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Essential Oil Yield and Composition of Garden Sage as a Function of Different Steam Distillation Times

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Abstract. **Garden sage (*Salvia officinalis* L.) is a medicinal, culinary, ornamental, and essential oil plant with a wide range of ecological adaptation. Garden sage essential oil traditionally is extracted by steam distillation from the above-ground biomass and has widespread applications as an aromatic agent in the food and pharmaceutical industries as well as in perfumery and cosmetics. The hypothesis of this study was that the steam distillation time (DT) may significantly affect essential oil yield and composition of garden sage and, therefore, DT could be used as a tool to obtain oil with different composition. Therefore, the objective was to evaluate the effect of various steam DTs (1.25, 2.5, 5, 10, 20, 40, 80, and 160 minutes) on garden sage oil yield and composition. Most of the oil in the garden sage dry herbage was extracted in 10-minute DT; extending DT up to 160 minutes did not significantly increase oil yields. Overall, 39 oil constituents were identified in the garden sage essential oil. Fourteen oil constituents with the highest concentration in the oil were selected for statistical analyses. Monoterpenes represented the major percentage (58.2% to 84.1%) of oil composition followed by sesquiterpenes (4.0% to 16.1%) and diterpenes (0.3% to 7.6%). Overall, the monoterpene hydrocarbons (α-pinene, camphene, β-pinene, myrcene, and limonene) were eluted early in the steam distillation process, which resulted in their high concentration in the oil at 5- to 10-minute DT and relatively low concentrations in the oil obtained at 160-minute DT. In general, the concentration of sesquiterpenes (β-caryophyllene, α-humulene, and verdifloral) increased with increasing duration of the DT and reached their respective maximum concentrations in the oil at 160-minute DT. The relative concentrations of major constituents, camphor and cis-thujone, in the oil obtained at 2.5-minute DT were higher than in the oils obtained at longer DT. Therefore, if oil with high concentrations of camphor and cis-thujone is desirable, garden sage dried biomass ought to be steam distilled for 2.5 to 5 minutes and the oil collected. If oil with a high concentration of monoterpene hydrocarbons and a high concentration of oxygenated monoterpenes is desirable, then garden sage should be distilled for 20 minutes. If oil with a high concentration of the diterpene manool is desirable, then garden sage should be steam-distilled for 80 minutes. If oil with a high concentration of sesquiterpenes is desirable, then garden sage should be steam-distilled for 160 minutes. The duration of steam distillation can be used as an economical method to obtain garden sage oil with a different chemical composition. The regression models developed in this study can be used to predict garden sage oil yield and composition distilled for various amounts of time and to compare literature reports in which different durations of DT were used.**

Garden sage (*Salvia officinalis* L.) is a small herbaceous aromatic, medicinal, and culinary plant from the Lamiaceae family (Pederson, 2000). Garden sage essential oil is extracted from the whole above-ground herbage and has numerous applications as aromatic and medical ingredients in various products such as cosmetic items and also in the food and pharmaceutical industries (Heath, 1978; Tucker et al., 1980). Most of the commercial production of garden sage essential oil is concentrated in countries in eastern Europe, Russia, and in the Mediterranean region (Atanassova and Nedkov, 2004).

Ancient Greeks and Romans have been cultivating and using garden sage as a medicinal and culinary herb for some 2000 years. The plant has and continues to be used in the traditional medicine in many countries, especially in the Mediterranean region. For example, Bulgarian traditional medicine has been using garden sage leaves to improve digestion, to treat stomach cataracts and ulcers, to treat some liver and kidney diseases and inflammations, and to decrease milk in nursing mothers at the end of breastfeeding (Stojanov, 1973). Extract from garden sage also is used for bathing small children with skin inflammations (rashes). Garden sage essential oil has a long history of application in the food and liquor industries (as an aromatic vector in salami, cheese, and wine), in the pharmaceutical industry, and in perfumery and cosmetics (Stojanov, 1973). Garden sage plant extract has also been reported to treat Alzheimer's disease (Akhondzadeh et al., 2003) and can be used to derive plant-based antibiotic and treat various bacterial diseases in humans (Delamare et al., 2007).

