Chemical Composition and Antibacterial and Antioxidant Properties of Essential Oils of Zataria multiflora, Artemisia dracunculus and Mentha piperita

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ABSTRACT

Background and objectives: Utilization of essential oils instead of chemical preservatives has received significant attention in recent years. The present study aims to evaluate chemical composition and antibacterial and antioxidant properties of essential oils of Zataria multiflora, Artemisia dracunculus and Mentha piperita.

Methods: Chemical profile of the essential oils was analyzed by gas chromatography/mass spectrometry. The microwell dilution and agar disk diffusion methods were used to evaluate the antibacterial properties of the essential oils. Total phenolic content, β-carotene-linoleic acid bleaching test and 2,2-diphenyl-1-picrylhydrazyl (DPPH) assays were carried out to determine the antioxidant properties.

Results: Menthol (39.18%) and mentone (21.64%) were the main components of the essential oil of M. piperita, while estragol (34.75%) and limonene (15.72%) were the major components of the essential oil of A. dracunculus. The main components of the essential oil of Z. multiflora were carvacrol (36.81%) and thymol (33.04%). The essential oils of M. piperita and Z. multiflora showed greater antimicrobial effects. Moreover, Z. multiflora showed the greatest antioxidant activity among the essential oils. The total phenolic content of Z. multiflora was 228.14±0.45 mg gallic acid equivalent/g.

Conclusion: Given their favorable antioxidant and antimicrobial properties, the essential oils of Z. multiflora, A. dracunculus and M. piperita can be used as natural food preservatives.

Keywords: Zataria multiflora, Artemisia dracunculus, Mentha piperita, antibacterial effect, antioxidant effect.
INTRODUCTION

Foodborne or food spoilage microorganisms can cause illness in consumers and significantly reduce the shelf life of foods. *Staphylococcus aureus* can rapidly grow in foods, and is known as the most common foodborne microorganism (1). *Listeria monocytogenes* is another important foodborne bacterium, which can survive in extreme conditions, such as low temperature, high salinity and acidity (2). *Bacillus cereus* is commonly found in the environment and has the ability to form spores and grow under cold conditions. Moreover, inadequate cooking of foods contaminated with these microorganisms can lead to food poisoning (3). Consumption of *Escherichia coli*-contaminated food can cause asymptomatic gastrointestinal disease or more serious complications, which might lead to death if not treated (4). Despite the global advances in food safety, salmonellosis is still one of the most important public health issues. *Salmonella*, the main causative agent of this disease, especially serovar *typhimurium*, is resistant to multiple drugs, which has made this infection difficult to treat (5). Due to the harmful effects of synthetic additives on human health, special interest has been given to characterization of plant essential oils, which are important components of foods and beverages (6). One of the main benefits of using essential oils in food products is their favorable antibacterial activity against a wide range of microorganisms (6, 7). The inhibitory effects of essential oils against the growth of many gram-negative or gram-positive microorganisms and fungal species have been reported in several studies (7-9). Essential oils rich in phenolic compounds and other phytochemicals exhibit significant antioxidant and free radicals scavenging activities, and therefore can be used to extend shelf life of foods (10). Peppermint (*Mentha piperita*) is an important medicinal plant that grows in many countries. Certain parts of this plant, such as leaves, are used as herbal tea or spice for their known flavor and fragrance, while its extract/essential oil is used in cosmetic, pharmaceutical, and food industries (11). Peppermint is a hybrid of water mint (*M. aquatica* L.) and spearmint (*M. spicata* L.). Certain aroma compounds found in *Artemisia dracunculus* (Tarragon), such as monoterpenes and sesquiterpenes also have medicinal effects (10). *Zataria multiflora*, from the family *Lamiaceae*, is another important medicinal plant that grows wild in Iran, Pakistan, and Afghanistan (12). *Z. multiflora* has pain-relieving, immune-stimulating, antinociceptive, antibacterial, antifungal, antiviral, and antioxidant properties (12-14).

