Influence of drying, storage and distillation times on essential oil yield and composition of anise hyssop [Agastache foeniculum (Pursh.) Kuntze]

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RESEARCH ARTICLE

Influence of drying, storage and distillation times on essential oil yield and composition of anise hyssop [Agastache foeniculum (Pursh.) Kuntze]

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In the present study, the effects of two different drying methods, with different storage and distillation periods, on the essential oil content and composition of Agastache foeniculum (Pursh.) Kuntze were studied. The results showed a reduction of the oil content due to the drying treatments and the storage period. The plant material dried at room temperature (25°C) showed the highest essential oil content (2.2%), whereas these dried by oven (40°C) were lower (1.6%). The oil content of anise hyssop was also affected by storage time. The distillation time did not have a significant effect on the essential oil content of anise hyssop. The oil composition was then determined by gas chromatographic (GC) methods. Accurate quantitative analysis has been carried out through the measurement of correction factor of the most abundant oil constituent, methyl chavicol, and for this compound analytical data have been expressed as g/100 g of the oil. Methyl chavicol was quantified as 97.2–98.1 g/100 g, while the second most abundant compound, limonene, was determined as 0.8–1.4% of the total oil. The yield of those two compounds seemed to be roughly unaffected either by the two drying methods or by storage and distillation times.

Keywords: Agastache foeniculum; distillation; drying; Lamiaceae; methyl chavicol; storage

Introduction

Agastache foeniculum (Pursh.) Kuntze, commonly known as anise hyssop, is a perennial, herbaceous plant with medicinal and aromatic properties, belonging to the Lamiaceae (mint family) and native of North America. In recent years, this plant has gained economic importance in many countries as a source of nectar for honey bees, as well as an aromatic and medicinal plant. Indeed, anise hyssop produces aromatic oils that are commonly added to foods, drugs, perfumes and cosmetics, while its leaves and flowers have been used in herbal teas, cakes, sweets, salads and desserts. Its essential oil was found to possess antimicrobial and antifungal properties; nonetheless it is also used for stomach affections and bloating (1).

The biosynthesis of secondary metabolites, although genetically controlled, is strongly influenced by environmental factors (2). Some papers have also reported that postharvest conditions such as drying methods (3), storage conditions and distillation time significantly affected the essential oil content and composition of this plant species.

However, there is little or no information on postharvest factors controlling those important traits of Agastache spp. Several studies have been conducted on the components and the essential oil content of A. foeniculum (4) in which methyl chavicol and limonene reported to be its main components.

Medicinal plants are often dried and stored for a long time before use, in order to manufacture various types of products. Fresh anise hyssop usually contains 72–77% water, a percentage value that ought to be lowered to less than 10% for the sake of optimal preservation and storage. Drying is the most common and the oldest preservation method for plant material, as it inhibits enzymatic degradation and limits microbial growth. Dehydration of plants can be performed using different methods. Air drying and hot air drying are still the methods most widely employed, thanks to their minimal cost. Room temperature drying is the traditional technique used to preserve medicinal plants, as the low temperatures are thought to protect from degradation of the active components. However, this drying procedure is slow and metabolic processes may be long lasting, which may lead to a lower quality of the plant materials, for example color changes and loss in active ingredients (5). Anyway, the effect of a particular drying method on the release or retention of volatile compounds is not predictable and depends on the compound and the medicinal plant concerned. Oven drying and freeze drying of dill led to a decrease in the amount of most of the volatile compounds compared...
with the levels in the fresh plant (6). In contrast, shade drying of spearmint leaves has resulted in a product with a nice green color and few losses of volatiles (7). The same result on volatile compounds was observed after oven drying (30°C) and freeze drying in thyme and sage (8).

On the other hand, in some botanical species, certain compounds have been observed to normally increase after drying, as a result of oxidation or esterification reactions; some examples are eugenol in bay leaf (9), thymol in thyme (8) and some sesquiterpenes in various herbs (10).