Garden sage essential oil is traditionally extracted by steam distillation (Topalov, 1962). Although there are numerous reports on garden sage essential oil composition, there is no agreement in the literature regarding the optimal steam DT for the extraction of the essential oil from garden sage biomass. We hypothesized that the duration of the steam distillation process would have a significant effect on garden sage essential oil yield and composition. Furthermore, testing a range of DTs may identify the optimal DT for oil yields and to obtain oil with a specific desirable composition.

Indeed, recent reports demonstrated a significant effect of steam DT on the essential oil in other species from the same family such as peppermint (Cannon et al., 2013; Zheljazkov and Astatkie, 2012a), oregano (Zheljazkov et al., 2012a), Japanese cornmint (Zheljazkov and Astatkie, 2012b), and lavender (Zheljazkov et al., 2013). The plants from the Lamiacea family have a similar type of essential oil glands (Hay and Svoboda, 1993), and their essential oil is traditionally extracted by steam distillation (Topalov, 1962). Therefore, the objectives of this study were to evaluate a series of steam DTs for garden sage essential oil extraction and develop regression models to predict oil yield and composition of garden sage oil at any given DT. The findings can also be used to compare reports on garden sage oil yield and

composition in which different DTs have been used.

Materials and Methods

Plant material. Garden sage plants were established in 2006 at the North Mississippi Research and Extension Center at Verona, MS (lat. 34°43′22″ N, long. –88°43′22″ W) using certified seeds of commercially grown Bulgarian cv. Desislava of *Salvia officinalis* L.

Briefly, garden sage transplants were produced in a greenhouse in early spring of 2006 and transplanted out in the field in June 2006 in previously prepared raised beds covered with black plastic mulch. Fertilizers (80 kg·ha^{-1} P_2O and 100 kg·ha^{-1} K_2O,) were applied before land preparation and incorporated into the soil by disking. Nitrogen was applied at 130 kg·ha^{-1}; the rate was based on literature reports. A bed-shaping machine was used to form raised beds (15 cm height, 75 cm wide), to place a drip tape in the middle of the bed at ≈5-cm depth and to cover the bed with black plastic mulch as described previously (Zheljazkov et al., 2012b). Holes in the plastic mulch were made with a propane burner, and garden sage was transplanted in two rows on each bed at 45 cm in-row and 30 cm between-row spacings. The biomass for this DT study was collected in 2010 from well-established 4-year old garden sage plants to provide consistency.

Steam distillation and distillation times. The garden sage was harvested in Aug. 2010, and subsamples of above-ground plant parts (including stems, leaves, and flowers) were dried in a shaded and well-aerated barn. Dried subsamples (250 g each) were extracted in Sept. 2010 by steam distillation in 2-L steam distillation units as described previously in Cannon et al. (2013). In this study, eight different DTs (1.25, 2.5, 5, 10, 20, 40, 80, and 160 min) were performed in random order, each DT in three replications, amounting to 24 separate distillations and 24 oil samples. Each DT was measured from the moment that first drop of essential oil was seen in the separator; at the end of each DT, the power was turned off, the steam was removed, and the separator containing the oil and the water was removed from the distillation unit. The accumulated oil was separated from water, measured on an analytical scale, and kept in a freezer until the gas chromatography analyses were performed. Garden sage essential oil yield (content) was calculated as grams of oil per 100 g of dried garden sage herbage.

Gas chromatography analysis of the garden sage essential oil. The 24 garden sage essential oil samples (representing all DT treatments and replications) were subjected to oil compositional analyses on a gas chromatograph (Hewlett Packard 6890 GC) fitted with an autosampler. The carrier gas was helium, at 40 cm·sec^{-1}, 11.7 psi (60 °C), 2.5 mL·min^{-1} constant flow rate; the injection was split 60:1, 0.5 µL, the injector temperature was 220 °C, and the oven temperature program was as follows: 60 °C for 1 min and 10 °C·min^{-1} to 250 °C. The column was HP-INNOWAX (crosslinked polyethylene glycol; 30 m × 0.32 mm × 0.5 µm); the flame ionization detector temperature was 275 °C. Individual peaks representing different oil constituents were identified using internal standards (for all the major constituents) by retention time and also using mass spectroscopy.

The concentration of the individual oil constituents is expressed as percentage of the total oil. The yield of individual oil constituents was calculated from the oil yield and the concentration of that particular constituent at a given DT.

