Differences in the Aroma Profile of Chamomile (Matricaria chamomilla L.) after Different Drying Conditions

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Abstract: This experiment was conducted to examine the influence of drying methods on the essential oil of chamomile (Matricaria chamomilla L.) and its chemical composition. Chamomile flower heads were dried using five different methods: sunlight for 72 h; shade for 1 week; oven at 40 °C for 72 h; solar dryer for 72 h; and microwave for 5 min. Drying methods had slight and nonsignificant impacts on dry biomass of flower heads. The highest percentages of oil in flowers (0.35–0.50%) were observed after solar-drying methods, and the lowest percentage of oil was found after microwave drying (0.24–0.33%). Drying methods significantly influenced the number of identified compounds. The maximum was identified after solar drying (21 compounds), while the lowest was identified after microwave drying (13 compounds), which revealed the solar ability to preserve compounds in contrast to microwave, which crushed the compounds. Major compounds were α-bisabolol oxide A (33.0–50.5%), (Z)-tonghaosu (10.0–18.7%), α-bisabolol oxide B (8.2–15.4%), α-bisabolone oxide A (5.4–14.6%), and chamazulene (1.9–5.2%) of essential oil. Drying methods clearly affected major compounds’ content as the lowest α-bisabolol oxide A was after sun drying, and the lowest α-bisabolol oxide B was after solar drying. (Z)-tonghaosu increased during drying compared to fresh flowers. Solar drying maintained higher chamazulene content (3.0%) compared to other drying methods. The results of this study suggest that drying under the shady conditions preserved chemical composition of essential oil with higher α-bisabolol content compared to other drying methods.

Keywords: chamazulene; chamomile; drying; α-bisabolol oxide; (Z)-tonghaosu

1. Introduction

Industry and marketing of herbal medicine face many challenges in Egypt, including lack of scientific evidence, awareness of quality standards, marketing strategies, and adequate documentation to protect post-harvesting practices. Many practices can promote effective use of medicinal plants and expand global exportation. Examples include agriculture practices, proper planning of marketing, and applying modern molecular technologies [1,2]. These practices require a high portion of Egyptian income, along with the development of green technologies to produce pollution-free medicinal plants [1]. Drying is among the oldest preservation processes for food in general and for medicinal herbs in particular [2]. Drying processes that inhibit metabolic processes in herbs are required to avoid reducing contents of active substances (i.e., phenolic compounds). The objective of drying is decreasing the weight of plant raw material without affecting its quality. The drying process is critical for processing of aromatic and medicinal plants as it slows the growth of microorganisms and inhibits biochemical reactions that can influence organoleptic properties and increase the shelf-life of the products [3–5]. Appropriate drying methods
should always be selected considering active substances, plant species, and plant tissues where active substances are accumulated. The effect of drying on essential-oil yield and composition has been investigated in enormous numbers of aromatic plants [6].

The most common method for drying medicinal herbs is air drying in sunny or shady conditions. These methods require extended times that may lead to loss of desired constituents. Furthermore, environmental factors such as temperature and humidity cannot be controlled, and contamination of plant material is more likely. Several modern methods have also been used to preserve medicinal herbs, including oven, tray and freeze-drying [7]. The essential-oil content of shade-dried Roman chamomile flowers (1.9%) was found to be larger than that of sun-dried (0.4%) and oven-dried at 40 °C (0.9%). In addition, the drying method also had a significant effect on the proportion of the various components as both isobutyl and 2-methylbutyl angelate were higher after sun drying compared with the other two drying methods, while 3-methylbutyl isobutyrate and propyl tiglate were higher after oven drying [8]. Drying chamomile in different temperatures from 35 to 95 °C led to significant changes on the yield and composition of chamomile essential oil. It was also noticed that at 95 °C, flowers turned an undesirable caramel colour [9]. On the other hand, ref [10] revealed that drying of Satureja hortensis in the oven at 45 °C was most suitable and is recommended for fast drying and high-oil yield as well as for a high-percentage of carvacrol. On Juniperus phoenicea L. plants, Ennajar et al. [11] concluded that drying in oven-drying at 45 °C was more suitable and is recommended for obtaining a higher yield of essential oils, while for major components (α-pinene and δ-3-carene), shade drying was more suitable. The highest content of volatile compounds was obtained by vacuum-microwave in oregano, which is not recommended in rosemary due to significant reductions in both the volatile content and chemical quality [12,13]. Banout et al. [14] compared two solar-drying methods (direct cabinet solar dryer and indirect cabinet solar dryer) on the chemical composition of aerial parts of sacha culantro (Eryngium foetidum). They concluded that the indirect method was more suitable for drying E. foetidum since the dried product resembled the fresh herb more closely in its chemical composition and had better appearance. In the study of Calýn-Sanchez et al. [15] who investigated the impact of sun, shade, and oven-at-45 °C drying methods on yield and chemical components of Savory’ essential oils. They observed that oven drying at 45 °C was the most suitable for fast drying, high yield and higher carvacrol content. The essential oil content was significantly increased at ambient temperature and infrared drying 45 °C. Oxygenated monoterpenes were the often-detected compounds. Chen et al. [16] showed that drying jujube fruit under the hot-air and infrared drying methods speeded the drying process. The infrared drying method led to shorter drying time, higher drying yields, and better quality of products. Many other authors found variations in the chemical composition of essential oil of different medicinal plants according to the drying air temperature [4,17,18]. However, because volatile constituents are the most sensitive components during the process of drying, the effect of these techniques on the chemical components of the active ingredients is still limited.