The effect of drying on the active substances of different crops has been studied intensively; for example, ginger (10), basil (11), Roman chamomile (12), spearmint (13), thyme and sage (8). These studies showed that changes in the concentration of essential oils during the drying process depended on several factors like temperature and relative humidity (RH) of the drying stream as well as on the product properties.

One of the most important aspects to take into account in the commercialization of plants is their packaging and storage. There is a widespread belief that spices, once dried, possess a long shelf life from a microbiological point of view, which can be attributed to their low water content, thus preventing the growth of almost all microorganisms.

Nevertheless, the organoleptic properties of plants can be remarkably influenced by packaging materials, the storage length and its conditions, mainly temperature, relative moisture and light. Although the effects of drying on the quality of plant materials have been studied in detail (11–13), little information is available for anise hyssop regarding the effects of their drying and storage, this being a topic of great interest for both industry and consumers. It is common to observe that valuable volatiles are fairly stable in the intact plant tissue over the drying process, but they later become affected by storage conditions. In this case, relevant losses of volatile compounds are mainly due to evaporation and oxidative reactions (14).

However, selecting the best drying and storage parameters helps to minimize any loss of volatiles along the drying and storage stages. This work aimed at gaining practical knowledge about the effects of air and oven drying, distillation and storage duration on the essential oil content and composition of anise hyssop aerial parts.

Experimental

Plant material

Experiments were carried out in 2010 at the experimental farm of Tarbiat Modares University, College of Agriculture, at Pycan Shahr (35.43 N, 51.8 E and 1215 m above sea level), Tehran (Iran), a site characterized by a semidry climate, with 229.2 mm annual precipitation. During the experimentation period, the average maximum temperature was 29.3°C, the minimum was −1.7°C and the average humidity of the region was 38%. The aerial parts of anise hyssop were harvested at full flowering stage prior to drying and essential oil extraction.

Drying methods and equipment

The moisture content of aerial parts was measured immediately upon arrival. The initial moisture content was determined by oven drying approximately 5.0 g of the plant material in at 105°C until no further weight loss could be observed.

Fresh aerial parts were dried using the following procedures: (i) air drying in shade with no forced ventilation at room temperature (mean temperature 25±2°C; mean relative humidity 14±4%). In this case, 1 kg of fresh material was spread over an area 1 m² wide; (ii) oven drying in a ventilated oven (Universal Oven, Model UFP 800 RR, Memmert Company, Schwabach, Germany) at two different temperatures (40°C and 60°C).

In all cases, drying was terminated when the material reached a moisture content of about 10%. The moisture content of dried samples was determined in triplicate using a laboratory oven at 105°C. The continuous weighing of samples allowed calculation of their drying kinetics. The moisture content was calculated as the difference between the wet and dry weight divided by the wet weight.

Color analysis

A quantitative evaluation of the color changes in anise hyssop aerial parts (fresh and dried plants before storage) was made by a portable tri-stimulus colorimeter (Minolta Chroma CR-300, Osaka Japan) with a measuring area of 8 mm diameter. A calibration of the colorimeter was made before each measuring series. Five color measurements were taken for each treatment, resulting in numeric values for three chromatic scales (L*, a*, b*). L* is the brightness ranging from no reflection for black (L*=0) to perfect diffuse reflection for white (L*=100). The value a* is the redness ranging from negative values for green to positive values for red. The value b* is the yellowness ranging from negative values for blue to positive values for yellow. The color at the grid origin (a*=0 and b*=0) is achromatic (gray). A special white plate was used to calibrate the chromameter. From values a* and b*, the color attribute of saturation (√a*²+b*²) was calculated. The hue angle (h°) was calculated as h°=180+tan⁻¹(b/a) when a<0 and b>0 (15).
Storage test
The dried plant material was divided into two portions. One was immediately distilled to extract the essential oil; the other portion was stored in sealed polyethylene bags, placed into a box to protect the material against light, and kept refrigerated at 5°C. Samples were taken out and distilled after sixty days of storage.