The aim of the present study was to determine the chemical composition and antioxidant and antibacterial properties of essential oils from *M. piperita, A. dracunculus, and Z. multiflora*.

MATERIALS AND METHODS

Areal parts of *M. piperita, A. dracunculus* and *Z. multiflora* were purchased from a local spice store in Gorgan, Iran. Identification of the plants was carried out in University of Agriculture and Natural Resources of Gorgan, Iran. A Clevenger-type apparatus was used for extraction of the essential oils. The extractions were dried over anhydrous sodium sulfate and then stored at 4 °C (15). Components of the essential oils were identified according to a method described by Moradi et al. (16). Gas chromatography/mass spectrometry (GC/MS) analysis of the essential oils was carried out using a Hewlett Packard 5890 system equipped with an HP-5MS capillary column (30 × 0.25 mm ID × 0.25 mm film thickness). Flow rate of helium was 1 ml/min. Initial temperature of the column was 50 °C, which was progressively increased to 120 °C at a 2 °C/min rate for 3 min, and finally increased to 300 °C for 5 min. The MS procedure was operated with ionization energy of 70 eV. Compounds were identified by comparing their retention indices with those of standard samples and mass spectral data available in the Wiley library (Wiley-VCH 2001 data software, Weinheim, Germany).

Three gram-positive bacteria including *S. aureus* (PTCC 1015), *L. monocytogenes* (PTCC 1298), and *B. cereus* (PTCC 1665) and two gram-negative bacteria including *E. coli* (PTCC 1533) and *S. typhimurium* (PTCC 1730) were obtained from the microbial collection of the Department of Food Hygiene and Quality Control, Faculty of Veterinary Medicine, Urmia University, Urmia, Iran. One microliter of bacterial culture (18 hours) at a concentration of 10⁶ CFU/ml equivalent to 0.5 MacFarland standard was spread on Mueller-Hinton agar (Merck Darmstadt, Germany). Sterile paper disks (diameter: 6mm, purchased from Padtan Teb, Iran) were soaked...
The microwell dilution method was used to determine the minimum inhibitory concentration (MIC) of the essential oils against the bacteria. Bacterial suspensions were taken from 18h cultures in broth (10^6 CFU/ml equivalent to 0.5 MacFarland standard). The essential oils were dissolved in 10% dimethyl sulfoxide. Subsequently, the solutions were diluted to the highest concentration (100000 μg/ml) as a stock solution, and then two-fold serial dilutions were prepared in a concentration range of 10000 to 1562.5 μg/ml in nutrient broth. Aliquots of 160 μl Brain Heart Infusion (BHI) broth (Merck Darmstadt, Germany) and 20 μl inoculums were dispensed into 96-well microplate. Then, 20 μl of the essential oil were added to each well. Negative control (180 μl of uninoculated BHI broth+20 μl of essential oil) and positive control (180 μl of BHI broth+20 μl of inoculums) were also considered in the last wells. Final volume of each well was 200 μl, and the final concentration of the essential oils was between 10000 and 156.2 μg/ml. In addition, final bacterial suspension in each well was approximately 1.5×10^8 CFU/ml. The lowest concentration at which no visible bacterial growth was observed was determined as the MIC (15).

The 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay was carried out based on a method described previously with slight modifications (17). Briefly, 50 μl of different concentrations of the essential oils and a reference antioxidant (BHT) were added to 2 ml of DPPH methanolic solution (24 μg/ml). The mixture was shaken and kept in dark and at room temperature for 60 min. Then, absorbance was read at 515 nm using a spectrophotometer (LKB Novaspec II; Pharmacia, Sweden). The same procedure was performed for a blank, which contained no antioxidant. The DPPH scavenging capacity of the essential oils was determined based on the following equation:

\[ I\% = \left( \frac{A_{\text{blank}} - A_{\text{sample}}}{A_{\text{blank}}} \right) \times 100 \]

The essential oil concentration causing 50% inhibition (IC50) was recorded according to the inhibition percentage curve for each sample.