Chamomile (Matricaria recutita L., M. chamomilla L. or Chamomilla recutita L.) is a composite in the family Asteraceae. Chamomile use has a long history in Egypt, and it is still important. Organic farming and hand-picked flower heads give Egyptian chamomile a good reputation in export markets [19]. The total chamomile cultivation area reached approximately 9500 acres and ranked second among the cultivated medicinal plants in Egypt. The production reached approximately 8000 tons, of which 3000 tons were exported, amounting to approximately 5 million USD dollars [19–21]. Traditional uses involve consumption as an anti-inflammatory for throat and stomach ailments, and external application as a remedy for ophthalmitis and skin problems. It is also currently used in homeopathy and several cosmetics [22].

Chamomile flowers are common in herbal teas, cosmetics, alcoholic beverages, and baked foods [23]. Moreover, demand for chamomile in the domestic chemistry and food industries is increasing. Finally, therapeutic indications are continuously expanding using
improved research techniques [22]. Within the framework of developing drying herbs and comparing modern methods with traditional methods to reach the best drying methods maintaining higher volatile oil content and composition, a comparison study was conducted between traditional drying methods (shade and sun drying) and modern methods (oven, solar, and microwave drying). The research hypothesis was that chamomile (M. chamomilla) essential oil and its constituents are determined by the drying method, which undoubtedly affects the pharmacological value of the plant. The main objective of this study is to understand the impact of drying methods on the effectiveness of medicinal plants for therapeutic and medicinal purposes by comparing different modern and traditional drying treatments on the chemical composition of chamomile essential oils, which are due to their therapeutic effect.

2. Materials and Methods

2.1. Field Site Description and Growth Conditions

This study was carried out at a private farm in the western desert, Aswan Governorate, Egypt, 20 km north of Aswan city (24°30'02.0" N 32°44'26.8" E), during successive season in 2018/2019. A total of 16.2 hectares of chamomile (M. chamomilla) was grown for export under the contract farming system. Physical and chemical properties of soil and irrigation water samples were determined (Tables 1 and 2).

Table 1. Chemical properties of the soil.

| Parameter                      | Value       |
|--------------------------------|-------------|
| pH                            | 7.8         |
| Conductivity (EC)              | 880 μS/cm   |
| Total hardness as (CaCO3)      | 283 mg/kg   |
| Calcium (Ca)                   | 64 mg/kg    |
| Magnesium (Mg)                 | 30 mg/kg    |
| Bicarbonate (HCO3−)            | 266 mg/kg   |
| Total alkalinity as(CaCO3)     | 218 mg/kg   |
| Bicarbonate alkalinity as (CaCO3) | 218 mg/kg |
| Carbonate alkalinity as (CaCO3) | 0.0 mg/kg  |
| Hydroxide alkalinity as (CaCO3) | 0.0 mg/kg  |
| Sodium (Na+)                   | 64 mg/kg    |
| Potassium (K+)                 | 8.4 mg/kg   |
| Chloride (Cl−)                 | 82 mg/kg    |
| Sulfate (SO4−)                 | 90 mg/kg    |
| Total dissolved solids (TDS)   | 540 mg/kg   |
| Ammonium (NH4−)                | 0.60 mg/kg  |
| Nitrate (NO3−)                 | 79.4 mg/kg  |
| Nitrite (NO2)                  | 1.26 mg/kg  |
| Phosphate (PO4)                | 2.38 mg/kg  |