Distillation time test
To investigate the effect of hydro-distillation duration on the essential oil content and composition, dried aerial parts of anise hyssop underwent hydro-distillation for 120 and 180 minutes in a Clevenger-type apparatus. Thirty grams of dried aerial parts were added to a flask and mixed with 500 mL of distilled water. The flask was then heated at 100°C. The amount of oil was measured in a calibrated tube after direct recovery from the distilling unit without any addition of solvent. The oils were dried over anhydrous sodium sulfate and stored in sealed vials at low temperature (4°C) before analysis.

GC/FID and GC/MS analyses
Gas chromatography/flame ionization detection (GC/FID) analyses were carried out using a Perkin Elmer Clarus 500 GC equipped with a 30 m × 0.32 mm Elite-5MS capillary column (0.25 μm film thickness). Samples (0.5 μL) were injected in split mode (1:30) with a column temperature program of 40°C for 5 minutes, then increased to 280°C at 4°C/minute and finally held at this last temperature for 5 minutes. Injector and detector were set both at 300°C; the carrier gas was He at 2 mL/minute.

The Clarus 500 mass spectrometer (GC/MS) analyses were carried out using a Perkin Elmer Clarus 500 GC equipped with a Clarus 500 mass spectrometer using the same capillary column and chromatographic conditions as for the GC/FID analyses. Samples (0.5 μL) were injected in split mode (1:30). Mass spectra were acquired over 40–500 amu range at 1 scan/second with ionizing electron energy 70 eV. The transfer line was set at 300°C; the carrier gas was He at 1.5 mL/minute.

Identification and quantification of essential oil components
The identification of the oil components was performed by their retention indices (RI) and their mass spectra, by comparison with a NIST database mass spectral library (16), as well as with literature data (17). Authentic reference compounds purchased from Sigma-Aldrich were also used. RIs were calculated using an n-alkane series (C₈–C₃₂) under the same GC conditions as for samples. The relative amount (RA) of individual components of the oil, except for methyl chavicol, were expressed as percent peak area relative to total peak area from the GC/FID analyses of the whole extracts, without the use of correction factors. Pure methyl chavicol from Sigma-Aldrich was then used for the measurement of correction factor (RF) with 3-methylcyclohexanone as internal reference (RF=1.0), and methyl chavicol was than reported as g/100g of the oil.

Statistical analysis
All data were subjected to analysis of variance using the Statistical Analysis System software package (SAS Institute, Cary, NC, USA). When a significant difference was found among different treatments, Duncan’s multiple range tests were performed to determine the differences among the mean values.

Result and discussion
Moisture content curve
The variations of water content of anise hyssop during drying time are shown in Figure 1. The average initial moisture content of anise hyssop was 74.27% on a wet weight basis (wwb), 76.81% (wwb) and 72.14% (wwb) for air-dried (25°C) and oven-dried (40° and 60°C) methods, respectively. The final moisture contents are summarized as follows: samples air dried at room temperature took 75 hours to reach a moisture content of 10.25%, while samples oven dried at 40°C took 60 hours to reach a moisture content of 9.90% and those oven dried at 60°C took 35 hours to reach a moisture content of 9.30%. The time needed was longer for air-dried samples due to the lower operating temperature. There was a clear effect of temperature on the drying kinetics in that as the temperature increased, the drying time decreased. By using the oven-drying (60°C) method, the drying time to the moisture content
of 9.30% (wwb) could be shortened by 53.4%, when compared with air drying (25°C). Oven drying (40°C) shortened the drying time more than 20% when compared with the air-drying (25°C) method. The moisture content of the material was very high during the initial phase of the drying, which resulted in high drying rates with oven drying (60°C) due to the higher moisture diffusion.

