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*Full Length Research Paper*

# Influence of drying air velocity on the chemical composition of essential oil from lemon grass

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**Lemon grass (*Cymbopogon citratus* (D.C.) Stapf) is widely cultivated in Brazil and utilized for medicinal and industries purposes. The chemical composition of its essential oil is wide, but it has three main components: myrcene, geranial and neral. The effect of drying air velocity upon the chemical composition of the essential oil extracted from Brazilian lemon grass leaves was evaluated. The drying treatments were arranged in randomized blocks with a 3x2 factorial design: 3 drying air velocities (0.8 m $s^{-1}$, 1.3 m $s^{-1}$ and 1.8 m $s^{-1}$) x 2 air velocity control methods, with three repetitions each. The essential oil components, after drying, were compared with the values obtained from the fresh plant (control). All drying treatments showed no difference for the main components (myrcene, geranial and neral) of the essential oil obtained from lemon grass, when compared to the fresh plant (control).**

**Keywords:** Active principles, *Cymbopogon citratus*, dryer, medicinal plants.

## INTRODUCTION

The use of medicinal plants is part of a competitive market, which includes pharmaceuticals, food, cosmetics, and perfumery markets. In pharmaceuticals, plant extracts are especially relevant due to the use of their active substances for medicine development and as sources of raw material, to obtain adjuvant (Schenkel et al., 2003).

The growing demand for medicinal species indicates the emergence of a market with high potential for consumption, requiring a consistent and readily available supply of high quality raw material. To supply this demand, the size and number of cultivation areas is growing in various regions of Brazil. The post-harvesting process of medicinal plants has great importance in the production chain, because of its direct influence on the quality and quantity of the active principles in the product sold (Silva and Casali, 2000). For this reason, adequate dryers are needed, using temperature, velocity and humidity values for drying air that provides a rapid reduction in the moisture content without affecting the quality of the active principles of medicinal plants. The drying process may also contribute to a regular supply and facilitate the marketing of plants, because drying improves the transport and storage (Calixto, 2000).

According to Gomes (2001), Brazilian industries use three methods of drying, including: solar drying covered storage rooms, without air control, and dryers with forced heated air. After the drying process, the packing method is an important factor in the quality conservation of the product during storage (Martinazzo et al., 2009).

Lemon grass (*Cymbopogon citratus* (D.C.) Stapf), is widely cultivated in Brazil and utilized for medicinal purposes, especially as infusion. Its essential oil is used in perfume, food and pharmaceuticals (Koshima et al., 2006). *C. citratus* leaves present a characteristic flavour of lemon due primarily to citral. The flavour is due to its composition, especially citral that presents great importance to the industry. The composition of the essential oils can be variable, due to many factors such as genetic diversity, habitat, weather and cultural treat-

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ments (Peisíno et al., 2005).

The essential oil of the *C. citratus* is one of the most important volatiles oils. This essential oil is internationally known as "West - Indian Lemongrass" and it is important due to its chemical composition, which has three main active principles: myrcene, geranial and neral. Neral and geranial isomers combine to make citral, the most economically important component of the essential oil of lemon grass (Lewinsohn et al., 1998).

Approximately 60% of the medicinal plants cultivated in Brazil fail to meet quality standards for the international market due to the lack of technical knowledge by the producers. Chemical changes are the most important in the post-harvest of medicinal plants and can be influenced by drying (Fennell et al, 2004; Costa et al., 2005). Moreover, drying can promote changes in product appearance (color) and smell, modifying the final quality. According to Lorenzi and Matos (2002), drying of medicinal species is a preparation process, carried out to meet the needs of the pharmaceutical industry, which doesn't have the adequate conditions to use fresh plants on the scale required by industry.

The essential oils of medicinal plants are the constituents most sensitive in the drying process. The drying air temperature limits are determined according to the sensitivity of these substances, because the product temperature is increased during the drying process (Venskutonis, 1997; Martins, 2002).

