Comparative study for the volatile constituents and the antioxidant activity of the essential oils of dried Achillea fragrantissima cultivated in Madinah Monawara, Saudi Arabia and Egypt

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ABSTRACT
Hydrodistilled essential oils (HD) of dried aerial parts of Achillea fragrantissima cultivated in Egypt and Madinah Monawara, Saudi Arabia, and their volatiles extracted by solid phase microextraction (SPME) were analyzed using Gas Chromatography – Mass Spectrometry. Thirty – four constituents of the essential oil of Egyptian A. fragrantissima were identified, representing 90.15% of the total oil constituents, while SPME revealed 15 components constituting 94.72% of the volatile material. Santolina alcohol, artemisia ketone, α-thujone, 4(10)-thujen-3-ol, β-thujone, yomogi alcohol and trans-sabinyl acetate were the predominant components in both extracts, with quantities varying with extraction method. Many terpenes e.g. β-pinene, sabine, α-terpinene, p-cymene, linalool, p-menth-2-en-1-ol, 4(10)-thujen-3-ol, borneol, carvone, p-menth-1-en-3-one, bornyl acetate and germacrene D, were identified for the first time. α-Thujone, 4-terpineol, trans-pinocarveol, and spathulenol were the major components among 42 identified components accounting for 93.65% of the total identified volatiles of Madinah hydrodistillate. Monoterpenes concentration was higher in Madinah SPME volatile extract than in HD essential oil. A. fragrantissima essential oil of Madinah exhibited higher antioxidant activity (IC50 1.09 mg/ml) than did Egyptian oil (IC50 1.72 mg/ml), consistent with the differences in phenolic content and volatile constituents identified in both oils.

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Introduction
Food suppliers have applied synthetic antioxidants to their food products for many decades in order to avoid quality deterioration due to autoxidation of food components especially lipid. However, nutrition specialists and the general public are increasingly concerned about their potential health and anti-aging benefits. Interests in using natural antioxidants rich in phenolic compounds such as herbs and spices in foods, nutraceuticals and cosmetics is driven by customer trends especially interest in substitutes for synthetic antioxidants such as butylated hydroxyl toluene (BHT) and butylated hydroxyl anisole (BHA), which are associated with adverse effects on health.[1]

Achillea fragrantissima (known in Arabic as Qaysūm, family Asteraceae) is a well-known small perennial aromatic herb, distributed regionally in North Africa, eastern Mediterranean coast, and Middle East. [2] However, it is now cultivated worldwide due to its various medicinal
uses. Traditionally, *A. fragrantissima* is prepared as oil or infusion and used in folk medicine as a stomachic, anthelmintic, diuretic, antichloristic, antispasmodic and antiseptic agent. Many researchers have investigated the antimicrobial, anti-inflammatory, antiviral, anticancer, antifungal and antibacterial effects of the essential oil of *A. fragrantissima*, but not the antioxidant activity.

In order to determine the bioactive components responsible for such activities, studies have investigated the chemical composition of *A. fragrantissima* hydrodistilled essential oil using Gas Chromatography – Mass Spectrometry (GC-MS), with the detected chemical constituents varying with environmental, climatic, and geographic conditions. For example, El-Shazly et al. identified cis-thujone, santolina alcohol and artemesia ketone as the major constituents of the essential oil of *A. fragrantissima* collected from Sinai desert, while Choucry reported carphyllene oxide, 1-terpinene-4-ol and veridiflorol as the abundant components in the oil extracted from the herb cultivated in North coast, Alexandria. Selection of a suitable extraction technique is important to obtain reliable results. Hydrodistillation (HD) is the most common technique applied in many studies. However, it is associated with limitations such as chemical changes in monoterpenes, isomerization, saponification and polymerization due to thermal treatment. Recently, solid–phase microextraction (SPME) has been successfully used as alternative technique with no negative effects for the analyses of aroma, flavors, essential oils and contaminants but has not been applied to *A. fragrantissima*.

Meanwhile, despite the fact that the flora of Saudi Arabia represents some of the most diverse flora in the Arabian Peninsula and a very important resource for medicinal plants such as *A. fragrantissima*, neither the chemical constituents nor the antioxidant activity of *A. fragrantissima* cultivated in different regions of Saudi Arabia (e.g., the western province which is known as Hejaz) have been studied. Hejaz is separated from Egypt on the west by the Red Sea, on the north by Jordan, on the east by the Najd, and on the south by 'Asir Region. It is the most populated province in Saudi Arabia, and Madinah Monawara is the largest region in the province, covering 7.7% of the total area of Saudi Arabia.