The following 39 constituents were identified in the garden sage oil: cis-salvene, cis-3-hexenol, transsalvene, hexanol, santolina triene, tricyclene, α–thujene, α-pinene, camphene, sabinene, β-pinene, 1-octen-3-ol, myrcene, hexenyl acetate, paracymene, limonene, eucalyptol, cis-sabinene hydrate, paracymenenene, cis-thujone, transthujone, isothujol, camphor, borneol, menthol, 4-terpineol, paramethyl acetophenone/paracymen-8-ol, α-terpineol, myrtenol, bornyl acetate, sabinyl acetate, myrtenyl acetate, β-caryophyllene, α-humulene, allo-aromadendrene, caryophyllene oxide, veridifloral, humulene epoxide II, and manool. Of these, 14 oil constituents with the highest concentration in the oil were selected for statistical analyses and presentation.

Statistical analysis. The effect of DT on essential oil content and the concentration and yield of α-pinene, camphene, β-pinene, myrcene, limonene, eucalyptol, cis-thujone, transthujone, camphor, borneol, bornyl acetate, β-caryophyllene, α-humulene, veridifloral, humulene epoxide II, and manool was determined using a one-way analysis of variance. For each response, the validity of model assumptions was verified by examining the residuals as described in Montgomery (2013). The effect of DT was significant ($P < 0.05$) on all yield responses and all concentration responses other than transthujone and borneol. For the responses with a significant DT effect, multiple means comparison was completed using Duncan's multiple range test at the 5% level of significance, and letter groupings were generated. The analysis was completed using the GLM Procedure of SAS (SAS Institute Inc., 2010).

Regression analysis to determine the relationship between DT and the concentration of each of the constituents suggested that 10 of the concentrations (essential oil content and the concentration of α-pinene, camphene,

Table 1. Mean essential oil (EO) content (in g/100 g of dried garden sage herbage, %) and the concentrations of the oil constituents α-pinene, camphene, β-pinene, myrcene, limonene, eucalyptol, cis-thujone, camphor, bornyl acetate, β-caryophyllene, α-humulene, veridifloral, humulene epoxide II, and manool (in % of the total oil) obtained from eight (for EO) and seven (for the constituents) distillation times (DTs).

DT	EO content	α-pinene	Camphene	β-pinene	Myrcene	Limonene	Eucalyptol	Cis-thujone	Camphor	Bornyl acetate	β-caryophyllene	α-humulene	Veridifloral	Humulene epoxide II	Manool
(min)	(g oil/100 g dry herbage)	----------Percent of individual constituents of the total oil----------													
1.25	0.058 c[z]														
2.5	0.125 c	3.2 b	5.6 ab	1.7 bc	1.0 c	2.4 bc	6.7 ab	29.1 a	27.3 a	1.3 bcd	1.2 c	2.7 c	0.8 d	0.7 bcd	0.3 e
5	0.234 b	4.7 a	7.7 a	2.3 a	1.3 a	2.8 ab	7.4 a	26.4 ab	24.2 abc	1.1 d	1.3 c	2.9 c	0.9 d	0.5 d	0.7 de
10	0.264 ab	3.6 ab	6.7 ab	2.1 ab	1.3 a	2.8 a	6.8 ab	25.8 b	24.8 ab	1.2 cd	1.9 b	4.1 bc	1.6 cd	0.5 d	1.1 d
20	0.330 a	3.3 ab	5.9 ab	1.9 abc	1.2 ab	2.6 abc	6.5 bc	26.1 b	23.9 abc	1.3 bcd	2.1 ab	4.5 b	2.3 c	0.6 cd	2.2 c
40	0.263 ab	3.0 b	5.1 b	1.7 bc	1.2 abc	2.6 abc	5.8 cd	25.7 b	21.7 bcd	1.4 abc	2.6 ab	5.5 ab	3.3 b	0.8 bc	3.5 b
80	0.301 ab	2.6 b	4.7 b	1.6 bc	1.2 abc	2.5 abc	5.2 de	26.0 b	20.8 cd	1.5 ab	2.7 a	6.2 a	4.0 b	0.9 ab	7.6 a
160	0.238 ab	2.4 b	4.1 b	1.5 c	1.0 bc	2.2 c	4.0 e	23.5 b	18.3 d	1.5 a	2.7 a	6.5 a	5.7 a	1.2 a	0.3 e

[z]Within each column, means sharing the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