Most essential oils are volatile and sensitive in the air conditions (humidity, temperature and velocity). The influence of drying on the quantity and quality of the essential oils was extensively studied. Radünz et al (2002) used 5 temperatures (ambient air and heated air at 40, 50, 60 and 70 ºC) to dry plants of *Lippia sidoides* Cham and compared essential oil chemical composition with that of the fresh plant. No significant qualitative changes were found either in the thymol percentage (main constituent) or in ρ-cymene, compared to the fresh plant. However, significant increases in caryophyllene values were observed when the drying air was heated to 50, 60 and 70 °C (Radünz et al., 2002).

Costa et al (2005), studying two drying types (oven with forced ventilation at 40 °C, and room temperature with dehumidifiers) of lemon grass, concluded that the most abundant component in the essential oil was citral, and had the highest concentrations in the leaves dried in the dehumidifiers. Mendes et al. (2006) investigated the effect of natural and artificial drying on the composition of the essential oil of *Cymbopogon nardus* and concluded that, especially for this plant, the drying operation did not influence the composition of the volatile compounds.

Braga et al (2005) evaluated the effects of different drying air temperatures (35, 40, 45, 50, 55 and 60 ºC) on the yield and composition of essential oil from long pepper (*Piper hispidinervium* C. DC.) leaves in a fixed-bed dryer. They observed that the essential oil yield increased twice after the drying process compared with the fresh plant. However, safrole content decreased about 20 percent when temperature was above 50 ºC.

Barbosa et al (2006) submitted *Lippia alba* leaves to 6 drying treatments (ambient air and air heated to 40, 50, 60, 70 and 80 °C), comparing with fresh leaves (control). They found that the citral level presented a significant increase when the leaves were submitted to drying, independent of treatment, compared to the fresh plant. The increase was attributed to the oxidation of geraniol during drying, converting it into geranial. It was also observed that the nerol content did not differ significantly between drying treatments, but statistically showed a significant decrease when compared with the fresh plant. This decrease was attributed to the oxidation of nerol during drying, which was transformed into neral. Considering that citral is the main chemical constituent of interest in the oil from this plant, it was concluded that drying for marketing purposes can be carried out using heated air from 40 to 80 °C.

David et al. (2006) evaluated the influence of the drying air temperature on *Ocimum selloi* Benth essential oil composition. They observed that the main components of essential oil were elimicin (69.8%), trans-caryophyllene (6.0%), germacrene D (3.7%) and bicyclogermacrene (3.5%), and they found that increasing temperature above 40°C reduced the levels of the components.

The highest value of air velocity found in the literature for drying medicinal plants was 3.3 m $s^{-1}$, used by Venskutonis et al (1996) and Venskutonis (1997) to dry plants of *Thymus vulgaris* L. and *Salvia officinalis* L., respectively. Martins et al (2002) observed that drying lemon grass leaves with air velocities of 0.5 m $s^{-1}$ and 1.0 m $s^{-1}$ had no statistically significant effect on final product quality.

Soares et al (2007) studied the influence of 4 drying air temperatures (40, 50, 60 and 70 °C), in thin layers, and 2 air velocities (0.9 and 1.9 m $s^{-1}$) on the essential oil content of brazilian linalool (*Ocimum basilicum* L). The higher essential oil contents were obtained in the drying process with an air temperature at 40 °C and air velocity of 1.9 m $s^{-1}$. The highest linalool contents were obtained with drying air temperature from 50 to 60°C and an air velocity of 1.9 m $s^{-1}$. They concluded that the essential oil chemical composition of *Ocimum basilicum* L. was affected by both temperature and air velocity during drying.

The drying process of medicinal plants to optimize quantity and quality of essential oils is of great challenge for researcher. The aim of this work was to evaluate the effect of the control of different drying air velocities on the essential oil content extracted from lemon grass leaves.

## MATERIALS AND METHODS

Lemon grass (*Cymbopogon citratus* D.C. Stapf) utilized for the drying tests and chemical analyses was cultivated

at the experimental area of the Agricultural Engineering Department at the Federal University of Viçosa – UFV (Minas Gerais, Brazil). Viçosa is located 648 m above sea level, at latitude 20°45'14" south and longitude 42º52'55" West. After harvest, the lemon grass was immediately transported to laboratory for moisture content determination and cooled in refrigerated chamber at 5 ºC for subsequent drying. Were used only apparently healthy plants.