It is evident that there was a longer constant rate period in the drying of the anise hyssop by air-drying (25°C) method than oven drying at 40° and 60°C. The drying curves also mostly exhibited a longer falling rate period for oven drying (60°C) than oven drying (40°C) and air drying (25°C).

**Effect of drying on color parameters**

Since the color of the final product is a very important attribute, dried anise hyssop aerial parts should retain the bright green colors of fresh samples. The variation of color is evaluated by parameters \( L^* \), \( a^* \), \( b^* \), \( c^* \) and hue.

The \( L^* \) value represents the change in the lightness level of a sample and is useful to evaluate the brownness and darkness of aerial parts after drying. The \( L^* \) values of anise hyssop aerial parts decreased with drying. The \( L^* \) values of samples oven dried at 40°C were the lowest recorded (Table 1). This may be due to the relatively high temperature coupled to a long drying period, in which the heat possibly diffused from the surface to the interior of the tissues so that the rate of water evaporation on the surface was faster than the diffusion to the surface. Moreover, heat and atmospheric oxygen may have enhanced the enzymatic activity of polyphenol oxidase, causing a browning effect (3). The \( a^* \) values were found to be −6.9, −5.2, −3.9 and −3.5 for the fresh samples, the air-dried at 25°C, the oven-dried at 40°C and that at 60°C, respectively (Table 1). Samples obtained at 25°C, showing a more negative \( a^* \) value, indicated that they were more greenish in color compared with other samples. The loss of green color is mainly due to the degradation of chlorophyll pigments. Degradation of chlorophyll a and b during thermal processing produces color changes from bright green to olive brown typical of pheophytins a and b, due to the loss of Mg²⁺. The major green pigment, the blue green colored chlorophyll a (Chl a) is less stable than the yellow green chlorophyll b (Chl b) so, in heat damaged products, the Chl a/Chl b ratio decreases and the color shifts from green–blue green to green–yellow green. Another possible pathway for chlorophyll breakdown is the loss of phytol, catalyzed by chlorophyllase, with formation of chlorophyllides, which are more sensitive than chlorophylls to the loss of Mg²⁺ (18). The development of brown pigments is observed as a function of drying conditions. As leaves become heated, the intercellular spaces collapse liberating acidic compounds and releasing chlorophylls from the protein complexes. These events promote the change of chlorophylls into pheophytins, providing a substrate for the enzymatic browning (19).

The positive value of \( b^* \) is a measure of the yellowness in aerial parts. The \( b^* \) values of fresh samples were higher than those of dried samples. The air-dried samples showed the highest \( b^* \) values, while lowest \( b^* \) values was observed in samples oven dried at 40°C (Table 1). Chroma (\( c^* \)) describes the vividness or dullness of a color, and the drying method also affected this trait of the anise hyssop aerial parts. Fresh samples showed the highest \( c^* \) values (18.9), followed by those air dried (25°C) and oven dried at 60°C, whereas those oven dried at 40°C had a lower \( c^* \) values (Table 1).

The results showed that drying of anise hyssop samples in an oven (40°C) caused a significant decrease in hue angle. This may be due to the high temperature and long drying time. There was no significant difference for values of \( h^\circ \) between samples dried at 25°C and fresh samples, which are 104.5 and 107, respectively. This indicates that the color of these leaves is more similar to the color of the fresh leaves considered a reference (Table 1).

These results show that oven drying at 40°C caused color darkening. Therefore, relatively long drying times and high temperatures are believed to be the main factor in color changes in leaves. Previous studies also reported that drying of aromatic and medicinal plants at

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**Table 1.** The \( L^* \), \( a^* \), \( b^* \), \( c^* \) values and hue angle of fresh and dried anise hyssop samples.