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β-pinene, eucalyptol, camphor, β-caryophyllene, α-humulene, veridifloral, and humulene epoxide II) can be adequately modeled (satisfying all convergence of iteration criteria and model assumptions as described in Bates and Watts, 2007) using either the Asymptotic [Eq. (1)] or Power [Eq. (2)]. There was no clear relationship between DT and the concentration of the other seven constituents. The relationship between DT and the yields of six constituents (bornyl acetate, β-caryophyllene, α-humulene, veridifloral, humulene epoxide II, and manool) can be adequately modeled by the Asymptotic [Eq. (1)] or Power [Eq. (2)], or Concave [Eq. (3)] model. There was no clear relationship between DT and the yields of the other 10 constituents. All these three models are nonlinear (Bates and Watts, 2007). The parameters of these nonlinear regression models were estimated iteratively as described in Bates and Watts (2007) using the NLIN Procedure of SAS (SAS Institute Inc., 2010).

$$Y = \theta_1 - \theta_2 e^{-\theta_3 x} + \varepsilon \quad [1]$$

$$Y = \theta_1 x^{\theta_2} + \varepsilon \quad [2]$$

$$Y = \theta_1 \ln(x - \theta_2) + \varepsilon \quad [3]$$

where Y is the dependent (response) variable, x is the independent (distillation time) variable, and the error term ε is assumed to have normal distribution with constant variance. The model parameters are represented by θ (instead of by β used for linear models) to highlight that these models are nonlinear (Bates and Watts, 2007).

Results

Distillation time had a significant effect on essential oil yield (content) of garden sage (Table 1). Overall, the oil yields in different DTs ranged from 0.06% to 0.33% based on the dry weight. The essential oil yields increased with increasing DT from 1.25- to 10-min DT; after that, there was no significant increase in oil yields. Monoterpenes represented the major percentage (58.2% to 84.1%) of oil composition followed by sesquiterpenes (4.03% to 16.12%) and diterpenes (0.31% to 7.61%). Cis-thujone (23.5% to 29.1% concentration range of the total oil) and camphor (18.3% to 27.3% range of the total oil) were the major oil constituents (Table 1). Overall, increasing the DT up to 160 min resulted in decreased concentrations of cis-thujone and camphor in the oil.

All of the monoterpene hydrocarbons (α-pinene, camphene, β-pinene, myrcene, and limonene) were eluted early in the steam distillation process. Therefore, the highest concentrations of these constituents in the oil were at 5- to 10-min DT and the lowest at 160-min DT (Table 1; Fig. 1). The concentration of eucalyptol (1,8 cineole) (4.0% to 7.4% of the total oil) followed the same pattern as monoterpene hydrocarbons depending on the duration of the