The moisture content of the samples was determined using the gravimetric method recommended by ASAE Standards (2000) for forage and similar plants. This was done by placing 25 g of the product in an oven with forced air circulation at 103 ± 2 °C for 24 h, each done in triplicate.

To conduct the experiment, a randomized block design was used, with three repetitions. In each block, all drying treatments were tested as well as the extraction of essential oil, aiming to minimize the effect of storage on lemon grass after drying. The drying treatments were arranged in a factorial (3x2) with three drying air velocities (0.8 m $s^{-1}$, 1.3 m $s^{-1}$ and 1.8 m $s^{-1}$) and two control system of air velocity (automatic and manual).

A fixed-bed dryer was used, which contained 5 perforated trays (0.25 x 0.25 x 0.15 m each) with upward air flow and three electrical resistances for heating the drying air (Figure 1). Each drying test was done using 250 g of lemon grass leaves, making a layer of 5 cm thick inside of drying chamber. The leaves were cut into pieces of 2 cm length and the drying air temperature was kept at 50 ºC, because essential oil content and active principle concentration are high at this length and temperature, as described by Martinazzo (2006). Only 1 of the dryer trays, dryer chamber number 3, was filled up with lemon grass leaves (Figure 1a). The reason for not completely filling the all trays was due to the amount of plant samples available.

The amount of water to be removed from the lemon grass leaves, $M_f$, was calculated using the following equation:

$$M_f = M_i\left(\frac{100 - W_i}{100 - W_f}\right) \quad (1)$$

where: $M_i$ is the initial mass of product to be dried; $W_i$ is the initial moisture content, % w.b. and $W_f$ is the final moisture content, % w.b. The initial moisture content was previously measured by gravimetric method and the final moisture content desired in this case was 10% w.b. The tray with the samples were weighed with a digital scale every 10 min during the first hour, every 20 min for the second hour and every 30 min for the remaining time of drying process. The drying treatment was interrupted when the final mass ($M_f$) was achieved.

The control of the temperature and velocity of drying air were done with an automatic controller as described by Prates (2011), when a PID control was applied. The dryer's manual control was done through regulation (opening and closing) of the diaphragm (Figure 1b). Temperature data was taken with the use of thermocouples previously calibrated and placed in pre-set points of the dryer. Drying air velocity was measured by an anemometer. The data of temperature and velocity of drying air were taken in an automatic data acquisition system that registered their values in a microcomputer.

After drying, the samples were packed in polyethylene bags (40 µm) and stored in refrigerated chamber at 5 ºC, until being submitted to extraction of the essential oil.

The essential oil was extracted by hydrodistillation utilizing Clevenger equipment, adapted to a round-bottomed two liter flask as described by Skrubis (1982) and Ming et al. (1996), with heating maintained at the minimum temperature required to the water boil. The flask was loaded with samples of 20 and 90 g of dried and fresh leaves of lemon grass, respectively. One litter of distilled water was added, which was volume sufficient to cover the material, beginning the hydrodistillation process. The extraction time was 90 min which was determined by preliminary tests, and three repetitions were performed for each treatment. After the beginning of process, hydrolat samples (mixture of water and oil) were taken each 30 min.

The oil was separated with pentane (3x30 mL) in a 500 mL separation funnel and the procedure was repeated 3 times. The organic fraction (pentane and essential oil) obtained was transferred to a 125 mL Erlenmeyer flask and treated anhydrous magnesium sulfate (5 g). The mixture was filtered directly to a flask of 125 mL and concentrated in a rotary evaporator at 38 ºC and the oil obtained was transferred into a 5 mL bottle to be weighed. The sample was then subjected to gaseous nitrogen about 5 minutes to evaporate the residual solvent. Quantification of essential oil was performed by weighing the samples on an analytical scale with an accuracy of 0.0001 g. After weighing, the flasks were closed, sealed with parafilm and wrapped with aluminum paper to protect from light and then stored at 4ºC for chromatographic analysis. The essential oil contents, obtained from drying treatments, were compared to the fresh plant (control), and calculated according to Venskutonis (1997), based on dry matter.