The β-carotene-linoleic acid bleaching test was carried out based on a method described by Miraliakbari and Shahidi with slight modifications (18). In order to prepare the stock solution of β-carotene–linoleic acid, approximately 0.5 mg β-carotene (type I synthetic, Sigma–Aldrich) was dissolved in chloroform (1 ml) in a flask. Then, 20 μl of linoleic acid (Sigma–Aldrich) and 200 mg of tween 40 (Sigma–Aldrich) were added to the flask. Chloroform was removed at 40 °C using a rotary evaporator (Heidolph laborta 4003, SchwaBach, Germany). After adding 100 ml of distilled water, the mixture was shaken vigorously. Aliquots of the mixture (2.5 ml) were pipetted to test tubes containing 350 μl of the essential oils (concentration: 2 mg/ml). The same procedure was done with BHT and a blank. Absorbance of each tube was measured at 470 nm immediately and after two hours. The tubes were placed in a water bath at 50 °C. Finally, β-carotene protective capacity of the essential oils was determined based on the equation below:

\[ I\% = \left( \frac{A_{\beta\text{-carotene 2nd hour}} - A_{\beta\text{-carotene initial}}}{A_{\beta\text{-carotene initial}}} \right) \times 100 \]

Total phenolic content of the essential oils was determined using the Folin-Ciocalteu assay. Gallic acid was used as standard in this assay (19). Briefly, 0.5 ml of the essential oil (2 mg/ml) was mixed with 250 μl of Folin-Ciocalteu reagent (Merck, Darmstadt, Germany) and 2.25 ml of distilled water. The mixture was vortexed and kept for 5 min. A 2 ml aliquot of Na₂CO₃ solution (7.5%) was added, and the mixture was incubated for 120 min at room temperature. Absorbance of the mixture was measured at 760 nm and data were expressed as mg gallic acid equivalent (GAE)/g of essential oil, relative to the values obtained from a standard curve of known concentrations of gallic acid.

All experiments were performed in triplicate. Statistical analysis of data was performed using SPSS, Inc, Chicago, IL software (version 16.0). Tukey’s test was used to compare the differences between the mean values at significance of 0.05.

**RESULTS**

Table 1 shows the chemical composition of the essential oils of *M. piperita*, *A. dracunculus*, and *Z. multiflora*. 

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Based on the results of GC-MS analysis, menthol (39.18%) and mentone (21.64%) were the main components of *M. piperita*, while estragol (34.75%) and limonene (15.72%) were the major components of *A. dracunculus*. In addition, the major components of *Z. multiflora* were carvacrol (36.81%) and thymol (33.04%).

Results of the disk diffusion method demonstrated that the essential oils of *M. piperita* and *Z. multiflora* had higher antibacterial effect against *S. aureus*, *L. monocytogenes*, and *B. cereus* than the essential oil of *A. dracunculus* (P<0.05). However, none of the essential oils had significant antibacterial effect against *E. coli* and *S. typhimurium*. As seen in Table 2, the essential oil of *Z. multiflora* had the highest inhibitory effect against *S. aureus*. Overall, the essential oils of *M. piperita* and *Z. multiflora* showed promising antibacterial activity in the disk diffusion assay. Moreover, the essential oils were most effective against *S. aureus* and *B. cereus* (Table 2). *L. monocytogenes*, *S. typhimurium* and *E. coli* were the most resistant pathogens. The essential oil of *Z. multiflora* showed the highest antibacterial activity against *S. aureus* and *B. cereus* (156.2 ppm). On the other hand, the highest MIC of *A. dracunculus* and *M. piperita* essential oils were recorded against *E. coli* and *S. typhimurium*, respectively.

The antioxidant activity of the essential oil of *Z. multiflora* was 31.12±1.17 μg.ml⁻¹ in the DPPH test and 66.46±0.55% in the β-carotene-linoleic acid bleaching assay (Table 3). Furthermore, the total phenolic content of this essential oil was 228.14±0.45 mg GAE/ g.