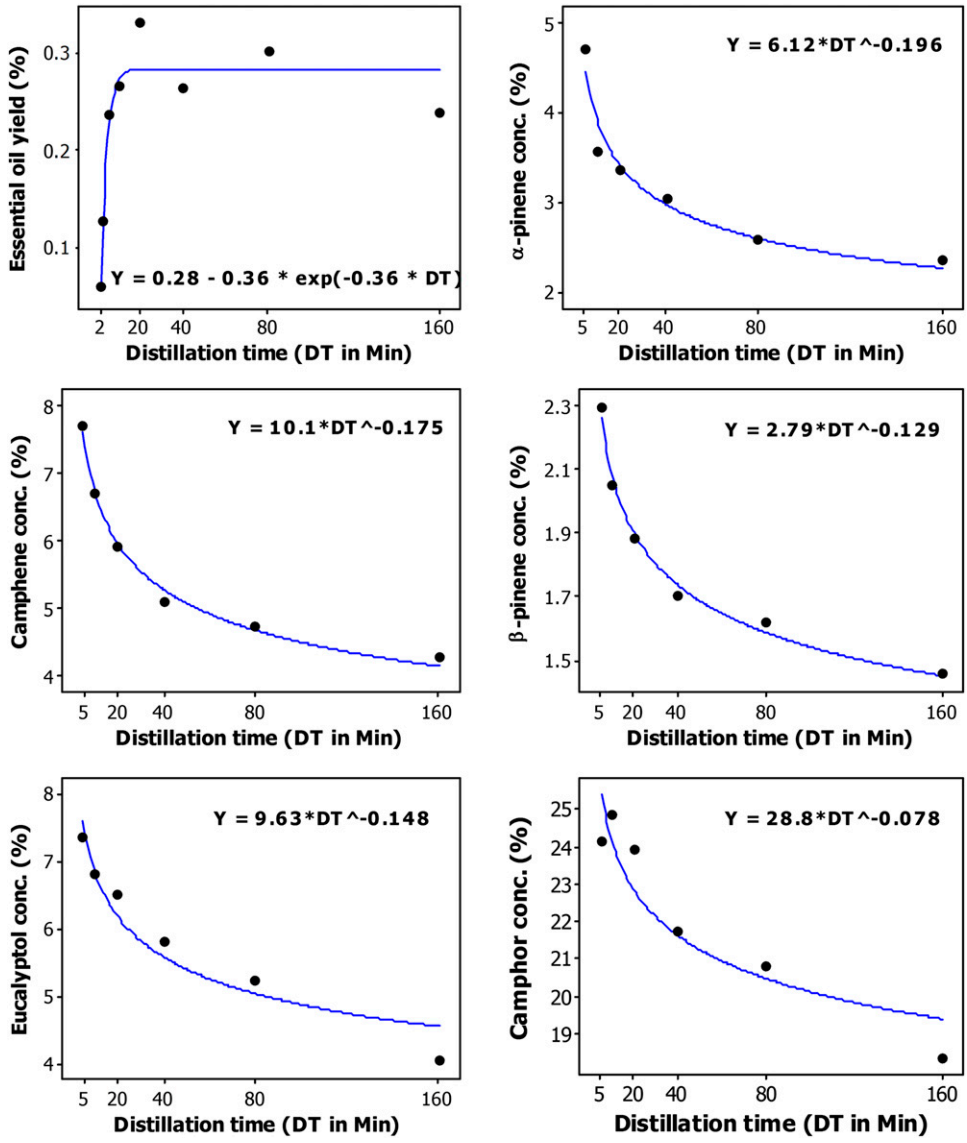

Fig. 1. Plot of distillation time (DT) vs. essential oil (EO) content (starting at DT = 1.25 min) and the concentration of five constituents (starting at DT = 5 min) along with the fitted Asymptotic (for EO) and Power (for the others) nonlinear regression models. Equations of the fitted models are shown within each plot.

DT (Table 1; Fig. 1). In contrast, the concentration of bornyl acetate (1.1% to 1.5% concentration range in the oil) was lowest at 5- to 10-min DT and increased with increase in DT.

In general, the concentration of sesquiterpenes (β-caryophyllene, α-humulene, and verdifloral) increased with increase in DT and reached their respective maximum concentrations in the oil at 160-min DT, whereas the other sesquiterpene, humulene epoxide II, increased gradually after 10-min DT (Table 1; Fig. 2). The concentration of β-caryophyllene, α-humulene, verdifloral, and humulene epoxide II at 160-min DT were 2.71%, 6.50%, 5.74%, and 1.17%, respectively (Table 1). The concentration of manool (a diterpene) increased gradually from shorter DT to longer DT until 80-min DT and decreased sharply at 160-min DT (Table 1). The concentrations of transthujone (mean of 9.22%) and borneol (mean of 1.52%) were unaffected by the DT.

The yields of the oil constituents were calculated from the oil yield and the concentration of each constituent in the oil at any given DT (Table 2). Generally, the yields of the monoterpene hydrocarbons constituents (α-pinene, camphene, β-pinene, myrcene, and limonene) were higher at 5-min DT relative to the 2.5-min DT; increasing DT to 80 min did not significantly increase yields relative to the respective yields at 5-min DT (Table 2).

The yield of the oxygenated monoterpenes (eucalyptol, cis-thujone, transthujone, camphor, borneol, and bornyl acetate) reached their respective maximum at 5- to 20-min DT (Table 2). The maximum yields of the sesquiterpenes (β-caryophyllene, verdifloral, α-humulene, and humulene epoxide II) were reached later, at 20- to 80-min DT (Table 2; Fig. 3). The yield of manool (a diterpene) increased stepwise with an increase in DT and reached a maximum at 160-min DT (Table 2; Fig. 3).

As shown in Figures 1 and 2, the relationship between DT and essential oil yield as well as between DT and the concentrations of nine constituents were very well described by either the Asymptotic model or the Power model. The relationship between DT and the yields of six constituents were also described by either the Asymptotic model or the Power model (Fig. 3). The fitted models given in each plot of Figures 1, 2, and 3 can be used to predict essential oil yield or the concentration or the yield of the constituents for any given DT within the studied range (2.5 to 160 min) as well as a little beyond 160 min.