<table>
<thead>
<tr>
<th>Drying method</th>
<th>( L^* )</th>
<th>( a^* )</th>
<th>( b^* )</th>
<th>( c^* )</th>
<th>( h^\circ )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh plant</td>
<td>42.3 ± 3.0(^a)</td>
<td>−6.9 ± 0.3(^a)</td>
<td>17.6 ± 1.1(^a)</td>
<td>18.9 ± 1.0(^a)</td>
<td>107.0 ± 0.3(^b)</td>
</tr>
<tr>
<td>Air drying (25°C)</td>
<td>39.4 ± 1.5(^ab)</td>
<td>−5.2 ± 0.1(^b)</td>
<td>17.0 ± 0.9(^ab)</td>
<td>17.8 ± 0.9(^a)</td>
<td>104.5 ± 0.7(^b)</td>
</tr>
<tr>
<td>Oven drying (40°C)</td>
<td>36.9 ± 0.7(^b)</td>
<td>−3.9 ± 0.3(^c)</td>
<td>15.2 ± 1.0(^b)</td>
<td>15.7 ± 1.0(^b)</td>
<td>101.8 ± 0.5(^c)</td>
</tr>
<tr>
<td>Oven drying (60°C)</td>
<td>39.7 ± 0.9(^ab)</td>
<td>−3.5 ± 0.2(^c)</td>
<td>17.0 ± 0.1(^ab)</td>
<td>17.4 ± 0.1(^ab)</td>
<td>111.4 ± 1.4(^a)</td>
</tr>
</tbody>
</table>

Note: Mean value ± standard deviation within the same column with the different following letters are significantly different (\( p<0.01 \)). See text for explanation of abbreviations.
high temperature did not maintain original color values and caused considerable darkening (3).

Essential oil yield

Figure 2(A) presents the effects of drying methods on the essential oil yield of anise hyssop aerial parts on a dry weight basis. Results showed that the oil yields were significantly affected (***p<0.0001) by the drying procedure. Oven drying at 60°C badly affected the essential oil content. With this kind of treatment, all oil was lost, so that no parameters could be further measured and compared. The plant materials dried at room temperature (25°C) showed the highest essential oil content (2.2%), whereas it was lower in those oven dried at 40°C (1.6%).

Comparing essential oil yields obtained by other authors with samples both oven and infrared dried at 40°C (20) in Finland with those obtained in this study, a substantial difference in their amounts has been found out. This might be attributed to the weather conditions under which anise hyssop was grown before harvest. Those authors recommended infrared radiation drying for anise hyssop, since it is gentler and shortens the processing time. In earlier investigations in Iran and India, the essential oil content in the aerial parts of anise hyssop was reported to be in the range of 0.1–1.9% (21, 22). In addition, Omidbaigi and Mahmoudi (4) reported an essential oil content of 1.6–2.3% in anise hyssop plants kept under water stress. Thus, the essential oil content observed in the present study was within the range reported in the previous experiments in Iran.

In general, the drying of plant material caused either an increase (23) or a decrease (24) in the essential oil yield. Indeed, according to Moyler (25), many compounds are dragged to the leaf surface by the evaporating water during drying, and are consequently lost. On the other hand, it seems that most of the essential oil components of anise hyssop are stored near the leaf surface; it is worth noting that compounds in that area have been reported to be considerably affected by the drying methods (26).

Some authors stated that drying plant material in oven took several days (six to ten days), so the time in which essential oils are lost by diffusion in the drying atmosphere is longer in the case of oven drying compared with infrared drying, which takes only a few hours (3–5 hours) (20). In contrast, the results here presented showed that the rise in temperature was more determining than the drying duration, since the essential oil content of plant material dried at room temperature was higher than that from oven-dried material. It seems that oil glands became broken in oven drying, especially at high temperature (60°C). Our idea was confirmed by results obtained in another paper (3) on basil.

Figure 2. The effect of drying methods (A), storage (B) and distillation times (C) and their interactive effects (D) on the essential oil content of anise hyssop.
The oil yield of anise hyssop was affected mainly by storage time. Extraction of essential oil immediately after drying yielded higher oil content (2.2%), compared with extraction after a two-month storage (1.6%) (Figure 2B). This result was in agreement with previous works on tarragon leaves (27) and rosemary (28). However, the mechanisms underlying this occurrence are not yet clear.

