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*Full Length Research Paper*

# The influence of organ and post-harvest drying period on yield and chemical composition of the essential oils of *Etlingera elatior* (Zingiberaceae)

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**Four different parts from *Etlingera elatior* (Jack) R. M. Smith plant were subjected to four different post-harvest drying times (6, 24, 48 and 72 h, respectively) to study the effect of post-harvest drying period on its essential oil yield and composition. The essential oils were extracted using the hydrodistillation method for 5 h. The oils were analyzed by capillary GC and GC/MS. The highest yield was obtained from leaves dried for 48 h (0.16% v/w), pseudostems dried for 24 h (0.013% v/w), rhizomes dried for 6 h (0.047% v/w) and inflorescences dried both for 24 and 72 h (0.1% v/w), respectively. Thirty five compounds were identified from essential oils of leaves, 18 from pseudostems, 28 from rhizomes and 20 from inflorescences, of which 42 compounds had not been detected previously. The most prominent compounds identified with the highest percentages were 2-cyclohexen-1-one (93.42%) from leaves dried for 6 h, 2-tridecanone (51.55%) from pseudostems dried for 24 h, 1-dodecanol from rhizomes (63.64%) dried for 48 h and from inflorescences (54.48%) dried for 24 h.**

**Key words:** *Etlingera elatior,* essential oils, gas chromatography and mass spectrometry (GC-MS), post-harvest drying, Zingiberaceae.

## INTRODUCTION

*Etlingera elatior* (also known as torch ginger or wax flower) is a species of herbaceous perennial plant belonging to the family Zingiberaceae. It is widely cultivated throughout the tropics as spices for food flavorings or just eaten raw as a salad (Classen, 1987) and as ornamentals or cut flowers (Larsen et al., 1999). In Peninsular Malaysia the plant is cultivated for its young flower shoots, which can be eaten raw and used to flavor local dishes such as *laksa asam, nasi kerabu* and *nasi ulam*. A decoction of the fruits and leaves are utilized medicinally to treat earache and healing wounds (Burkill, 1966; Ibrahim and Setyowati, 1999) while the ripe seeds are eaten raw. According to Larsen et al. (1999), the inflorescences are also sold as cut flowers in Australia and Costa Rica. Leaves of *E. elatior*, mixed with other aromatic herbs in water, are used by post-partum women for bathing to remove body odour (Chan et al., 2009).

The mature fruits of *E. elatior* are edible but sour, and are reputed to have antihypertensive activity and the essential oil of this species have been reported to possess significant biological activities (Mohamad et al., 2005). The same authors reported that the species possessed antimicrobial, antioxidant as well as antitumour promoting activities. Chan et al. (2007) stated that the leaves of *E. elatior* had the most outstanding antioxidant properties among five *Etlingera* species investigated. Moreover, Chan et al. (2008) reported that of 26 ginger species, *Etlingera* species had the highest phenolic content and radical activity compared to other Zingiberaceae species. Recently, Chan et al. (2009) reported that freeze-dried leaves of *E. elatior* possess highly significant antioxidant properties.

The presence of biologically active volatile compounds in this plant is highlighted as a new oriental in flavour and fragrances. Research on volatile compounds of *E. elatior* offers promising development of natural resources into

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nutraceuticals, cosmeceuticals and biopharmaceuticals. The essential oil composition of *E. elatior* was previously by Zoghbi et al. (2005) who reported that the major compounds identified in the oils of inflorescence and inflorescence axis of *E. elatior* from Brazil were dodecanol (42.5 and 34.6%), dodecanal (14.5 and 21.5%) and α-pinene (22.2 and 6.3%), respectively. In another study, flavonoids in leaves of *E. elatior* have been identified as kaempferol 3-glucuronide, quercetin 3-glucuronide, quercetin 3-glucoside, and quercetin 3-rhamnoside (Williams and Harborne, 1977). While, Jaafar et al. (2007) reported that the percentage yield of volatile constituents of the leaves, stems, flowers and rhizomes of *E. elatior* were 0.0735, 0.0029, 0.0334 and 0.0021%, respectively.