Discussion

The effect of DT was significant on yield and on concentration of oil constituents responses with the exception of transthujone and borneol (which gave an overall mean of 9.22% and 1.52%, respectively), hence confirming the hypothesis of the study.

The essential oil content (0.06% to 0.28%) of garden sage in this study was lower than in previous reports (Farhat et al., 2009; Perry et al., 1999; Pitarevic et al., 1984). The DTs used by Farhat et al. (2009) and by Pitarevic et al. (1984) were 180 min, whereas the DT used by Perry et al. (1999) was 60 min. In our study (2.5- to 160-min DT), the oil yield was lower than that found in the 60-min DT (Perry et al., 1999). However, these reports were on experiments conducted in different geographical regions and on different cultivars, supporting the notion that factors such as geographical origin, ecological conditions, and genetic factors influence the relative proportion of the oil constituent and yield (Farhat et al., 2009; Mockuté et al., 2003). As a result of the variation of geographical regions, climate conditions, organ age, seasonality, and DT, and also the existence of chemotypes within the species, garden sage essential oil composition may not match the profile defined by the standard ISO 9909 (Farhat et al., 2009) described as follows: α-thujone (18% to 43%), β-thujone (3% to 8.5%), camphor (4.5% to 24.5%), 1,8-cineole (5.5% to 13%), humulene (0% to 12%), α-pinene (1% to 6.5%), camphene (1.5% to 7%), limonene (0.5% to 3%), linalool [free and esterified (1% maximum)], and bornyl acetate (2.5% maximum). In our study, the concentrations of camphene and camphor exceeded those defined by the ISO 9909 standard, whereas the concentration of α-humulene was below the ISO 9909 standard. The concentration of all the other oil constituents in our study was within their respective range of the ISO standard.

The essential oils of our study contained large proportions of oxygenated constituents (52.48% to 89.03%) represented by oxygenated monoterpenes, oxygenated sesquiterpenes, and oxygenated diterpenes. Our results are in agreement with those of Avato et al. (2005), Farhat et al. (2009), Pinto et al. (2007), and Santos-Gomes and Fernandes-Ferreira (2001) who reported the oxygenated monoterpenes as the major compounds in garden sage.

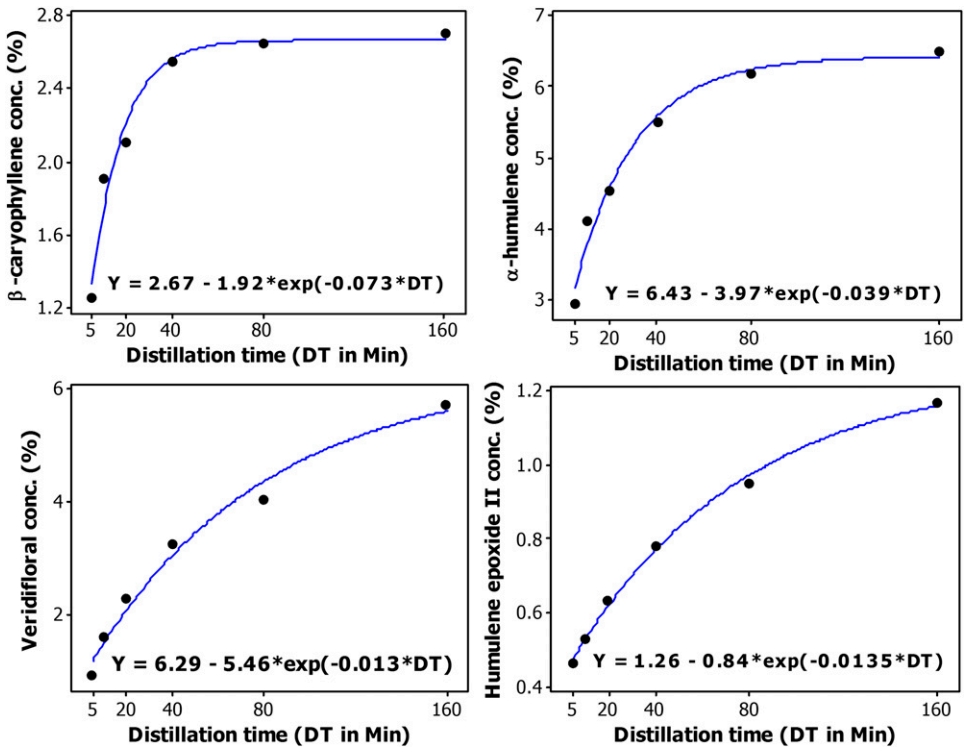

Fig. 2. Plot of distillation time vs. the concentration of four constituents along with the fitted Asymptotic nonlinear regression models. Equations of the fitted models are shown within each plot.