Individual components of the extracted oil were identified using a gaseous chromatograph system coupled to a mass spectrometer (Shimadzu GC-EM, GC-14A/QP-5000) and equipped with a capillar column DB-5, (30 m x 0.25 mm (ID) x 0.25 µm film). Helium was used as the carrier gas at a flow rate of 1.0 mL/min. The temperature of the injector was 220 °C and the temperature of the detector was 240 °C. Initial temperature in the oven was kept at 60 °C for 2 min, and was increased at a rate of 3 ºC per minute until 240 °C. This temperature was maintained for over 30 min. Only ions at charge mass (m/z) ratios between 29 and 600 were detected by the mass spectrometer.

The sample volume injected was 1 µL, at a concentration of 10000 ppm with hexane as a solvent.

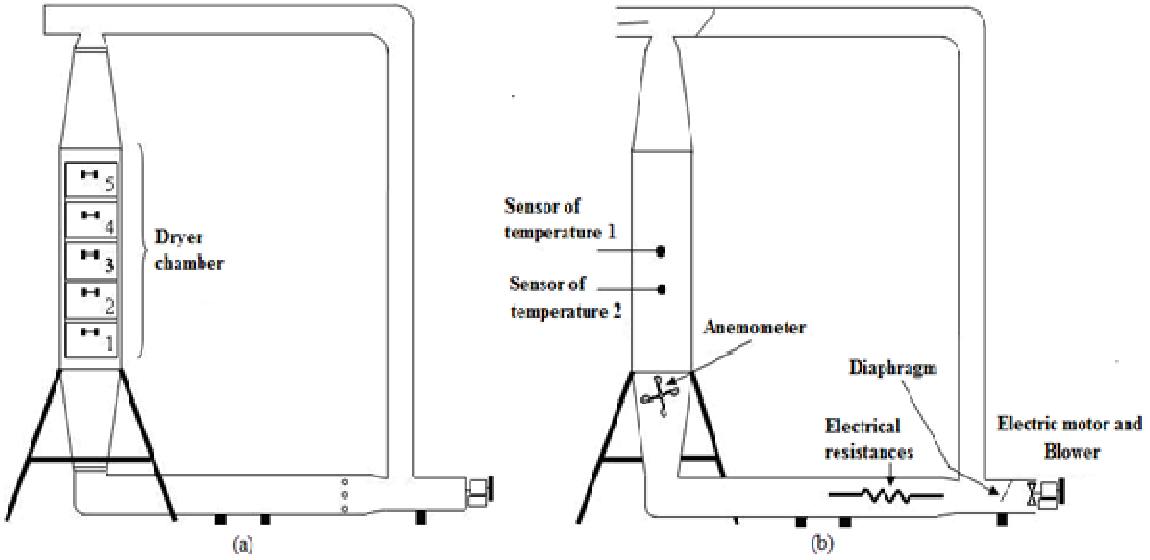


**Figure 1.** Front view (a) and frontal section (b) of dryer.

The identification of components was conducted by comparing mass spectrometer readings obtained from the equipment database and Kovats retention index for each component, as shown in equation 2 (Lanças, 1993; Adams, 1995).

$$IK = 100NC + 100\left(\frac{\text{Log } t'_{RX} - \text{Log } t'_{RZ}}{\text{Log } t'_{R(Z+1)} - \text{Log } t'_{RZ}}\right) \quad (2)$$

where: IK: Kovats index; NC : number of carbons from hydrocarbon immediately before the evaluated component; $t'_{RX}$: retention time of evaluated component; $t'_{RZ}$: retention time of hydrocarbon immediately before the evaluated component; $t'_{R(Z+1)}$: retention time of the hydrocarbon immediately after the evaluated component.