Awareness on factors that influence the yield and content of essential oil is important especially for the producers (Ames and Mattews, 1968). Harvesting and post-harvesting steps of herbal and aromatic plants are essential to obtain higher essential oil content and better quality.

The main factors to be accounted on harvesting aromatic plants are the harvesting time, drying temperature, and period of drying (José Luiz et al., 2006).

Drying is the most common and fundamental method for post-harvest preservation of medicinal plants because it allows for the quick conservation of the medicinal quail-ties of the plant material in an uncomplicated manner (Muller and Heindl, 2006). Tanko et al. (2005) reported that freshly harvested plants occupy large volumes and pose difficulty in transportation and storage. Hence, the drying of medicinal plants is necessary for handling and preservation purposes, but drying protocols must be designed such as they do not result in a decrease in phytochemical concentrations (Tanko et al., 2005).

Drying the plant materials results in increase of oil yields (Faridah et al., 2010) and accelerates distillation, by improving the heat transfer (Whish and Willams, 1998). Other advantages are the reduction of microbial growth and the inhibition of some biochemical reactions in the dried material (Baritaux et al., 1992; Combrinck et al., 2006). However, oil may be lost due to volatilization and mechanical damage to oil glands during harvesting and drying (Combrinck et al., 2006). Although the composition of essential oil from *E. elatior* has been much studied, the interference of certain factors, especially drying period that influenced the yield and composition of essential oil, until now is little or remains unknown.

With respect to lack of information about drying period effects on essential oil yield, this research was conducted to determine and optimize the extraction of essential oil from *E. elatior*, to determine which parts of this species produces the optimum oil yield and to identify the chemical constituents in the essential oils extracted from this species and to predict the optimum post-harvest drying period prior to distillation.

## MATERIALS AND METHODS

### Plant materials

Fresh samples of *E. elatior* were collected from Agricultural Conservatory Park, University of Putra Malaysia, Malaysia in December 2008. The inflorescences of *E. elatior* were collected from Kampung Jenjarom, Kuala Langat in Selangor. Plant was identified by a plant taxonomist Mr. Shamusul Khamis. Voucher specimen (SK 1746/10) has been deposited at the Herbarium of the Biodiversity Unit, Institute of Bioscience, Universiti putra Malaysia. The fresh plant materials were cleaned with ionized water and chopped into small portions for about 3-5 cm. then, the plant materials were dried at room temperature (27°C), relative humidity 56% and light intensity from 130 to 134 Lux for 6, 24, 48 and 72 h, respectively. Then the fresh and air-dried parts were separately subjected to hydro-distillation for 5 h, using a Clavenger-type apparatus. The oils obtained were dried over anhydrous sodium sulfate (Merck, AR grade) and stored in a dark place until further analysis. The oil yield was estimated on a fresh weight basis (v/w). The experiment was repeated three times under the same conditions.

### GC-MS analysis

Analysis of the essential oil was performed by gas chromatography and mass spectrometry (GC-MS), using Shimadzu GC-17A (Shimadzu Corporation, Kyoto, Japan) chromatograph coupled with a Shimadzu mass spectrometer detector GC-MS QP-5050A (Shimadzu corporation, Kyoto, Japan). The following column and temperature conditions were used: initial temperature 30°C, maximum temperature 300°C, equilibration time 1 min, at the rate of 4°C/min, final temperature 220°C; inlet: split less, initial temperature 280°C, pressure 21 kPa, column flow 0.7 mL/min, linear velocity 30.0 cm/s, split ratio 1/13; column: capillary, 30m x 0.25 mm, film thickness 0.25 µm and helium as carrier gas.

### Identification of compounds

The chemical constituents were identified by matching their mass spectra with those stored in the spectrometer database using the National Institute of Standards and Technology Mass Spectral database (NIST-MS, 1998), using retention indices as a pre-selection routine (Alencar et al., 1984; 1990). The concentrations of the component of the essential oils were obtained from GC peak area by applying appropriate correction factors.