Table 2. Chemical properties of irrigation water.

| Parameter                      | Value       |
|--------------------------------|-------------|
| pH                            | 7.7         |
| Conductivity (EC)              | 2.88 dS/mL  |
| Carbonate (CO3−)               | 1843 ppm    |
| Bicarbonate (HCO3−)            | 3.87 meq/L  |
| Chloride (Cl−)                 | 13.05 meq/L |
| Sulfate (SO4−)                 | 6.24 meq/L  |
| Calcium (Ca+2)                 | 1.41 meq/L  |
| Magnesium (Mg+2)               | 1.19 meq/L  |
| Sodium (Na+)                   | 20.43 meq/L |
| Potassium (K+)                 | 0.13 meq/L  |
| Sodium Carbonate               | –           |
| Adsorbed Sodium                | 17.93%      |
Seeds of *M. chamomilla* plants were sown in a nursery on 25 September 2018 by Royal Company, El-Giza Governorate, Egypt. Two months after sowing, uniform seedlings were transplanted into plots of rows 25 m in length spaced 70 cm apart; seedlings were spaced 30 cm apart within a row. The organic farming system was applied. Experimental soils were supplied with 47.4 m$^3$/hectare of mature high-quality compost characterized with neutral pH (7.0), a sufficient amount of soluble anions and cations, and a moderate level of organic matter and nutrients.

Fertigation was supplied via a drip irrigation system. Plants were fertilized according to the recommended fertilization plan for export from the beginning of November 2018 to the end of February 2019 with the following applications per hectare: 247 kg 46.5% Urea; 198 kg phosphate; 74 kg potassium sulfate; 5 kg humic acid; 2.5 kg amino acid; 74 kg phosphoric acid; and 2.5 kg action balance. Plants have been irrigated day after day with a rate of 8 L/plant each time, and hand weed control with no pesticides was applied.

### 2.2. Flower Heads Collection

Data of yield were obtained by collecting the heads of flowers three times: the 1st harvest occurred in January, the 2nd in February, and the 3rd in March 2019. After collection, flower heads were immediately dried using different drying methods.

### 2.3. Drying Methods

Flower heads were immediately dried using one of five different methods: sunlight (air temperature reached to 30 °C) for 72 h, shade for one week (room temperature averaged 20–25 °C), oven at 40 °C for 72 h, solar dryer (air temperature reached 35–40 °C) for 72 h (Figure 1), or microwave at 1500 watts for 5 min (temperature reached higher than 90 °C). Dry climate was prevalent with average humidity of 28–30%.

![Solar-drying unit.](image)

### 2.4. Essential Oil Production and GC-MS Analysis

From each of harvest times, samples were harvested and hydro was distilled to determine essential-oil content using a Clevenger apparatus. About 100 g fresh/dried flower heads were subjected to hydro-distillation for 3 h, at an average temperature of 40 °C using a Clevenger-type apparatus. Essential-oil percentages of the air-dried flower heads were measured according to the methods described by Guenther [24], and the percentage (%) was expressed as milliliter per 100 g flower heads. Essential-oil yield per acre was calculated. The anhydrous sodium sulfate was used to dehydrate the extracted essential oil and was stored in a freezer for further gas chromatography-mass spectrometry (GC-MS) analysis. The chromatographic (GC-MS) analysis was carried out at the Department of Chemistry, Faculty of Science, Aswan University, Aswan, Egypt according to previous study [25]. Major components were identified using the following analytical techniques:
(a) Kovats indices, in reference to n-alkanes (C9-C22), and (b) mass spectra (authentic chemicals, Wiley spectral library collection and NIST library) according to the technique and database shown by Adams [26] and König et al. [27].

2.5. Statistical Analysis

The statistical analysis was carried out using JMP (versions 4.0; SAS Institute Inc., Cary, NC, USA). Data were subjected to statistical analysis using an F test according to Snedecor and Cochran [28], in which the data for each harvest were analyzed separately. One factor was considered in this experiment, which was drying method. The differences among treatments were detected using Tukey’s Honest Significant Difference test.

3. Results and Discussion

The fresh flower-head yield of the chamomile (M. chamomilla) plant was 35 g per plant in the first cut, 43 g per plant in the second cut, and 63 g per plant in the third cut, with a total of 140 g per plant per season. The total yield of fresh flower heads was 2800 kg per acre per year. The yield of dry flower heads was 7, 8.6, and 12.4 g per plant in the first, second and third cut, respectively. The total dry flower yield was 28 g per plant per season with a total of 560 kg per acre per season.