In addition, the distillation time had not a significant effect on the essential oil content of anise hyssop. As expected, the highest oil yield was obtained by hydro-distillation for 3 hours (Figure 2C). The effects of distillation time on the essential oil content and composition of Mentha piperita were also previously studied (29) and were in accordance with our results.

Interactive effects of drying methods, storage and distillation times were not significant on essential oil yields (Figure 2D). Nevertheless, the highest essential oil content was observed in samples that underwent air drying and were extracted immediately.

**Essential oil composition**

Table 2 reports the quali-quantitative composition of the volatiles isolated from the dried aerial parts of anise hyssop. Figure 3 reports a representative GC trace of the volatile oil of *A. foeniculum*. Twelve components were identified in the essential oils obtained by different drying methods, storage and distillation times, representing 99.2–99.9% of the oils. Compounds have been listed in order of elution on a DB-5 capillary column. All compounds, except for methyl chavicol, were expressed as percent peak area relative to total peak area from the GC/FID analyses of the whole extracts, without the use of correction factors. Area normalization with response factor (RF) and internal standard method has been carried out for exact quantification of the most abundant compound, methyl chavicol, and results expressed as g/100g. RF has been measured by injecting solutions at different concentration of standard compound, and each standard solution was chromatographed consecutively for three runs. As internal standard, a stock solution (10 g/100 g) of 3-methylcyclohexanone has been added either to the standard solution (100 μL diluted to 1 mL of solution containing the standard) or to the oil samples (100 μL of oil added with 100 μL of 3-methylcyclohexanone solution and diluted in diethyl ether to 1 mL). RF has

![Gas chromatography/flame ionization detection (GC/FID) trace of the volatile oil of *Agastache foeniculum*. IS, internal standard (3-methylcyclohexanone). For peak identification, see Table 2.](image)

Table 2. Composition of the essential oil of *Agastache foeniculum* under the different effect of drying methods, storage and distillation times.

<table>
<thead>
<tr>
<th>#</th>
<th>Compound namea</th>
<th>R1b</th>
<th>RIc</th>
<th>After drying</th>
<th>Oven drying</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2 h 3 h 2 h 3 h</td>
<td>2 h 3 h 2 h 3 h</td>
</tr>
<tr>
<td>1</td>
<td>1-octen-3-ol</td>
<td>974</td>
<td></td>
<td>0.1 0.1 0.2 0.2</td>
<td>0.2 0.1 0.1 0.1</td>
</tr>
<tr>
<td>2</td>
<td>3-octanone</td>
<td>979</td>
<td>986</td>
<td>tr tr tr tr</td>
<td>tr tr tr tr</td>
</tr>
<tr>
<td>3</td>
<td>limonene</td>
<td>1024</td>
<td>1025</td>
<td>1.0 1.0 1.2 1.1</td>
<td>0.9 0.8 1.0 1.4</td>
</tr>
<tr>
<td>4</td>
<td>linalool</td>
<td>1095</td>
<td>1100</td>
<td>tr – tr tr</td>
<td>tr tr tr tr</td>
</tr>
<tr>
<td>5</td>
<td>1-octen-3-ol acetate</td>
<td>1110</td>
<td>1109</td>
<td>0.1 tr tr 0.1</td>
<td>0.1 0.1 0.1 0.1</td>
</tr>
<tr>
<td>6</td>
<td>methyl chavicol</td>
<td>1195</td>
<td>1199</td>
<td>97.8 97.9 98.0 98.1</td>
<td>97.5 97.7 97.7 97.2</td>
</tr>
<tr>
<td>7</td>
<td>β-caryophyllene</td>
<td>1417</td>
<td>1412</td>
<td>0.4 0.4 0.3 0.3</td>
<td>0.4 0.5 0.4 0.4</td>
</tr>
<tr>
<td>8</td>
<td>α-humulene</td>
<td>1452</td>
<td>1448</td>
<td>tr tr tr tr</td>
<td>tr tr tr tr</td>
</tr>
<tr>
<td>9</td>
<td>germacrene D</td>
<td>1484</td>
<td>1474</td>
<td>0.1 0.1 0.1 0.1</td>
<td>0.1 0.1 0.1 0.1</td>
</tr>
<tr>
<td>10</td>
<td>bicyclogermacrene</td>
<td>1500</td>
<td>1489</td>
<td>tr tr tr tr</td>
<td>tr tr tr tr</td>
</tr>
<tr>
<td>11</td>
<td>δ-amorphene</td>
<td>1511</td>
<td>1513</td>
<td>tr tr tr tr</td>
<td>tr tr tr tr</td>
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<tr>
<td>12</td>
<td>caryophyllene oxide</td>
<td>1582</td>
<td>1574</td>
<td>tr tr tr tr</td>
<td>tr tr tr tr</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td></td>
<td>99.5 99.7 99.9 99.9</td>
<td>99.2 99.3 99.5 99.3</td>
</tr>
</tbody>
</table>