### Statistical analysis

Collected data was analyzed using the SPSS statistical package software version 16.0 (Chicago, USA). One-way analysis of variance (ANOVA) was used to determine the significance of variation among the different treatments for oil yield. The experiments were conducted three times. The same conclusions were drawn from each experiment. Thus, a combined analysis of variance was performed.

## RESULTS AND DISCUSSION

The essential oil yields in leaves were 0.1, 0.1, 0.16 and 0.14 (v/w) for 6, 24, 48 and 72 h, respectively. The highest

yield was from leaves dried for 48 h. The essential oils exhibited colorless and strong smell for drying period of 6 h, light yellow in colour and strong smell for drying period of 24 and 48 h, yellowish in colour and strong smell for drying period of 72 h and yellowish in colour and moderate smell. The essential oil yields in pseudostems were 0, 0.013, 0 and 0.007% (v/w) for 6, 24, 48 and 72 h, respectively. The highest yield was from pseudostems dried for 24 h while pseudostems dried for 6 and 48 h does not produce any oil. The essential oils from pseudostems dried for 24 h exhibited colorless and moderate smell while essential oils from pseudostems dried for 72 h exhibited soft smell and colorless. The essential oil yields in rhizomes were 0.047, 0.02, 0.013 and 0.02 (v/w) for 6, 24, 48 and 72 h, respectively. The highest yield was from rhizomes dried for 6 h. The essential oils from rhizomes dried for 6 h exhibited strong smell and yellowish in colour while the essential oils from rhizome dried for 24, 48 and 72 h, respectively, exhibited light yellow in colour and soft smell. The essential oil yields in inflorescences were 0, 0.1, 0.08 and 0.1% (v/w) for 6, 24, 48 and 72 h, respectively. The highest yields were from inflorescences dried for 24 and 72 h. The essential oils from inflorescences dried for 24 and 48 h exhibited colorless soft smell. The analysis of variance showed that the drying period had a statistically significant effect on the yield of *E. elatior* essential oil ($p<0.05$). The highest yield was obtained in leaves dried for 48 h, pseudostems dried for 24 h, rhizomes dried for 6 h and inflorescences dried both for 24 and for 72 h. The results showed that increasing of the drying period significantly increased the essential oil yield ($p<0.05$). This shows that drying period does have effect on essential oil yield. Still there was an increase and decrease on yield depends on the plant part. The essential oil yields were higher in leaves dried for 48 h, in pseudostems dried for 24 h, in rhizomes dried for 6 h and in inflorescences dried for both 24 and 72 h. This indicated that the ideal drying period varies from plant to plant and among different part of plant. Low amount of essential oil yield in leaves at drying period of 6 and 24 h could be due to moisture content in leaves tissues. The moisture could not fully remove from the plant surface due to the act of barrier that prevents water loss. Consequently, the oil cannot move out from its glands or cells under the barrier. On the other hand, it has been found that fresh leaves of *Lychnophora pinaster* had higher yield (0.71%) than dried ones (0.04%, 35°C) (Blanco et al., 2002). Similarly, reduction on content was also observed after drying leaves. This contradiction in the result may be due to the differences in plant species, secretory structures and their position in plant body and chemical composition of essential oil.

According to Asekun et al. (2007), the dried plant material of *Mentha longifolia* yielded more essential oils than did the fresh leaves materials. While, José Luiz et al. (2006) reported that the essential oil content and yield of *Ocimum basilicum* L. were higher when leaves and inflorescences were fresh and there was a decrease in the content and yield after two days of drying but after drying leaves and inflorescences for four and eight days, there was a tendency of stabilization of the essential oil yield. This suggests that the loss of essential oil at the beginning of drying may be limited to places of easy removal. After that, stabilization on the amounts of essential oil occurs. Stabilization after the fourth drying day supports the existence of places of difficult removal, where essential oil is located, being only removed by hydrodistillation.

Some plant materials might be need to be dried before extraction in order to reduce the moisture content and rupture the glands or cells containing desired essential oil. These dried materials will reduce the growth of microbial and inhibit the biochemical reactions. Some other plant materials need to be distilled immediately after harvested. Drying period also affected the essential oil composition of a plant. Some compounds may be lost or reduced at higher temperature, while others may be increased or showed no obvious trend. This might be due to some chemical transformations during the drying process.