Therefore, the aim of the present study was to compare the volatile constituents of *A. fragrantissima* cultivated in Madinah Monawara, Saudi Arabia, and Nile Delta, Egypt using two different techniques, i.e., HD and SPME. Further, the antioxidant activity of the essential oils extracted using HD was assayed in order to be applied and used as a food additive.

### Material and methods

#### Plants and chemicals

Qaysūm herb (*A. fragrantissima*) was collected from a Wilderness Area (Khils Region in Madinah, Saudi Arabia), while the Egyptian herb was obtained from Bilbis, Sharkia, Egypt in August 2015. Both Madinah and Egyptian herbs were identified by a taxonomist at the Department of Botany, Faculty of Science, Zagazig University and deposited in Madinah Monawara Municipality Lab for Food, Water Analysis and Environmental Research with voucher specimens number AF-36003932–2015 and AF-36003933–2015. Diethyl ether and methanol were purchased from Fisher Chemicals (Pittsburgh, USA). The mixture of n-alkanes C6–C26, authentic compounds, sodium bicarbonates, linoleic acid (≥99%), Tween 40, β-carotene (≥97%), Folin – Ciocalteu reagent for total phenolics, 2,2’-diphenyl-1-picrylhydrazyl (DPPH), and gallic acid were obtained from Sigma Aldrich Chemical Co. (St. Louis, MO, USA).

#### Essential oil extraction by HD

Air dried aerial parts of *A. Fragrantissima* (100 g) in three replicates that were cut into small pieces and subjected to HD for 3 h, using a Clevenger-type apparatus, according to the method of El-massry
et al.\textsuperscript{[14]} The extracted essential oils were dried using anhydrous sodium sulfate and stored in airtight glass vials covered with aluminum foil at –20°C until analysis.

**Headspace solid – phase microextraction (HS-SPME)**

The air dried herb of *A. fragrantissima* was cut into 1–2-cm-long pieces before being subjected to SPME. Two grams of leaves were placed in a 20mL SPME vial. The SPME device (fused-silica fiber) coated with a 100-μm layer of polydimethylsiloxane (Supelco, Bellefonte, PA, USA) was used for extraction of the plant volatiles, and the vial was sealed with a silicone septum. The samples were exposed to 60°C for 30 min and immediately introduced into the gas chromatography injector. This method has been used and optimized by many authors.\textsuperscript{[15–18]}

**Gas chromatography–mass spectrometry (GC–MS)**

The components of the essential oil obtained using HD and the volatiles trapped by the SPME fiber were analyzed using a GC–MS apparatus. Separation was performed on a Trace GC Ultra Chromatography system (Thermo Scientific, USA) equipped with an ISQ-mass spectrometer (Thermo Scientific, USA) with a 60 m × 0.25 mm × 0.25 μm-thick TG-5MS capillary column (Thermo Scientific, USA). The column separation was programmed from 50°C with a holding time of 3 min, and then the temperature was increased at a rate of 4°C per min to 140°C with a holding time of 5 min. Thereafter, the temperature was increased at a rate of 6°C per minute to 260°C for a 5-minisothermal holding time. The injector temperature was 180°C, the ion source temperature was 200°C, and the transition line temperature was 250°C. The carrier gas was helium with a constant flow rate of 1.0 Ml min\textsuperscript{–1}. The mass spectrometer had a scan range from m/z 40–450, and the ionization energy was set at 70 Ev. The identification of compounds was based on matching with the MS computer library (NIST library, 2005 version) and comparison with those of authentic compounds and published data.\textsuperscript{[19]} The relative percentage of the oil constituents was calculated from the GC peak areas. Kovat’s index was calculated for each compound, using the retention times of a homologous series of C\textsubscript{6}–C\textsubscript{26} n-alkanes and by matching with literature.\textsuperscript{[4,10,14,19,20]}

**Antioxidant activity measurements**

*DPPH radical scavenging assay*: Potential antioxidant activity of *A. fragrantissima* oils was assessed according to the methods reported by Hatano et al.\textsuperscript{[21]} in comparison to a synthetic antioxidant used in food industry, tert-butyldihydroquinone(TBHQ). The absorbance was measured at 517 nm using a spectrophotometer(Evolution 300 Thermo UV–VIS); all tests were run in three replicates and the results were averaged.

