperatures (70 and 80$^{o}$C). This could also be explained by the phenomenon that higher temperature may result in the thermal degradation of the polyphenolic compounds [3, 22].

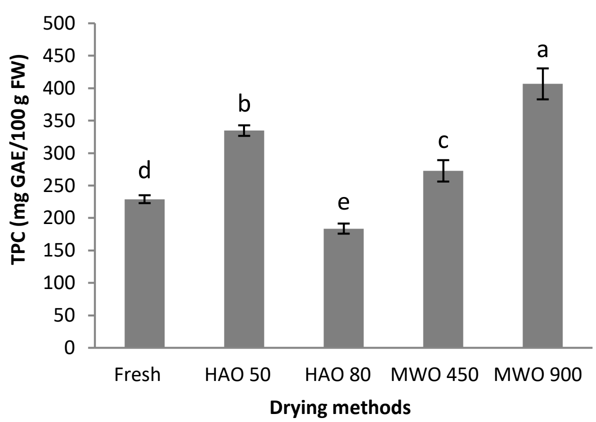


**Fig. 1** Impact of drying methods on total polyphenol content (TPC) of peppermint leaves. HAO 50: hot-air oven at 50$^{o}$C; HAO 80: hot-air oven at 80$^{o}$C; MWO 450: microwave oven at 450W; MWO 900: microwave oven at 900W.

**Impact of drying methods on total flavonoid content of peppermint leaves**

Fig. 2 depicts the impact of drying procedures on the TFC of peppermint leaves. The drying methods showed almost a similar effect on the TFC as was on the TPC of the peppermint leaves. Microwave oven drying at 900W showed the highest TFC (247 mg CE/100 g FW) of peppermint leaves, followed by the hot-air oven drying at 50$^{o}$C (181 mg CE/100 g FW). Interestingly, except for that dried at 80$^{o}$C in the hot-air oven, the TFC of all other dried samples were significantly higher ($P$<0.05) than that of fresh leaf sample. These findings are similar to the outcomes of a previous study, which reported that the TPC, TFC and the antioxidant potential of the fresh peppermint were lower than the samples dried by vacuum-oven, and the higher values were obtained for the samples dried at 50 and 70$^{o}$C [5]. Most of the phenolic compounds exist in the conjugated bound form in the plant matrix and microwave energy potentiates the liberation of these compounds [13, 14, 23]. Al-Juhaimi et al. [24] reported similar results stating that the contents of most of the flavonoid compounds of apricot kernels were enhanced by microwave roasting. Ghafoor et al. [25] described a decrease in the contents of phenolic constituents of poppy seed on heating, but still, the microwaving process retained the higher contents as compared to the conventional oven heating of poppy seeds. A unique phenomenon for the microwave catalysis was proposed by Bren et al. [26] describing that due to an increase in the rotational rate of the polar molecule, the rotational temperature is increased as compared to the translational temperature causing a decrease in the

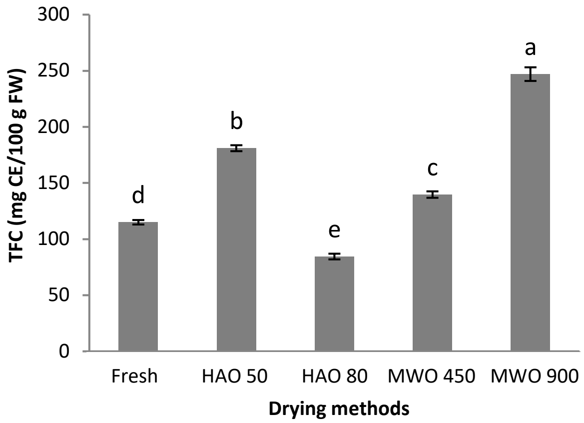


**Fig. 2** Impact of drying methods on total flavonoid content (TFC) of peppermint leaves. HAO 50: hot-air oven at 50ºC; HAO 80: hot-air oven at 80ºC; MWO 450: microwave oven at 450W; MWO 900: microwave oven at 900W.

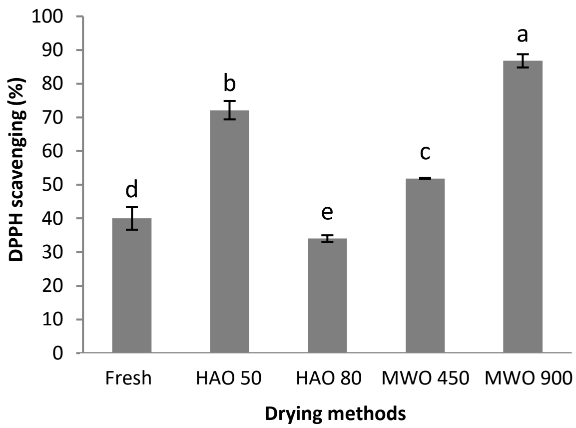


**Fig. 3** Impact of drying methods on 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging potential of peppermint leaves. HAO 50: hot-air oven at 50ºC; HAO 80: hot-air oven at 80ºC; MWO 450: microwave oven at 450W; MWO 900: microwave oven at 900W.