Table 2. Mean yield (mg per 100 g of dried garden sage herbage) of α-pinene, camphene, β-pinene, myrcene, limonene, eucalyptol, cis-thujone, transthujone, camphor, borneol, bornyl acetate, β-caryophyllene, α-humulene, veridifloral, humulene epoxide II, and manool obtained from seven distillation times (DTs).

DT (min)	α-pinene	Camphene	β-pinene	Myrcene	Limonene	Eucalyptol	Cis-thujone	Trans-thujone	Camphor	Borneol	Bornyl acetate	β-caryo phyllene	α-humulene	Veridifloral	Humulene epoxide II	Manool
	(mg per 100 g of dried garden sage herbage)															
2.5	4.2 b[z]	7.4 b	2.2 b	1.3 c	3.0 b	8.5 c	36.5 b	11.1 c	33.7 c	2.0 c	1.6 d	1.4 c	3.3 d	1.0 e	0.9 c	0.4 f
5	11.1 a	17.9 a	5.4 a	2.9 ab	6.4 a	17.2 a	61.9 ab	21.9 ab	56.6 abc	3.4 bc	2.7 cd	2.9 c	6.8 c	2.1 d	1.1 c	0.7 f
10	9.3 ab	17.6 a	5.4 a	3.4 ab	7.4 a	17.9 a	68.0 a	24.8 ab	65.8 ab	4.2 ab	3.1 bc	5.1 b	9.9 c	4.2 c	1.4 c	1.7 e
20	11.0 a	19.5 a	6.2 a	4.1 a	8.4 a	21.4 a	86.0 a	31.4 a	79.0 a	5.2 a	4.1 ab	7.0 a	14.9 b	7.5 b	2.1 b	3.5 d
40	8.1 ab	13.5 ab	4.5 ab	3.1 ab	6.8 a	15.3 ab	67.8 a	26.0 ab	57.3 abc	3.8 ab	3.6 abc	6.7 ab	14.3 b	8.5 b	2.0 b	5.6 c
80	7.9 ab	14.5 ab	4.9 a	3.5 ab	7.5 a	15.8 ab	78.1 a	26.3 ab	62.8 ab	4.5 ab	4.4 a	7.9 a	18.5 a	12.0 a	2.9 a	10.3 b
160	5.7 ab	10.4 ab	3.5 ab	2.5 bc	5.4 ab	9.7 bc	56.0 ab	20.3 bc	43.7 bc	3.3 bc	3.7 abc	6.4 ab	15.3 ab	13.5 a	2.8 a	17.7 a

[z]Within each column, means sharing the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