In this study, different chemical compounds have been identified from different drying period for each plant part. GC-MS analysis of *E. elatior* essential oil resulted in the detection of 35 compounds in leaves, 18 compounds in pseudostems, 28 compounds in rhizomes and 20 compounds in inflorescences. The chemical compounds present in essential oil possess different function according to their chemical and physical properties. The chemical compounds identified in the essential oils of all parts of *E. elatior* were listed in Tables 1, 2, 3 and 4.

The major compounds of the oil from leaves and rhizomes dried for 6 h were 2-cyclohexen-1-one (93.42%) and 1-dodecene (41.6%) while, both pseudostems and inflorescences does not produce any oil. The major compounds of the oil from leaves and pseudostems dried for 24 h were β-pinene (39.1%) and 2-tridecanone (51.5%), 1-dodecanol was the major component identified in the oils of both rhizomes and inflorescences dried for 24 h with percentages of 48.15 and 54.48% respectively. β-pinene (37.3%) was the major component of the oil from leaves dried for 48 h. While, 1-dodecanol was the major component found in rhizomes and inflorescences dried for 48h with percentages of 63.64 and 53.12%, respectively. There was no oil produced by pseudostems. The major component of the oil from leaves, rhizomes and inflorescences dried for 72 h was 1-dodecanol with percentages of 42.3, 54.3 and 51.6%, respectively. While, dodecanal (22.43%) was the major component of pseudostems dried for 72 h.

In this study, there were 35 compounds identified in leaves. The major compounds of the oil from leaves dried

**Table 1.** Essential oils constituents of the leaves of *Etlingera elatior* at different post-harvest air drying periods.

| No. | Compound | RI[a] | Area%[b] | | | |
|---|---|---|---|---|---|---|
| | | | 6 h | 24 h | 48 h | 72 h |
| 1 | Limonene | 881.20 | 1.98 | 0.94 | 0.91 | 0.19 |
| 2 | Cyclohexanone | 883.11 | 2.04 | - | - | - |
| 3 | 2-Cyclohexen-1-one | 889.48 | 93.42 | 0.96 | - | - |
| 4 | Cyclohexanol | 898.72 | 0.45 | - | - | - |
| 5 | Acetic acid,phenyl- | 913.04 | 0.28 | - | - | - |
| 6 | n-Hexadecanoic acid | 916.86 | 1.74 | - | - | - |
| 7 | Eicosane | 921.96 | 0.08 | - | - | - |
| 8 | Bicyclo[3.1.1]hept-2-ene | 976.09 | - | 8.07 | 12 | 5.72 |
| 9 | β-pinene | 987.23 | - | 39.1 | 37.3 | 8.16 |
| 10 | Bicyclo[3.1.1]heptan-3-ol | 989.14 | - | 1.39 | - | - |
| 11 | Bicyclo[3.1.1]heptan-3-one | 994.55 | - | 5.05 | 3.31 | 0.38 |
| 12 | 1-Decanol | 1000.28 | - | 0.53 | - | - |
| 13 | Dodecanal | 1007.29 | - | 0.49 | 3.29 | 19.21 |
| 14 | 1-Undecene | 1042.31 | - | 0.66 | - | 1.21 |
| 15 | 2,6,10-Dodecatrien-1-ol | 1054.09 | - | 3.73 | 3.68 | 0.87 |
| 16 | 1,6,10-Dodecatriene | 1064.28 | - | 3.52 | 15.76 | - |
| 17 | α-Caryophyllene | 1068.74 | - | 5.45 | 0.64 | 1.96 |
| 18 | 1-Dodecanol | 1080.20 | - | 16.03 | 10.09 | 42.3 |
| 19 | 1,6,10-Dodecatrien-3-ol | 1088.48 | - | 0.63 | - | - |
| 20 | n-Decanoic acid | 110.90 | - | 1.9 | - | - |
| 21 | 9-Tetradecen-1-ol | 1105.04 | - | 1.17 | - | - |
| 22 | 1,13-Tetradecadiene | 1152.80 | - | 1.08 | - | 2.82 |
| 23 | 1-Tetradecene | 1156.62 | - | 3.51 | 3.41 | - |
| 24 | β-Mycrene | 1163.62 | - | - | 2.36 | - |
| 25 | Bicyclo[3.1.1]hept-3-ol | 1172.22 | - | - | 3.61 | - |
| 26 | 1-Dodecene | 1176.36 | - | - | 0.57 | - |
| 27 | Cyclohexane | 1179.23 | - | - | 1.76 | - |
| 28 | 1,12-Tridecadiene | 1184.00 | - | - | 1.32 | - |
| 29 | Bicyclo[3.1.1]hept-2-ene-2-methanol | 1125.08 | - | - | - | 0.45 |
| 30 | 1-Nonanol | 1228.90 | - | - | - | 0.87 |
| 31 | 2-Undecanone | 1246.41 | - | - | - | 0.61 |
| 32 | Cis-6-Nonenal | 1250.55 | - | - | - | 0.25 |
| 33 | 2-Tridecanone | 1263.28 | - | - | - | 0.91 |
| 34 | Acetic acid, dodecyl ester | 1290.03 | - | - | - | 7.7 |
| 35 | 1-Tetradecanol | 1304.68 | - | - | - | 6.4 |
| | Total | | 99.99 | 94.21 | 100.01 | 100.01 |
| | Yield (%v/w) | | 0.100 | 0.100 | 0.160 | 0.140 |