*β-Carotene bleaching assay*

The antioxidant activity of *A. fragrantissima* oils was determined using a β-carotene/linoleic acid system, as described by Taga et al.\textsuperscript{[22]} in comparison to TBHQ. The absorbance was measured at 470nm over a 60-min period.

**Total phenolic content**

Total phenolic content of the essential oils was determined using the Folin–Ciocalteu reagent according to a method modified from that of Singleton et al.\textsuperscript{[23]} using gallic acid as the standard. The reaction mixtures were incubated in a thermostat at 45°C for 45 min before the absorbance at 765 nm was measured.
### Statistical analysis

Statistical analyses were performed using SPSS software version 16. The data were expressed as mean ± SD and analyzed using Student's t-test and analysis of variance.

### Results and discussion

Hydrodistillation of dried aerial parts of *A. fragrantissima* produced pale yellow oil, with an aromatic fragrant odor with 0.53 ± 0.06% in Madinah essential oil and 0.42 ± 0.08% in the Egyptian one. For the essential oil of dried Egyptian *A. fragrantissima*, a total of 34 components were identified, representing 90.15% of the total oil content (Table 1). The major compounds in the HD oil were santolina alcohol (27.21%), artemisia ketone (14.5%), α-thujone (11.77%), 4(10)-thujen-3-ol (8.33%), β-thujone (7.19%), Yomogi alcohol (4.83%) and trans-sabinyl acetate (4.65%). These findings are consistent with the previous reports of Aboutabl et al., Fleisher and Fleisher, and El-Shazly et al. despite the differences in the nature of the hydrodistilled parts of the herb; dried parts were used in the this study, while the previous studies mentioned above investigated the fresh aerial parts of the plant cultivated in Sinai peninsula, Egypt. Another study by Choucry revealed that the essential oil of *A. fragrantissima* cultivated in North coast of Egypt had an entirely different profile, in which caryphyllene oxide, 1-terpinene-4-ol and veridiflorol were the major components. This is likely due to differences in climatic and geographic conditions.

Meanwhile, many terpenes were identified in the Egyptian *A. fragrantissima* HD essential oil for the first time; β-pinene (0.17%), sabinene (0.11%), α-terpinene (0.25%), p-cymene (0.37%), linalool (0.37%), p-menth-2-en-1-ol (0.22%), 4(10)-thujen-3-ol (8.33%), borneol (0.3%), carvone (0.52%), p-menth-1-en-3-one (0.23%), bornyl acetate (0.11%) and germacrene D (0.22%) (Table 1, Figure 1(a)). Solvent extraction has the advantage of recovering higher molecular weight natural components, which could be interesting from the point of view of bioactivity but also recovers non-volatile compounds. El-Shazly et al. and Choucry used solvent extraction (SE) and hexane to detect additional volatiles and non-volatiles (e.g. sabinene hydrates, methyl eugenol, BHT, bergamal, cis-chrysanthenol, iso-3-thujanol, and phytol) and many fatty acids and sterols. Surprisingly, many of these compounds could be identified in the present study, which depends on HD essential oils such as cis-sabinene hydrate (1.66%), eugenol (0.11%), 4(10)-thujen-3-ol (8.33%) in addition to many other monoterpenes. Well-known negatives of HD and solvent extraction techniques may responsible for the non detection of such compounds previously in the literature.

There was a necessity toward find out an alternative optimized extraction technique without known drawback, in order to determine the volatile constituents of the herb with an efficient and reliable recovery. SPME analysis is a simple, rapid, and economic procedure, currently used on a wide scale for studying volatiles of aromatic plants. Fifteen compounds were identified as the adsorbed volatiles of Egyptian *A. fragrantissima* on SPME fiber, accounting for 94.72% of the total identified components (Table 1, Figure 1(b)). Santolina alcohol (30.77%), α-thujone (18.92%), artemisyl acetate (12.49%), artemisia ketone (11.83%), β-thujone (8.64%) and trans-sabinyl acetate (8.31%) were the major identified components of the dried Egyptian plant. These compounds are in line with those identified in the HD essential oil (Table 1) but with significant differences in the quantities; many monoterpenes e.g., thujone isomers, lavandulol and sabinyl acetate were identified among the volatiles adsorbed by SPME. Sesquiterpenes such as germacrene D, spathulenol and eudesmol were identified at a lower amounts using SPME or not detected at all (Table 1). This is obviously due to the key differences in these extraction techniques. The use of the HD technique for the extraction of essential oil volatiles is unreliable, because of the possible chemical changes, losses, and degradation of aroma compounds by heat, steam, pH, and thermal or hydrolytic effects. In addition, in line with a report by Zheljazkov et al., the duration of the HD process may have also affected the essential oil composition. Shorter distillation time yields higher concentrations of
Table 1. Volatile constituents identified from the essential oils of *A. fragrantissima* cultivated in Egypt and Madinah using GC-MS with HD extraction and SPME.