The hypothesis that the essential-oil content and its chemical composition are affected by drying method was extensively studied. Drying method, speed, and drying temperature have a significant impact on the quantity and quality of active ingredients in aromatic and medicinal plants. In spite of technical developments, the selection of suitable drying methods remains a central economic and ecological criterion for preserving medicinal plants. Recommended drying methods in the literature and methods used in practice are different, confirming an urgent need for research on this topic [29]. Requirements for drying aromatic and medicinal plants are: (1) reducing moisture content to an equilibrium level defined by relative air humidity and temperature; (2) minimizing impacts to quality in terms of active ingredients, aroma, flavor and color; and (3) reducing microbial count to prescribed limits [30].

In this study, drying methods showed nonsignificant impacts on dry biomass of flower heads (data not shown). Essential-oil content of chamomile flowers after drying showed significant differences in essential-oil content among drying treatments. The highest percentage of oil in flowers after solar drying was 0.5%, followed by direct drying in the sun and shade. The lowest content was observed after microwave drying (Table 3). These results suggest that solar drying might best preserve essential oil content, while exposing flowers to microwave radiation may induce polar molecules and produce thermal energy that leads to loss of volatile oil.

Table 3. Essential-oil content under different drying conditions.

| Treatments      | 1st Cut | 2nd Cut | 3rd Cut |
|-----------------|---------|---------|---------|
| Direct sun      | 0.39 ± 0.019 b | 0.35 ± 0.016 b | 0.31 ± 0.012 ab |
| Shade           | 0.37 ± 0.055 b | 0.34 ± 0.008 b | 0.29 ± 0.009 b |
| Solar energy    | 0.50 ± 0.016 a | 0.43 ± 0.029 a | 0.34 ± 0.024 a |
| Oven            | 0.33 ± 0.024 b | 0.32 ± 0.023 bc | 0.29 ± 0.021 b |
| Microwave       | 0.33 ± 0.016 b | 0.28 ± 0.006 c | 0.24 ± 0.015 c |
| F value         | 22.03    | 31.57    | 20.79    |
| Probability     | <0.0001  | <0.0001  | <0.0001  |

Data are mean ± standard deviation of four samples for each drying method. Difference in letters (a, b, and c) mean significant differences, and vice versa.

Egyptian chamomile is classified as a member of the α-bisabolol oxide A group [19–21]. In addition to essential oil, chamomile is rich in flavonoids, including apigenin-7-glucoside, quercetin glycosides, and luteolin glucosides. Apigenin-7-glucoside is the most abundant
flavonoid in chamomile flowers [31]. In addition, caffeeic and ferulic acid derivatives have been detected in chamomile flowers [32]. Chamomile contains a volatile blue oil that may be adulterated with synthetic and natural mixtures of bisabolol and azulenes [33]. Major compounds in the oil are sesquiterpenes, including chamazulene, (−)-α-bisabolol and bisabololoxides A and B [34]. Pharmacopeial grade chamomile consists of both fresh and dried flowers [35]. In the present study, chromatographic analysis of essential oils (collected from the third harvest) detected about 24 compounds, representing about 95% of oil composition (Table 4). Most compounds were sesquiterpenes groups: oxygenated sesquiterpenes (83.11–87.71%) and sesquiterpene hydrocarbons (5.74–12.02%). Major oxygenated sesquiterpenes were α-bisabolol oxide A, (Z)-Tonghaosu, α-bisabolol oxide B, and α-bisabolone oxide A. Major sesquiterpene hydrocarbons were chamazulene and β-Farnesene. The highest oxygenated sesquiterpene content was detected after shade drying and the lowest after oven drying. In contrast, the highest sesquiterpene hydrocarbon content was detected after oven drying and the lowest after shade drying. These results indicate a key role of drying in maintaining the balance among major essential-oil constituents. Drying resulted in transforming sesquiterpene hydrocarbons to oxygenated sesquiterpenes and vice versa. Also, α-bisabolol was transformed after drying to α-bisabolol oxide A or B.