[a] Retention index; [b] oil abundance in percentage (%).

for 6 h was 2-cyclohexen-1-one (93.42%), while for leaves dried for 24 and 48 h was β-pinene (39.1%) and (37.3%). 1-dodecanol was the major compounds for leaves dried for 72 h. Jaafar et al. (2007) reported that β-pinene (19.17%) was the major compound in leaves essential oil of *E. elatior* with 23 compounds identified. There were 18 compounds identified in pseudostems in this study. The major component of the oil from pseudostems dried for 24 h was 2-tridecanone with 51.5%, while compounds found in pseudostems dried for 72 were dodecanal (22.43%) and 1-dodecene (22.52%) respectively. While, 1,1-dodecanediol, diacetate (34.26%) was reported as the dominant one in stems (Jaafar et al., 2007).

For rhizomes, there were 28 compounds were identified in this study. On the other hand, Jaafar et al.

**Table 2.** Essential oils constituents of the pseudostems of *Etlingera elatior* at different post-harvest air drying periods.

| No. | Compound | RI[a] | Area%[b] | | | |
|---|---|---|---|---|---|---|
| | | | 6 h | 24 h | 48 h | 72 h |
| 1 | n-Hexadecanoic acid | 916.86 | - | - | - | 1.44 |
| 2 | Hexadecanoic acid | 919.73 | - | - | - | 2 |
| 3 | Decanal | 1000.92 | - | 1.71 | - | 0.85 |
| 4 | Dodecanal | 1007.29 | - | 4.96 | - | 22.43 |
| 5 | 1-Dodecanol | 1080.20 | - | 4.54 | - | 2.64 |
| 6 | Tetradecanoic acid | 1093.89 | - | 1.72 | - | 1.12 |
| 7 | Acetic acid,decyl ester | 1101.85 | - | 7.57 | - | - |
| 8 | 1-Tridecyne | 1136.24 | - | 12.18 | - | - |
| 9 | 1,13-Tetradecadiene | 1148.66 | - | 3.61 | - | 1.94 |
| 10 | Undecanoic acid | 1150.57 | - | - | - | 5.5 |
| 11 | 1-Tetradecene | 1156.62 | - | - | - | - |
| 12 | 1-Dodecyne | 1161.40 | - | - | - | 0.67 |
| 13 | 1-Dodecene | 1176.36 | - | 7.3 | - | - |
| 14 | 1-Nonanol | 1228.90 | - | 3.16 | - | 0.81 |
| 15 | 2-Undecanone | 1246.41 | - | 1.74 | - | - |
| 16 | 2-Tridecanone | 1263.28 | - | 51.5 | - | 1 |
| 17 | Acetic acid,dodecyl ester | 1290.03 | - | - | - | 4.6 |
| | Total | | 0.00 | 99.99 | 0.00 | 45.00 |
| | Yield (%v/w) | | 0.00 | 0.013 | 0.00 | 0.007 |

[a] Retention index; [b] oil abundance in percentage (%).