| S/N | Compound             | Egyptian *A. fragrantissima* | Madinah *A. fragrantissima* |
|-----|----------------------|------------------------------|-----------------------------|
|     | % Area\(^a\)         | HD SPME                      | HD SPME                     |
| 1   | 1-Pentanol           | 0.29 ± 0.06 n.d              | 0.31 ± 0.04 n.d             |
| 2   | 3-Hexen-1-ol         | 0.09 ± 0.01 n.d              | 0.78 ± 0.09 n.d             |
| 3   | Santolina triene     | 0.53 ± 0.05                 | 1.12 ± 0.52 2.3 ± 0.21     |
| 4   | α-Pinene             | 0.12 ± 0.06 n.d             | 0.96 ± 0.1 n.d             |
| 5   | Sabinene             | 0.11 ± 0.02 n.d             | 0.82 ± 0.08 n.d             |
| 6   | β-Pinene             | 0.07 ± 0.05                 | 2.08 ± 0.88 n.d             |
| 7   | ß-Terpine            | 0.25 ± 0.05 0.09 ± 0.00     | 0.45 ± 0.07 n.d             |
| 8   | p-Cymene             | 0.37 ± 0.02 n.d             | n.d                      |
| 9   | 1,8-Cineole          | 0.59 ± 0.09 n.d             | n.d                      |
| 10  | Santolina alcohol    | 27.2 ± 2.1 20.77 ± 2.6      | 8.24 ± 0.58 n.d             |
| 11  | Phenylacetaldehyde   | 0.09 ± 0.01 n.d             | n.d                      |
| 12  | Artimisia ketone     | 7.19 ± 1.1 6.46 ± 1.4       | 2.59 ± 0.98 24.6 ± 3.2     |
| 13  | cis-Sabinene hydrate | 1.66 ± 0.2 n.d              | n.d                      |
| 14  | Artemisia alcohol    | 3.52 ± 0.8 n.d              | 1.93 ± 0.11 n.d             |
| 15  | Terpinolene          | 0.2 ± 0.06 n.d              | 0.57 ± 0.02 n.d             |
| 16  | Linalool             | 0.37 ± 0.08 n.d             | 2.8 ± 0.54 1.58 ± 0.56     |
| 17  | α-Thuone             | 11.8 ± 2.2 18.92 ± 2.2      | 143 ± 1.6 31.61 ± 2.4     |
| 18  | β-Thuone             | 7.19 ± 1.1 6.46 ± 1.4       | 2.59 ± 0.98 24.6 ± 3.2     |
| 19  | 4(10)-Thujen-3-ol    | 8.33 ± 0.6 1.64 ± 0.28     | n.d                      |
| 20  | Bornol               | 0.3 ± 0.05   0.3 ± 0.05     | 1.95 ± 0.14 n.d             |
| 21  | Lavandulol           | 0.33 ± 0.04 12.49 ± 2.3     | n.d                      |
| 22  | Artemisyl acetate    | 0.94 ± 0.08 n.d             | n.d                      |
| 23  | 4-Terpineol          | 0.16 ± 0.01 12.89 ± 2.4     | 3.38 ± 0.96 n.d             |
| 24  | Carvone              | 0.52 ± 0.09 n.d             | n.d                      |
| 25  | p-Mentha-2(1)-en-3-one| 0.23 ± 0.03 n.d             | 0.76 ± 0.05 n.d             |
| 26  | Bornyl acetate       | 0.11 ± 0.01 n.d             | n.d                      |
| 27  | Cymene-7-ol          | 0.97 ± 0.01 n.d             | n.d                      |
| 28  | Thymol               | 2.98 ± 0.82 n.d             | n.d                      |
| 29  | trans-Sabinyl acetate| 4.65 ± 0.68 8.31 ± 1.4     | n.d                      |
| 30  | Eugenol              | 1.6 ± 0.47 2.82 ± 0.61     | n.d                      |
| 31  | cis-Jasmine          | 0.28 ± 0.02 n.d             | 1.21 ± 0.42 n.d             |
| 32  | n-Tetradecean        | 0.48 ± 0.06 n.d             | n.d                      |
| 33  | Massoialactone       | 2.61 ± 0.92 n.d             | n.d                      |
| 34  | 2.6-Flavone           | 1.0 ± 0.54 0.85 ± 0.09     | n.d                      |
| 35  | Germacrene D         | 0.22 ± 0.04 0.15 ± 0.02    | n.d                      |
| 36  | Bicyclogermacrene D  | 0.16 ± 0.03 n.d             | n.d                      |
| 37  | -Sesquiphellandrene  | 0.82 ± 0.04 0.71 ± 0.02     | n.d                      |
| 38  | Germacrene D -4-ol   | 1.62 ± 0.29 n.d             | n.d                      |
| 39  | Spathulenol          | 4.99 ± 1.5 3.03 ± 0.84     | n.d                      |
| 40  | Caryophyllene oxide  | 1.95 ± 0.44 n.d             | n.d                      |
| 41  | Globulol             | 1.23 ± 0.18 n.d             | n.d                      |
| 42  | Cedrol               | 1.4 ± 0.42 2.11 ± 0.36     | n.d                      |
| 43  | Eudesmol             | 1.96 ± 0.69 n.d             | n.d                      |
| 44  | β-Bisabolole         | 0.93 ± 0.12 n.d             | n.d                      |
| 45  | Santalole            | 0.94 ± 0.11 n.d             | n.d                      |
| 46  | Isolongifolol        | 1.96 ± 0.28 n.d             | n.d                      |
| 47  | Bisabolole oxide     | 1.54 ± 0.17 n.d             | n.d                      |
| 48  | Phytol               | 2.22 ± 0.88 n.d             | n.d                      |
| 49  | Total                | – 90.15% 94.72% 93.65%     | 95.38% –                   |