Table 4. The chemical compositions (%) of chamomile essential oil extracted from fresh and dried flowers (collected from the third harvest).

| No. | RT  | Compound Name       | Molecular Formula | FW Shade | Sun | Oven | Solar | Microwave |
|-----|-----|---------------------|-------------------|----------|-----|------|-------|-----------|
| 1   | 5.11| Yomogi alcohol      | C_{10}H_{16}O     | 0.23     | –   | –    | 0.31  | –         |
| 2   | 5.66| α-Cymene            | C_{10}H_{14}      | –        | –   | –    | –     | 0.09      |
| 3   | 6.03| α-Pinene            | C_{10}H_{16}      | 0.16     | –   | –    | –     | –         |
| 4   | 6.29| β-Ocimene           | C_{10}H_{16}      | 1.21     | –   | –    | –     | –         |
| 5   | 6.62| Artemisia ketone    | C_{10}H_{16}O     | 1.28     | 0.41| 0.50 | –     | 0.53      |
| 6   | 9.65| Borneol             | C_{10}H_{16}O     | –        | 0.31| 0.37 | –     | 0.21      |
| 7   | 18.85| β-Farnesene       | C_{15}H_{24}      | 2.36     | 2.06| 3.08 | 7.30  | 2.80  | 4.90 |
| 8   | 19.19| Caryophyllene oxide| C_{15}H_{24}O     | –        | –   | –    | 0.11  | –         |
| 9   | 19.47| Germacrene D       | C_{15}H_{24}      | 0.64     | 0.22| 0.22 | 1.20  | 0.36  | 0.67 |
| 10  | 19.95| Bicyclogermacrene  | C_{15}H_{24}      | 0.84     | 0.18| –    | 0.56  | 0.23  | 0.33 |
| 11  | 22.02| Caryophyllene oxide| C_{15}H_{24}O     | 0.25     | –   | –    | 0.19  | 2.40  | –    |
| 12  | 22.32| (−)-Spathulenol    | C_{15}H_{24}O     | 0.26     | 1.81| 2.92 | 1.09  | 0.13  | 1.82 |
| 13  | 24.17| tau.-Cadinol       | C_{15}H_{24}O     | 0.22     | 0.90| 1.32 | 0.60  | 1.33  | 0.71 |
| 14  | 24.64| α-Bisabolol oxide B| C_{15}H_{24}O_{2} | 15.32    | 12.43|15.36| 8.23  | 12.74 | 11.09 |
| 15  | 24.79| cis-α-Santalol      | C_{15}H_{24}O     | 0.31     | 2.00| 2.28 | 1.13  | 2.23  | 0.80 |
| 16  | 25.38| α-Bisabolone oxide A| C_{15}H_{24}O_{2} | 8.66     | 9.28| 14.58| 5.37  | 10.27 | 7.01 |
| 17  | 25.44| α-Bisabolol        | C_{15}H_{24}O     | 4.10     | –   | –    | –     | –      | –    |
| 18  | 26.57| Chamazulene        | C_{15}H_{26}O     | 5.17     | 1.88| 2.37 | 2.25  | 3.09  | 2.55 |
| 19  | 27.25| α-Bisabolol oxide A| C_{15}H_{24}O_{2} | 44.80    | 50.46|32.95| 47.00 | 41.17 | 48.34 |
| 20  | 27.78| α-Costol           | C_{15}H_{24}O     | –        | 0.15| –    | –     | 0.07  | –    |
| 21  | 30.60| (Z)-Tonghaosu      | C_{13}H_{12}O_{2} | 9.95     | 10.02|16.39| 18.73 | 14.51 | 14.89 |
| 22  | 32.25| (E)-Tibetin spiroether| C_{14}H_{14}O_{2} | 0.36     | 0.55| 1.00 | 1.06  | 1.21  | 0.98 |
| 23  | 36.77| Linoleic acid      | C_{18}H_{32}O_{2} | –        | 1.01| 1.14 | 0.31  | 0.80  | 0.37 |
| 24  | 40.51| Heptacosane        | C_{27}H_{56}      | 0.09     | 0.50| 0.54 | 0.11  | 0.40  | –    |

Monoterpenic hydrocarbons 1.37 – – – 0.09 –
Oxygenated monoterpenes 1.28 0.95 0.87 – 1.06 –
Sesquiterpenic hydrocarbons 9.32 5.74 7.52 12.02 8.21 9.16
Oxygenated sesquiterpenes 84.01 87.71 86.61 83.11 85.65 85.30
Total detected compounds 95.98 94.40 95.00 95.13 95.00 94.46

RT: retention time, and FW: fresh weight of flower heads.