(2007) reported only six compounds. The major compounds in this study were 1-dodecene (41.6%) for rhizomes dried for 6 h and 1-dodecanol for rhizomes dried for 24 (48.15%), 48 (63.64%) and 72 h (54.3%), respectively. Jaafar et al. (2007) reported that 1,1-dodecanediol, diacetate (47.28%) was the major component in the rhizome of *E. elatior.*

There are many reports on the essential oil composition of inflorescences of *E. elatior*. In this study, 20 compounds were identified with 1-dodecanol as major component for all inflorescences dried for 24 h (54.48%), 48 h (53.12%) and 72 h (51.6%) respectively. 25 compounds were identified previously by Arbaayah (2008) and Jaafar et al. (2007) with 1-dodecanol as the major component represent 61.59 and 40.32% of overall oil percentage respectively. Zoghbi et al. (2005) found only 15 compounds from the inflorescences with 42.5% of 1-dodecanol as major component. Recently, Abdelwahab et al. (2010) found 73 compounds from the leaves of this species. All the previous studies indicated that 1-dodecanol as the major component in inflorescences. This difference might be due to different extraction techniques, genetic factors, different chemotypes and the nutritional status of the plants as well as other environmental factors. Also, these dissimilarities may be due to loss of compounds as drying period increase. Comparison of the results showed that the different drying periods had an effect on the percentage of the main compounds. Increased concentrations of various volatile substances with air-drying have been observed for numerous spices and are probably caused by the breakdown of glycosylated forms, dehydration reactions, or oxidation reactions (Baritaux et al., 1992; Bartley and Jacobs, 2000) or due to the rupture of the plant cells in which the volatiles are stored.

Some essential oil compounds could arise from the dehydration of oxygenated compounds, such as acetic acid, dodecyl ester, 1-tetradecanol, and n-decanoic acid. This might be due to some chemical transformations during the process of drying. The inability of the GC-MS to detect the presence of acetic acid, dodecyl ester and 1-tetradecanol in the fresh leaves and rhizomes and the quantity of the component and its sudden appearance after drying period of 72 h is noteworthy. On the other hand, a main chemical compound like 2-cyclohexen-1-one was not detected after drying period of 48 to 72 h. This compound might be stored on or near the leaf surfaces and vaporized upon drying (Moyler, 1994) or it might be converted to other compound upon drying.

In comparison to previous studies on *E. Elatior*, the current study revealed the absence of α-pinene, myrcene, *trans*-verbenol, decanol, β-caryophyllene, (Z) - β-farnessene, dodecanol, caryophyllene oxide, tetradecanal, dillpiole, and tetradecanal as reported by

**Table 3.** Essential oils constituents of the rhizomes of *Etlingera elatior* at different post-harvest air drying periods.