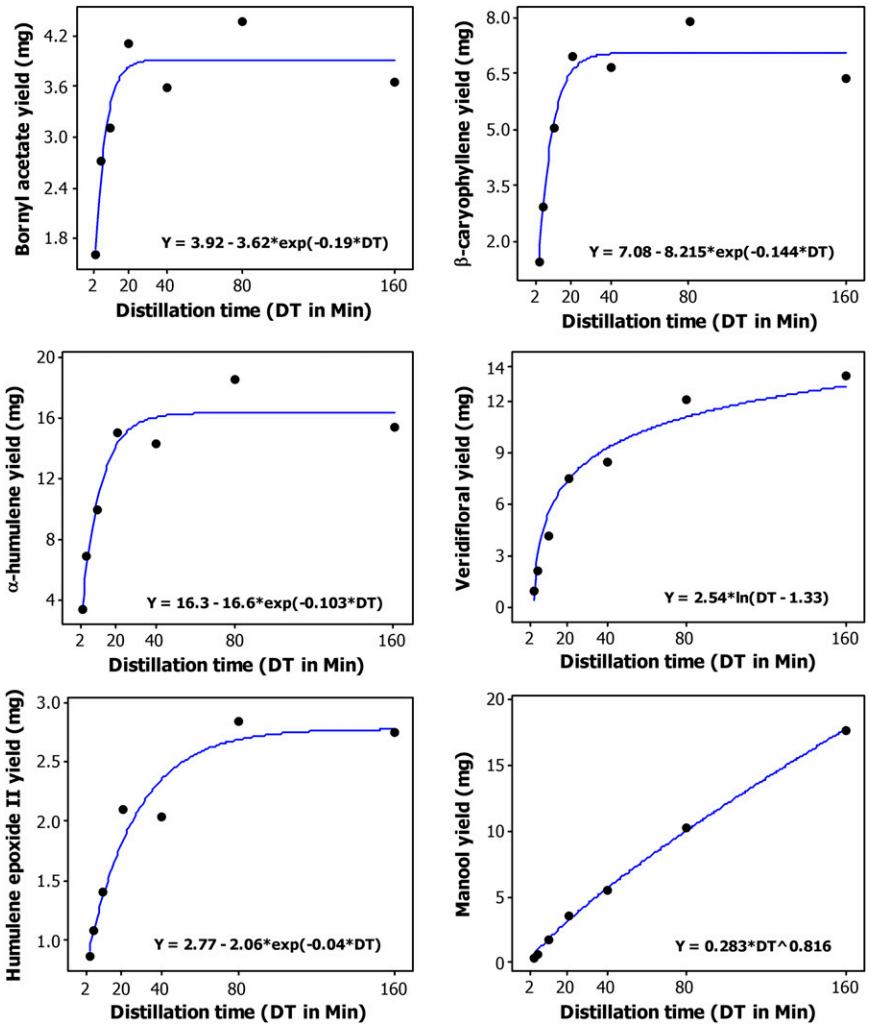

Fig. 3. Plot of distillation time vs. yields (mg) of six constituents along with the fitted Asymptotic (for bornyl acetate, β-caryophyllene, α-humulene, and humulene epoxide II), Power (for manool), and Concave (for veridifloral) nonlinear regression models. Equations of the fitted models are shown within each plot.

Tucker and Maciarello (1990) categorized sage commercial oils in five chemotypes according to the amount of the major compounds: 1) camphor > α-thujone > 1,8-cineole > β-thujone; 2) camphor > α-thujone > β-thujone > 1,8-cineole; 3) β-thujone > camphor > 1,8-cineole > α-thujone; 4) 1,8-cineole > camphor > α-thujone > β-thujone; and 5) α-thujone > camphor > β-thujone > 1,8-cineole. Our results indicate that the cultivar used in this study belongs to the fifth group with α-thujone (23.5% to 29.1%) > camphor (18.3% to 27.3%) > β-thujone (9.22%) > 1,8-cineole (4.04% to 7.36%), which is a very usual chemotype. Cis (α) thujone was the most abundant constituent of garden sage oil in our study, which is in accordance with the results of Mockuté et al. (2003).

Conclusion

The essential oil of dried garden sage biomass can be extracted for a relatively short period of time; maximum essential oil yield was achieved at 10- to 20-min steam DT. Further increase of the duration of the DT up to 160 min did not significantly increase oil yields.

The oil obtained at various DTs had a dissimilar composition, opening the possibility for obtaining oil with a specific and desirable composition. Garden sage oil with high concentrations of camphor and cis-thujone can be obtained by distilling the biomass for 2.5 to 5 min and collecting the oil. Garden sage oil with a high concentration of monoterpene hydrocarbons (α-pinene, camphene, β-pinene, myrcene, and limonene) and a high concentration of oxygenated monoterpenes (eucalyptol, cis-thujone, trans-thujone, camphor, borneol, and bornyl acetate) could be obtained when garden sage is distilled for 20 min. Oil with a high concentration of diterpene manool could be obtained when garden sage is distilled for 80 min. Oil with a high concentration of sesquiterpenes (β-caryophyllene, α-humulene, and verdifloral) could be obtained when garden sage is distilled for 160 min.

DT can be applied as a practical method to obtain garden sage oil with a desirable chemical profile. Regression models were developed

in this study, which can be used to predict garden sage oil yield and composition at specific DTs. These regression models may also be useful when comparing literature reports in which different durations of DT were used.

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