Note: aCompounds listed in order of elution of Elite-5MS capillary column; bRetention index (RI) on Elite-5MS calculated by using n-alkane series from C8 to C32; cRI from literature data (see references); dValue expressed as g/100g of the oil; tr, traces (<0.1%); >0.1% quoted to nearest 0.1%.
been measured (RF=1.0) and used for quantification of methyl chavicol in the samples.

The major compound was methyl chavicol (97.2–98.1 g/100g), followed by limonene (0.7–1.4%). The other components were β-caryophyllene (0.3–0.5%), 1-octen-3-ol (0.1–0.2%), 1-octen-3-ol acetate (0.1%), germacrene D (tr–0.1%), carophyllene oxide (tr–0.1%), and 3-octanone, linalool, α-humulene, bicyclogermacrene and δ-amorphene all detected in traces amount (<0.1%). The drying method caused some minor variation of the relative proportions of the components. The major compounds, methyl chavicol and limonene, showed no major variations due to the procedure followed; however, the highest amount of methyl chavicol was observed in the air-dried sample after two months of storage, followed by a 3-hour distillation. These results were in agreement with those obtained with other aromatic plants (12). Methyl chavicol and limonene have been found to be the major constituents in the essential oil of *A. foeniculum* in earlier studies (4, 21). Methyl chavicol is a phenylpropanoid and synthesized from the amino acid phenylalanine via the shikimate pathway (1). So it seems that this compound is not changed with different drying temperature, distillation time and storage and its synthesis is mainly controlled by the genetics of the plants (1).

Drying may cause an oxidation process and chemical rearrangements, which lead to the disappearance of some oil constituents and to the appearance of novel molecules. However, the change in the concentration of the essential oil during drying and storage depends on the type of compound, the plant species, the drying time and temperature and the storage conditions (8). Some researchers reported only slight alterations in the volatile composition of wormwood after drying both at room temperature and at 30°C (30). However, other authors reported lower levels of monoterpenes and higher levels of certain sesquiterpenes in dill (6) and in ginger (10).

In summary, the essential oil content and the color of anise hyssop aerial parts change during drying. As the oven drying at 40°C caused color darkening and oven drying at 60°C badly affected the essential oil content, the optimal drying temperature was 25°C. The essential oil content was also decreased with a two-month storage. The distillation times had not significant effect on essential oil content of anise hyssop. Drying methods, as well as storage and distillation times, did not cause any relevant change in the relative proportions of the isolated volatile components. However, air drying (25°C), and the immediate extraction of essential oil with a 2-hour distillation appeared to be the best post-harvest treatment of anise hyssop in order to maximize the amount of essential oil.

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**References**