\(^a\)Confirmed by comparison with Kovat's index on a DB5 column reported in the literature.

\(^b\)Values represent averages ±standard deviations for triplicate experiments.

\(^c\)Confirmed by comparison with the mass spectrum of the authentic compound.

\(^d\)Identification by comparison with data obtained from the NIST mass spectra library.

n.d: not detected
monoterpenes, e.g., α-pinene, myrcene, and phellandrenes, whereas the affinity of such compounds toward SPME fiber reduces negative artifacts.\(^\text{[29]}\)

Due to differences in ecological parameters, growing location, agronomical practices, as well as environmental conditions, significant variations are expected between both A. fragrantissima essential oils of Egypt and Madinah (Table 2).\(^\text{[10,20]}\) Forty – two compounds could be identified in the HD essential oil of dried Madinah A. fragrantissima (Table 1, Figure 2(a)). In agreement with the results of Hazem et al.\(^\text{[30]}\) and Alsohaili and Al-Fawwaz\(^\text{[7]}\), who studied the essential oil composition of A. fragrantissima in Jordan, α-thujone (14.3%), 4-terpineol (12.89%), trans-pinocarveol (6.54%), and spathulenol (4.99%) were the predominant compounds among the identified volatiles (Table 1). The levels of santolina triene (1.12%), linalool (2.8%) and trans-pinocarveol (6.54%) of Madinah essential oil were considerably higher than those in the Egyptian essential oil, while those of yomogo alcohol (2.08%), santolina alcohol (3.63%), artemisia ketone (1.27%)and β-thujone (2.59%) of the same oil were considerably lower (Figure 3). 4-Terpineol, iso-3-thujanol, thymol, carvacrol, β-farnesene and

Figure 1. Volatile extracts chromatograms for Egyptian A. fragrantissima isolated by (a) hydrodistillation and (b) SPME.
germacrene – D 4-ol were dominant among the volatiles of Madinah A. fragrantissima essential oil but were not identified in the Egyptian oil.

Dramatically higher levels of the monoterpenes of dried Madinah A. fragrantissima adsorbed on SPME than those in the HD oil were also observed, where the levels of α- and β-thujone, artemisia ketone and santolina alcohol were higher by 31.61, 24.25, 12.55 and 8.24% respectively (Table 1, Figures 2(b), and 3). Sesquiterpenes such as β-farnesene and spathulenol were identified among SPME volatiles but at lower concentrations relative to those in Madinah HD oil. Other compounds such caryophyllene oxide, β-santalole and β-eudesmol were not detected at all (Figure 3).