| No. | Compound | RI[a] | Area%[b] | | | |
|---|---|---|---|---|---|---|
| | | | 6 h | 24 h | 48 h | 72 h |
| 1 | n-Hexadecanoic acid | 916.86 | 0.81 | 0.92 | - | 0.81 |
| 2 | Hexadecanoic acid | 919.73 | - | 0.55 | - | - |
| 3 | Bornyl acetate | 973.54 | 3 | 4.28 | - | 0.9 |
| 4 | 1-Decanol | 1000.28 | - | - | 0.67 | - |
| 5 | Decanal | 1000.92 | - | - | - | 0.56 |
| 6 | Dodecanal | 1007.29 | 32.9 | 25.99 | 17.01 | 20.17 |
| 7 | 1-Undecene | 1042.31 | 4.2 | - | 1.65 | 2.56 |
| 8 | 1-Dodecanol | 1080.20 | - | 48.15 | 63.64 | 54.3 |
| 9 | Tetradecanoic acid | 1093.89 | - | 1.67 | - | - |
| 10 | n-Decanoic acid | 1100.90 | 3.2 | - | 2.14 | - |
| 11 | Acetic acid,decyl ester | 1101.85 | 4.5 | 4.54 | 3.4 | 3.86 |
| 12 | 1,13-Tetradecadiene | 1148.66 | 1.72 | 1.91 | 2.44 | 2.77 |
| 13 | Z-7-Tetradecenol | 1150.25 | - | 0.57 | 0.82 | - |
| 14 | Undecanoic acid | 1150.57 | - | - | - | 2.71 |
| 15 | 1-Tetradecene | 1156.62 | 6 | 5.14 | 7.05 | - |
| 16 | 1-Dodecyne | 1161.40 | 0.83 | - | - | - |
| 17 | E-7-Dodecen-1-ol acetate | 1174.13 | - | 0.14 | - | 0.52 |
| 18 | 1-Dodecene | 1176.36 | 41.6 | 4.16 | - | 0.25 |
| 19 | cis-7-Tetradecen-1-ol | 1224.44 | - | - | - | 0.88 |
| 20 | 1-Nonanol | 1228.90 | 0.48 | 0.72 | - | 0.56 |
| 21 | 2-Undecanone | 1246.41 | - | 0.44 | - | - |
| 22 | 2-Tridecanone | 1263.28 | 0.81 | - | 0.32 | 0.47 |
| 23 | Acetic acid,dodecyl ester | 1290.03 | - | - | - | 0.61 |
| 24 | Nonanal | 1340.02 | - | - | 0.17 | - |
| 25 | Hexadecanal | 1354.98 | - | - | 0.48 | - |
| 26 | E-8-Dodecenyl acetate | 1358.80 | - | - | 0.21 | - |
| 27 | Undecanal | 1443.80 | - | - | - | 0.27 |
| 28 | 1-Tetradecanol | 1459.74 | - | - | - | 7.81 |
| | Total | | 100.05 | 99.18 | 100.00 | 100.01 |
| | Yield (%v/w) | | 0.047 | 0.020 | 0.013 | 0.02 |

[a] Retention index; [b] oil abundance in percentage (%).

Zoghbi et al. (2005), or α-pinene, camphene, sabinene, β-pinene, β-myrcene, α-terpinolene, 1,3,8-p-methatriene, α-terpinene, cyclododecane, eucalyptol, camphor, 2-ethyl fenchol, borneol, dihydrocavreol, α-terpineol, 1,1-dodecanediol,diacetate, β-elemene, caryophyllene, α-caryophyllene, E-β-farnesene, trans nerolidol, octadac-9-enoic acid, from leaves as reported by Jaafar et al. (2007), or bicycle(3,1,1)hept-2-ene,2,6,6-trimethyl, acetic acid, 1,3-propanediol,2-dodecyl in leaves as reported by Abdelwahab et al. (2010) or α-pinene, β-pinene, E-5-dodecene, 1,2-dimethylcyclooctane, cyclododecane, eucalyptol, camphor, α-terpineol, 1,1-dodecanediol, diacetate, copaene, 1-cyclohexylnonene, caryophyllene, α-caryophyllene, Z-β-farnesene, (+)-d-cadinene, dodecamethyl cyclohexasiloxane, trans nerolidol, caryophyllene oxide, 1-hexadecanol, eicosane, heptadyl oxirane, glyceryl palmitoleate, oleic acid, glyceryl monooleateor β-sesquiphellandrene (20.5%), β-bisabolene (12.10%), 1,8-cineole (11.56%), β-caryophyllene (4.39%) from pseudostems as reported by Jaafar et al. (2007) or 1,7-bis(4-hydroxyphenyl)-2,4,6-heptatrienone, demethoxycurcumin, 1,7-bis(4-hydroxyphenyl)-1,4,6-heptatrien-3-one, 16-hydroxylabda-8(17),11,13-trien-15,16-olide, stigmast-4-en-3-one, stigmast-4-ene-3,6-dione, stigmast-4-en-6 β -ol-3-one, and 5 α,8 α -epidioxyergosta-6,22-dien-3 β -ol from rhizome as reported by Mohamad et al. (2005). or α-pinene, cyclododecane, 1,1-dodecanediol,diacetate, glyceryl palmitoleate, oleic acid, glyceryl monooleate from rhizomes as reported by Jaafar et al. (2007) or α-