In order to obtain the hydrocarbon standard curve to calculate the Kovats index, a solution of hydrocarbon was prepared, varying from hexane to tetracosane. Two milligrams of each hydrocarbon were weighed in the same flask in order to prepare the solution. The final mass was solubilized in 2 mL of hexane, producing a 1000 ppm solution in relation to each hydrocarbon. The solution was analyzed using a gas chromatograph, coupled with a mass spectrometer, with the same operational conditions used for essential oil samples.

To obtain the quantity of essential oil components, a Shimadzu GC-17A gas chromatograph, equipped with a flame ionization detector (FID) and a smelt silica capillar column with a DB-5 (30 m x 0.25 mm (ID) x 0.25 µm film) was employed. Nitrogen was used for the purging gas at a flow rate of 1.33 mL/min. The initial temperature of the column was kept at 60°C for 2 min, and programmed to increase at 3°C per minute, until reaching the maximum temperature of 240°C, where it was maintained for 61 min for analysis. Split ratio was 1:10 and the solvent cut period was 5 min. Injection and detection temperatures were fixed at 250 °C. The sample injection volume was 1 µL, at a concentration of 2000 ppm, using hexane as a solvent. The components were quantified based on the comparison of compound's retention period, which were similar in both techniques. The normalization method was used; the value of total peak areas is considered 100% and the percentage of each component was calculated using the area of each peak.

The statistical analysis of the essential oil content, obtained from the dried lemon grass and the fresh leaves (control) were carried out using the analysis of variance, and when necessary, the multiple averages comparison test - Duncan to 5% probability – using the program for statistical analysis, SAEG (2007).

## RESULTS AND DISCUSSION

The drying air velocity did not change the average moisture content of fresh plant and of dried samples (Table 1). Also the table shows the average values of ambient and drying air temperature, relative humidity and total drying time, with their standard deviations for the drying air velocity and air control method.

A sharp drop in temperature occurred when the plant was placed in the dryer chamber (Figure 2). For this particular case the average and standard deviation of drying air temperature was 49.9 ± 1.23 °C. This high value of standard deviation is precisely because the sharp drop in temperature at the beginning of drying. The behavior of the drying air temperature in all repetitions followed the same trend shown in Figure 2.

As expected, the increase of drying air velocity increased

**Table 1.** Parameters evaluated during the drying process of lemon grass using manual and automatic control of air velocity.

| Drying air velocity (m $s^{-1}$) | Temperature ambient (ºC) | Relative humidity ambient (%) | Moisture content fresh plant (d.b.) | Moisture content dried plant (d.b) | Drying time (min) | Drying air temperature (ºC) |
|---|---|---|---|---|---|---|
| **Manual control** | | | | | | |
| 0.8 | 30.36 ± 5.50 | 57,40 ± 15 | 3.12 ± 0.31 | 0.13 ± 0.01 | 220 ± 20 | 50.3 ± 0.96 |
| 1.3 | 27.01 ± 5.20 | 66,61 ± 12 | 3.12 ± 0.31 | 0.11 ± 0.01 | 200 ± 10 | 49.9 ± 1.23 |
| 1.8 | 29.19 ± 5.10 | 58,54 ± 10 | 3.12 ± 0.31 | 0.12 ± 0.02 | 190 ± 10 | 50.2 ± 0.87 |
| **Automatic control** | | | | | | |
| 0.8 | 31.75 ± 5.30 | 54,23 ± 15 | 3.12 ± 0.31 | 0.11 ± 0.09 | 220 ± 20 | 50.4 ± 0.97 |
| 1.3 | 26.05 ± 5.50 | 68,00 ± 10 | 3.12 ± 0.31 | 0.11 ± 0.01 | 200 ± 10 | 49.9 ± 0.92 |
| 1.8 | 28.30 ± 5.20 | 59,5 ± 12 | 3.12 ± 0.31 | 0.12 ± 0.01 | 190 ± 10 | 50.4 ± 0.84 |