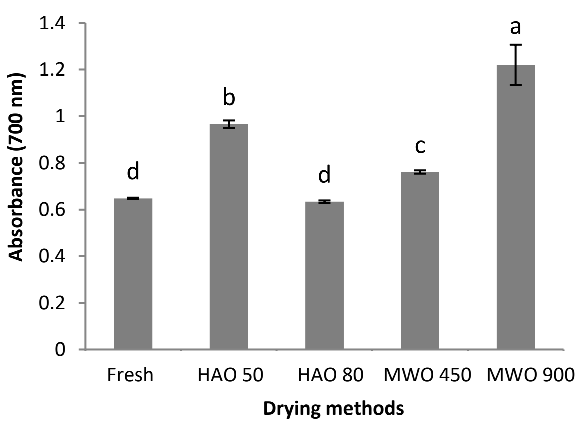


**Fig. 4** Impact of drying methods on reducing power of peppermint leaves. HAO 50: hot-air oven at 50ºC; HAO 80: hot-air oven at 80ºC; MWO 450: microwave oven at 450W; MWO 900: microwave oven at 900W.

activation energy, which in turn creates a catalytic effect. The peppermint leaves dried in the hot-air oven at 50ºC exhibited the higher TFC as compared to that of the sample treated at 80ºC. These results are coherent with the findings of Hihat et al. [19] who reported the highest and lowest TFC for the coriander samples dried in an oven at 60ºC and 100ºC, respectively. The TFC of the peppermint leaves dried at 900W was significantly higher ($P$<0.05) than that of the sample dried at 450W. Hihat et al. [19] also stated that a higher microwave power of 300W-500W exhibited the higher TFC of coriander leaves as compared to those dehydrated at a lower microwave power of 100W. Similarly, another study reported a higher TFC for the samples dried at higher microwave output power (560W–700W) as compared to those dried at lower output power (140W–430W) [27]. The microwave oven at 450W took longer time to dry the peppermint leaves as compared to the drying at 900W. Consequently, it showed lower TFC, which can be explained due to the evaporative loss of some dielectric species [14]. Similar results were found in some of our previous studies where the contents of flavonoid compounds were reduced when the samples were exposed for a longer time to the microwave irradiation [3, 13, 14].

## Impact of drying methods on the antioxidant activity of peppermint leaves

The effect of drying techniques on the antioxidant activity of peppermint leaves as assessed by 2,2-diphenyl-1-picrylhydrazyl (DPPH) and reducing power is given in Fig. 3 and Fig. 4, respectively. DPPH scavenging and reducing powers of all the samples were recorded at their concentration of 100 mg/ml. The least DPPH scavenging capacity (34%) was exhibited by the sample dried in the hot-air oven at 80ºC followed by the undried fresh sample (39.9%). While, the highest DPPH scavenging capacity (86.8%) was obtained for the peppermint leaves dried in the microwave oven at 900W among all the treatments, and it was followed by (72.1%) the sample dried at 50ºC in hot-air oven. A similar tendency for the antioxidant potential of the samples was found when tested by reducing power assay. The reducing power of the fresh peppermint leaves and of those dried at 80ºC was statistically similar, while other samples exhibited reducing power in the following order, MWO 450<HAO 50<MWO 900. These results are in agreement with the TPC and TFC of the samples explaining that the antioxidant activity was at least in a part due to the

total phenols and total flavonoids of the samples. In a study, coriander leaves were dried in a conventional oven and microwave oven at different temperatures and output powers, respectively. It was found that the sample dried at 60°C showed the highest DPPH scavenging followed by that dried at 40°C, while the higher temperature (100°C) lead to a lower antioxidant activity [19]. The same study reported that the higher DPPH inhibition was obtained for the samples dried at 300W and 500W microwave powers than of that dried at 100W in a microwave oven. The results of the present study are also in accord with the findings of Hamrouni-Sellami et al. [28] who described that a temperature of 65°C for the drying of sage plants in a conventional oven led to the highest radical scavenging activity while for microwave oven, the highest antioxidant activity was obtained for the sample dried at 800W. But our results are contrary to another study describing that drying of red peppers at the higher temperatures (80 and 90°C) led to higher antioxidant activity compared to those at lower temperatures (50, 60 and 70°C) [21]. This divergence can be due to the plant material used.

### Conclusions

In this study, the peppermint leaves were dried by conventional hot-air oven and microwave oven at different temperatures and microwave output powers, respectively. Both drying methods significantly impacted the total polyphenols, total flavonoids and antioxidant activity of peppermint leaves. The TPC, TFC and antioxidant activity of the dried samples were significantly increased as compared to the fresh samples. Overall, microwave drying yielded better results in a shorter time compared to the hot-air oven drying. The microwave drying could be a promising technology for the drying of peppermint leaves to be used as a spice, herbal tea or other food applications. The exact mechanism of the improvement of the functional properties of peppermint by drying could be explored in future research.

### Conflict of Interest

The author declares no conflict of interest for this study.

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