### Table 1- Chemical components of the essential oils of *Z. multiflora*, *A. deracunculus* and *M. piperita* using GC/MS analysis

| No | *Z. multiflora* | Retention Time (Min) | % | *A. deracunculus* | Retention Time (Min) | % | *M. piperita* | Retention Time (Min) | % |
|----|----------------|---------------------|---|-------------------|---------------------|---|--------------|---------------------|---|
| 1  | α-Thujene      | 17.34               | 0.82 | Alpha pinene      | 9.48                | 6.94 | Alpha-pinene | 5.45                | 0.71 |
| 2  | α-Pinene       | 17.78               | 1.03 | Camphene          | 10.27               | 0.14 | Sabine       | 6.38                | 2.81 |
| 3  | Camphene       | 18.17               | 0.23 | Sabine            | 10.72               | 0.57 | β pinene     | 6.52                | 0.21 |
| 4  | β-pinene       | 19.21               | 0.72 | Myrcone           | 10.93               | 0.74 | Alpha-terpinene | 7.43                | 2.12 |
| 5  | Myrcone        | 19.65               | 0.49 | Limonene          | 11.78               | 15.72 | Limonene     | 7.63                | 1.88 |
| 6  | α-Philandrene  | 20.20               | 0.29 | cis ocimene       | 12.01               | 2.21 | 1,8-Cineole  | 7.76                | 5.12 |
| 7  | Terpinene-4-ol | 20.70               | 0.57 | Beta ocimene      | 12.16               | 4.11 | Gamma        | 8.29                | 0.88 |
| 8  | O-Isopropyltholene | 21.21           | 3.26 | Estragol          | 14.74               | 34.75 | Terpinolene | 9.04                | 0.43 |
| 9  | Limonene       | 21.30               | 1.08 | L carvone         | 15.65               | 2.11 | Linalool     | 9.33                | 0.36 |
| 10 | 11 Terpinolene | 23.18               | 1.54 | Borsyl acetate    | 16.59               | 1.21 | Menthol      | 10.79               | 21.64 |
| 11 | Linalool       | 23.40               | 4.58 | Eugenol           | 17.61               | 2.25 | Menthol      | 11.18               | 39.18 |
| 12 | δ-3-Carene     | 23.49               | 0.22 | Methyl cinnamate  | 18.02               | 2.12 | Piperitone   | 11.48               | 2.1 |
| 13 | Gamma terpinene| 26.93               | 3.18 | Methyl eugenol    | 18.39               | 8.16 | Piperitoline oxide | 12.74               | 0.25 |
| 14 | Thymol methyl ether | 27.95            | 3.51 | Beta-caryophyllene| 19.12               | 2.89 | Menthol acetate | 13.52               | 7.55 |
| 15 | Thymol         | 30.10               | 33.0 | Humulene          | 19.80               | 0.54 | Beta- bourbonene | 15.39               | 1.12 |
| 16 | Carvacrol      | 30.79               | 36.8 | Germacrene-D      | 20.21               | 4.29 | Caryophyllene | 15.89               | 1.57 |
| 17 | Thymol acetate | 31.90               | 0.28 | Bicyclergmacrene  | 20.41               | 3.35 | Germacrene-d | 16.69               | 4.28 |
| 18 | Eugenol        | 32.11               | 0.72 | Spathulenden      | 21.59               | 4.24 | Viridiflorol | 18.95               | 5.11 |
| 19 | β-Caryophyllene| 33.57               | 0.17 | 7-methoxyxoumarin | 22.89               | 2.19 | ------------ | ------------ | ------------ |
| 20 | 3-              | 33.71               | 0.69 | Neophytadiene     | 24.92               | 0.12 | ------------ | ------------ | ------------ |
| 8  | Methylresacetophenone | 34.40            | 0.78 | -------            | -------              | ------- | ------- | ------- | ------- |
| 21 | α-Humulene     | 34.40               | 0.78 | -------            | -------              | ------- | ------- | ------- | ------- |
| 22 | Spathulenol    | 37.45               | 2.11 | -------            | -------              | ------- | ------- | ------- | ------- |
| 23 | Caryophyllene oxide | 37.62            | 1.23 | -------            | -------              | ------- | ------- | ------- | ------- |
| 24 | 1-Cycloheptene | 38.25               | 0.12 | -------            | -------              | ------- | ------- | ------- | ------- |
| 25 | β-Cemene       | 44.70               | 0.64 | -------            | -------              | ------- | ------- | ------- | ------- |
| 26 | α-Terpineine   | 44.84               | 0.17 | -------            | -------              | ------- | ------- | ------- | ------- |
| Total |            | 98.2               | 98.65 |          |          | 97.32 |