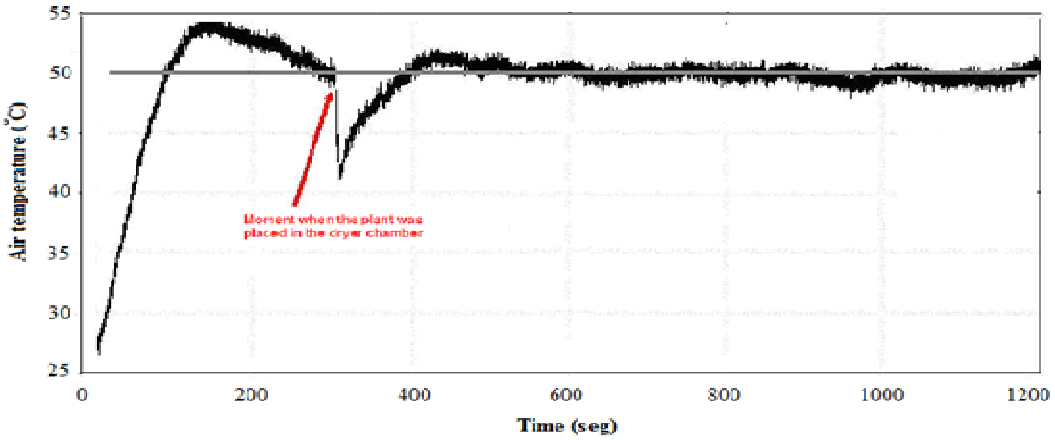


**Figure 2.** Variation on the drying air temperature during the drying process with manual control of drying air velocity (1.3 m $s^{-1}$).

the drying rate and consequently decreased the total time of drying (Figure 3). This behavior was also observed by Martins et al. (2002), drying the same specie, deduced that at 50 ºC there was a relative difference of 3.8% in drying time between the velocities of 0.5 m $s^{-1}$ and 1.0 m $s^{-1}$.

The same behavior observed in the initial variation of air temperature also occurred during the drying process using the control automatic of drying air velocity, as shows Figure 4. For this particular case the average and the standard deviation of air temperature during drying process was 49.9 ± 0.92 ºC. This high value of standard deviation is again due to the sharp drop of the temperature in the beginning of drying. Temperatures dropped to 42.5 ºC in 35 seconds.

The chromatographic analysis was done with the objective to compare the compositions of the essential oils extracted. The three major components of essential oil from lemon grass are mycene, neral and geranial, probably because they present the highest volatilization temperatures and suffered no volatilization during the drying process (Table 2). Citral is the combination of the neral and geranial isomers.

From the results showed in Table 2, it was observed that the different velocities (0.8 m $s^{-1}$, 1.3 m $s^{-1}$, 1.8 m $s^{-1}$) and the different control systems (manual and automatic) presented no significant effect on myrcene, neral, geranial and citral concentration in essential oil from the samples. These results are similar to the ones found by Peisíno et al (2005). These authors evaluated the air velocity effects of dried lemon grass at 40, 50 and 60 ºC with four conditions of air velocity (0.8, 0.6, 0.4 and 0.2 m $s^{-1}$). They concluded that the differences between the air velocities did not influence the composition of the essential oil. Also Martins et al (2002) observed, in an experiment with lemon grass leaves, no significant