Several studies showed that drying method had a clear impact on volatile-oil content and its composition in aromatic plants [8,9,36,37]. Traditional drying methods have many drawbacks to produce the required high-quality standards for medicinal plants. Further, intensive solar radiation had an adverse impact on quality, resulting in losses of essential
oils and/or changing color of dried herbs. The sensitivity of volatile oils determines the suitable temperature for drying processes. Thus, higher temperatures promote loss of more volatile constituents and degradation of less stable substances [5]. Generally, air temperatures influence both essential-oil quantity and quality in aromatic plants, and not only during drying; reduction in active ingredients continues during storage as well [38].

In the present experiment, the chemical composition of essential oil was clearly altered by drying method. The major compound affected was α-bisabolol oxide A that represented 44.8% in fresh flowers and ranged from 32.95–50.46% in dried flowers. The highest value was observed after shade drying and the lowest was under direct sun drying. The second major compounds were α-bisabolol oxide B and (Z)-tonghaosu with contents of 15.32% and 9.95%, respectively, in the fresh flowers. After drying, α-bisabolol oxide B content decreased and (Z)-tonghaosu increased. The α-bisabolol oxide B content ranged from 8.23–15.36%, and (Z)-tonghaosu ranged from 10.02–18.73%. The α-bisabolol oxide B was much higher than (Z)-tonghaosu after shade drying, and (Z)-tonghaosu was much higher after other drying treatments. The α-bisabolone oxide A content was 8.66% in fresh flowers, and this value increased to 14.58% after direct sun drying and decreased to 5.37% after oven drying. Conversely, the highest content of chamazulene was observed in fresh flowers (5.17%) followed by dried flowers after solar drying (3.09%) and was lowest, 1.88%, after shade flowers.

A literature review was performed on the effects of different drying methods on volatile-oil content and its chemical components. The influence of drying on the amount and profile of the essential oils is extensively reported. For chamomile, the effects of drying conditions on both phenol content and essential oil have been studied. An increase in drying temperature from 40 °C to 80 °C resulted in a significant loss of total phenols, GAE and apigenin-7-glucoside [7,9]. The effect of drying using a methodology of a fixed layer at 80 °C on the productivity and chemical components of chamomile (Chamomilla recutita) volatile oil has been studied by Borsato et al. [9], who concluded that the drying process of chamomile reduced volatile-oil content and altered its chemical components. Another observation was that drying at 70 °C resulted in shorter drying times, caused a negative impact on flavonoids content, and resulted in redder extracts and a corresponding raise in condensed tannins that might be a result of polymerization processing during high-temperature drying [7]. On the other hand, drying at 30 °C yielded high active component and phenol content, and retained potential anti-inflammatory characters with desirable color for incorporation into beverages. In a previous study, direct drying in the sun and in the shade in addition to drying in the oven at a temperature of 45 °C were compared to review the effect of these treatments on the productivity and chemical component of the volatile oils of Juniperus phoenicea L. [11]. The results of the study showed that although the oven-drying technique led to the highest productivity of volatile oils, the best attributes of oil quality, high in α-pinene and δ-3-carene, were obtained by using the shade-drying technique when the drying methods in Origanum vulgare and Rosmarinus officinalis and their effect on the active ingredients were evaluated by Figiel et al. [12] and Szumny et al. [13]. The results revealed that the hot air led to drastic losses of the oregano plant by causing the essential oils to volatilize in it and lose the quality of the dried product. The volatile compounds in the rosemary plant were not affected by drying in hot air. Several other authors confirmed the occurrence of differences in the chemical composition of the essential oil in several medicinal plants as a result of drying treatments, which is consistent with our findings [5,36,39]. In this study, the difference in the drying method led to differences in ratios of essential-oil constituents as well as the appearance of new compounds and the disappearance of others. Sesquiterpene hydrocarbons decreased to varying degrees after drying compared to fresh flowers, except for a noticeable increase when oven drying. In contrast, oxygenated sesquiterpenes increased to varying degrees after drying, except for a slight decrease after oven drying. Microwave drying led to a dramatic negative impact on the quality of flowers and its quality.
4. Conclusions

The results of this study extracted a set of prominent indicators, the most important of which is the efficiency and effectiveness of sun drying in maintaining essential-oil content. Secondly, microwave drying causes the loss of essential oil by volatilization. Finally, drying in the shade is best suited to preserve the quality of the flower in terms of color, appearance, and chemical oil composition after drying.

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