| Essential Oil | S. aureus | L. monocytogenes | B. cereus | E. coli | S. typhimurium |
|---------------|-----------|------------------|-----------|---------|---------------|
|               | DIZ (mm)  | MIC (ppm)        | DIZ (mm)  | MIC (ppm) | DIZ (mm)  | MIC (ppm) |
| *M. piperita* | 16.49±0.22b | 312.5            | 14.34±0.56c | 625  | 15.18±0.28d  | 312.5  | 9.28±0.26a  | 2500 | 12.52±0.45b  | 1250 |
| *A. dracunculus* | 11.13±0.11b | 625             | 10.26±0.43b  | 1250 | 11.48±0.33c  | 625   | 7.81±0.17a  | 2500 | 9.16±0.31b  | 2500 |
| *Z. multiflora* | 18.76±0.36b | 156.2           | 16.58±0.47c  | 312.5 | 16.74±0.17d  | 156.2 | 14.23±0.23a  | 625  | 16±0.53b    | 625  |

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bacteria were more sensitive to the essential oils than the gram-negative ones, which could be due to the presence of divalent cations and polysaccharides in their outer membrane structure. The antimicrobial effect of Z. multiflora might be due to the high carvacrol and thymol content of its essential oil.

Antimicrobial activities of the essential oils were determined quantitatively using the MIC test. Similar to the disc diffusion assay, the essential oils showed greater antibacterial activity against gram-positive bacteria, which is in line with findings of some previous studies (29). The lowest MIC was related to the essential oils of Z. multiflora, M. piperita and A. dracunculus, respectively. In a study by Fazeli et al., Salmonella typhi was more resistant to Z. multiflora than to E. coli, which is not in line with our findings (30).

The DPPH assay is one of the most frequently used methods of determining the antioxidant properties of samples (31). The IC_{50} value of Z. multiflora, M. piperita and A. dracunculus was 31.12±1.17 µg.ml^{-1}, 42.25±1.35 µg.ml^{-1} and 78.41±1.17 µg.ml^{-1}, respectively. In this assay, the IC_{50} value of BHT that was used as the positive control was 27.57±1.34 µg.ml^{-1}. Similar findings were reported by Saeidi-Dekordi et al. for the IC_{50} value of Z. multiflora (32).

The antioxidant activity of the essential oils was also evaluated using the β-carotene bleaching test, and the results were consistent with findings of the DPPH assay. Minor differences between the tests could be due to the presence of lipophilic compounds in the β-carotene bleaching test.

In order to establish a connection between the biological activity and the chemical
composition of the essential oils, the total phenolic content of each essential oil was determined using the Folin-Ciocalteu assay. In a previous study by Kaur et al., the total phenolic content of M. piperita was 399.8 ± 3.2 mg GAE/g, which is significantly higher than that of the Mentha species investigated in the present study. In another study, the total phenolic content of A. dracunculus was 24.10 ± 0.33 mg GAE/g, which is significantly lower than the value found in the present study. These variations may be due to the difference in the geographical location of the plants. Based on the findings, it can be concluded that thymol and carvacrol have high antioxidant activity.

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CONCLUSION

Given the antibacterial and antioxidant activities of the essential oils tested in the present study, they can be used as natural food additives to extend the shelf life of foods. However, further studies should be carried out to determine the active phytochemicals responsible for the antibacterial and antioxidant activities of these essential oils.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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