**Table 4.** Essential oils constituents of the inflorescences of *Etlingera elatior* at different post-harvest air drying periods.

| No. | Compound | RI[a] | Area%[b] | | | |
|---|---|---|---|---|---|---|
| | | | 6 h | 24 h | 48 h | 72 h |
| 1 | 2-Undecanol | 987.87 | - | - | 0.12 | - |
| 2 | Dodecanal | 1007.29 | - | - | 16.53 | 17.27 |
| 3 | 1-Dodecanol | 1080.20 | - | - | 54.48 | 53.12 |
| 4 | Tetradecanoic acid | 1093.89 | - | - | 1 | 1.27 |
| 5 | n-Decanoic acid | 1098.35 | - | - | - | 12.33 |
| 6 | Acetic acid,decyl ester | 1101.85 | | - | 6.17 | - |
| 7 | 1,13-Tetradecadiene | 1148.66 | - | - | 1.85 | - |
| 8 | Z-7-Tetradecenol | 1150.25 | - | - | - | 0.59 |
| 9 | Undecanoic acid | 1150.57 | - | - | 10.1 | - |
| 10 | 1-Tetradecene | 1156.62 | - | - | 4.46 | 4.6 |
| 11 | 1-Dodecyne | 1161.40 | - | - | 0.53 | - |
| 12 | E-7-Dodecen-1-ol acetate | 1174.13 | | - | - | 0.26 |
| 13 | Decanoic acid,decyl ester | 1175.09 | | - | 0.85 | - |
| 14 | 1-Dodecene | 1176.36 | - | - | 0.42 | 0.42 |
| 15 | Dodecane | 1177.63 | - | - | 0.54 | - |
| 16 | 9-Decen-1-ol | 1182.09 | - | - | - | 0.15 |
| 17 | 1-Nonanol | 1228.90 | - | - | 1.12 | 1.31 |
| 18 | 2-Undecanone | 1246.41 | - | - | 0.83 | 0.92 |
| 19 | 2-Tridecanone | 1263.28 | - | - | 0.62 | 0.67 |
| 20 | Acetic acid,dodecyl ester | 1290.03 | | - | 0.43 | 6.35 |
| | Total | | 0.00 | 0.00 | 100.05 | 99.27 |
| | Yield (%v/w) | | 0.00 | 0.100 | 0.080 | 0.100 |

[a] Retention index; [b] Oil abundance in percentage (%).

terpineol, benzene, 2-decanol, phenol, 1,12-tridecadiene, octyl ester, caryophyllene, 1,6,10-dodecatriene, α-caryophyllene, lauric acid, Z-4-decen-1-ol, undecylenic alcohol, acetate, nonyl ester, α-pinene, β-pinene, D-limonene, 9-octadecanal, camphor, Z-β-farnesene, Z-3-hexadecene, 1-heptadecene, trans-nerolidol, E-2-hexenal, dodecanoic acid, elaidic acid, glyceryl palmitoleate, oleic acid, glyceryl monooleate, 1,1-todecanediol, decanal, decanol, limonene, trans-verbenol, undecanal, β-caryophyllene, caryophyllene oxide, tetradecanol, for inflorescences as reported by Jaafar et al. (2007). This difference might be due to different extraction techniques, genetic factors, different chemotypes and the nutritional status of the plants as well as other environmental factors.

Finally, it is concluded that the drying period had a significant effect on the yield of *E. elatior* essential oil ($p<0.05$). The drying period also had an effect on composition of *E. elatior* essential oil showing the present of various compounds in different drying periods. In order to increase the effectiveness of essential oil production, one should have the knowledge about the nature of the plant and the causes of losses that may lead to both wastage and reduced in yield and quality of the product. This study highlights the importance of various post-harvest periods on providing the different compounds of the essential oil.

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