Antioxidant activity of both HD essential oils under investigation was tested using DPPH radical scavenging and β-carotene – linoleate bleaching assays. Results are presented in Table 3. Madinah essential oil of A. fragrantissima had a lower IC₅₀ (1.088 mg/ml) than Egyptian oil (IC₅₀ 1.72 mg/ml) which indicates a higher activity. This is consistent with the total phenolic content and differences in

| Site Characteristic | Site Bilbis, Sharkia, Egypt | Khils Region in Madinah | Site Bilbis, Sharkia, Egypt | Khils Region in Madinah |
|--------------------|-----------------------------|-------------------------|-----------------------------|-------------------------|
| Location           | 30° 25′ 18″ N, 31° 33′ 33″ E | 23° 49′ 24.72″ N, 39° 23′ 1.1″ E |
| Elevation          | 4m.                         | 608m.                   |
| Temperature        | In summer, the highs are 34°C, and the lows can drop to about 22°C, but in winter range from 7°C to 19°C | Summers daytime temperatures averaging about 43°C with nights about 29°C. Winters temperatures from 12°C at night to 25°C in the day. |
| Average rain intensity (mm) | 25 | 4.09 |
| Average moisture % | 65 | 25.3 |
| Irrigation         | River Nile                  | Rains                   |

Figure 2. Volatile extracts chromatograms for Madinah, Saudi Arabia A. fragrantissima isolated by (a) hydrodistillation and (b) SPME.
volatile constituents identified in both oils. In agreement with the higher total phenolic content detected in Madinah essential oil (Table 3), many phenolic compounds were identified in this oil but not found in Egyptian essential oil e.g., borneol (2.32%), thymol (2.98%), carvacrol (1.6%), eugenol (0.75%) and trans-pinocarveol (6.54%). Linalool was identified in both oils, but at a lower concentration in the Egyptian oil (0.37%) in comparison to Madinah oil (2.8%) (Table 1). Phenolic compounds are well-known as antioxidants with very higher activity,\cite{31} in comparison to that of synthetic antioxidants. To date, there is no report concerning the antioxidant activity of *A. fragrantissima* essential oil, but many researches showed such activity for the extracts. The most relevant research by Shahat et al.\cite{32} showed that, of the many extracts of medicinal plants cultivated in Riyadh KSA, the methanolic extract of *A. fragrantissima* was the most efficient ion chelator and showed 100% inhibition of the peroxidation of linoleic acid, however the responsible bioactive compounds were not identified. The essential oil of *A. fragrantissima* was reported as safe, with no effect on the nature and color of embryo fluid as well as experimental animals,\cite{4,6,33} therefore, according to the results introduced in this research, the essential oil of *A. fragrantissima* can be used safely as antioxidant in foods in replacement to the concerned synthetic antioxidant.

**Table 3.** Antioxidant activity of essential oils for *A. fragrantissima* cultivated in Egypt and Madinah in comparison to the synthetic antioxidant TBHQ.

| Material                                | \(IC_{50}/\text{mg/ml (DPPH)}^a\) | \(\beta\text{-Carotene/bleaching \% for 1 mg/ml}\) | \(\text{mg GA/g for 1 mg/ml}\) | \(\text{(DPPH)}^a \% for 1 mg/ml\) |
|-----------------------------------------|-----------------------------------|-----------------------------------------------|-----------------------------|-------------------------------------|
| *A. fragrantissima* volatile oil of Madinah | 1.09 ± 0.41                      | 50.5 ± 1.3                                     | 42.7 ± 1.52                 | 46.6 ± 2.2                          |
| *A. fragrantissima* volatile oil of Egypt | 1.72 ± 0.32                      | 28.8 ± 2.3                                     | 22.7 ± 0.22                 | 34.0 ± 0.83                         |
| TBHQ                                    | –                                 | 98.7 ± 0.91                                   | –                          | 98.9 ± 0.77                         |

\(^a^\)Values represent averages ± standard deviations for triplicate experiments.
Conclusion

In the present study, volatiles of dried A. fragrantissima cultivated in the Nile Delta, Egypt and Madinah Monawara, KSA were extracted using HD and HS-SPME followed by separation and analysis using GC–MS. Due to differences in the cultivation location, agronomical practices, and environmental conditions, significant differences in the quantity and quality of the extracts of both regions were observed. In addition, differences in the extraction techniques applied resulted in differences in the extracted essential oil, such as considerably higher quantity of the monoterpenes adsorbed on SPME than in the HD oil. Madinah HD essential oil showed a higher scavenging ability and greater inhibiting effect toward the oxidation of linoleic acid than that of the Egyptian oil due to the presence of many volatiles with phenolic nature and, therefore, antioxidant activity as well as higher total phenolic content.

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