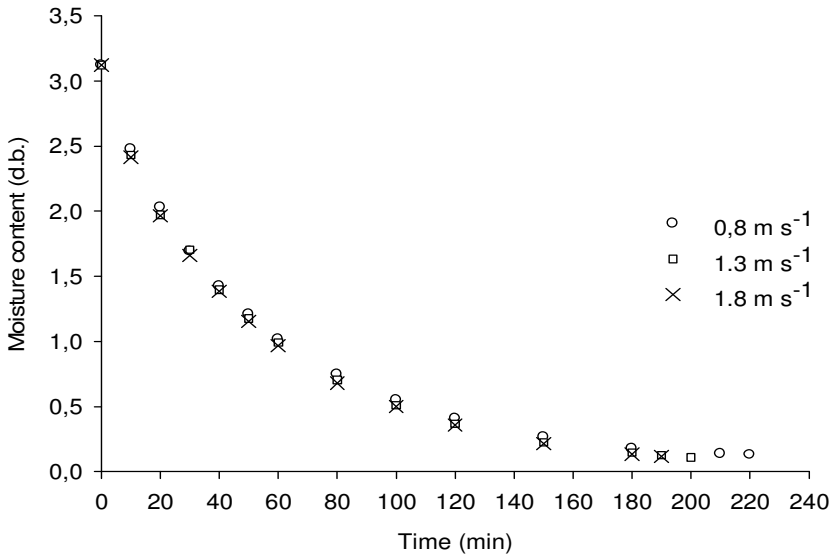


**Figure 3.** Average moisture content from *C. citratus* at different drying air velocities with manual control.

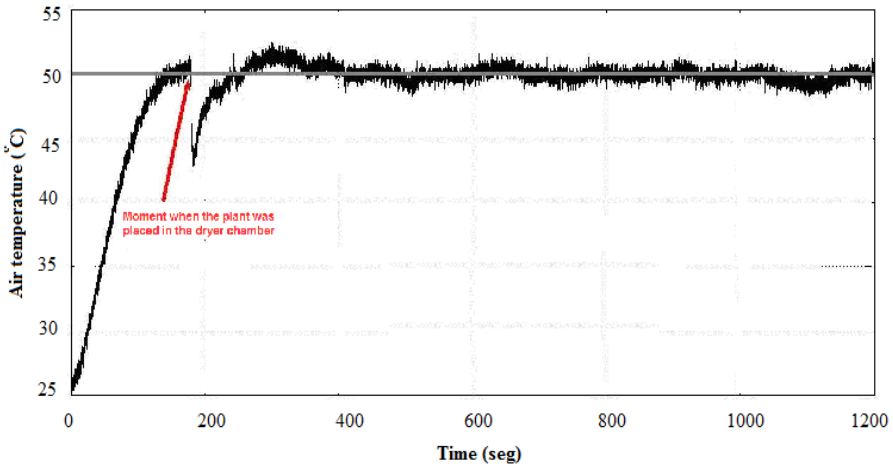


**Figure 4.** Variation on the drying air temperature during the drying process with automatic control of drying air velocity (1.3 m $s^{-1}$).

**Table 2.** Statistical analysis results of lemon grass's essential oil constituents compared with the fresh plant, expressed as a percentage proportion of area.

| Treatment | | Myrcene | Neral | Geranial | Citral (Neral + Geranial) |
|---|---|---|---|---|---|
| | Fresh plant | 14.15 a | 33.04 a | 41.74 a | 74.78 a |
| 0.8 m s-1 | Automatic | 13.60 a | 32.56 a | 44.01 a | 76.57 a |
| | Manual | 14.78 a | 32.58 a | 40.82 a | 73.40 a |
| 1.3 m s-1 | Automatic | 14.29 a | 32.62 a | 41.78 a | 74.40 a |
| | Manual | 11.23 a | 33.54 a | 44.44 a | 77.98 a |
| 1.8 m s-1 | Automatic | 13.80 a | 32.84 a | 42.28 a | 75.12 a |
| | Manual | 13.65 a | 32.58 a | 42.34 a | 74.92 a |
| Standard Deviation | | 10.51 | 1.69 | 3.42 | 2.21 |

difference in the essential oil components for the drying air velocity of 0.5 and 1.0 m $s^{-1}$. Soares et al. (2007) studied the influence of 4 drying air temperatures (40, 50, 60 and 70 °C), in thin layers, and 2 air velocities (0.9 and 1.9 m $s^{-1}$) on the linalool contents from *Ocimum basilicum* L. The highest linalool contents were obtained with drying air temperature from 50 to 60 °C and an air velocity of 1.9 m $s^{-1}$. They concluded that the essential oil chemical composition of *Ocimum basilicum* L. was affected by both temperature and air velocity during drying.

The values found show small differences in relation to the constituents described by Martinazzo et al. (2009). These variations are according to those described by Simões and Spitzer (2003), who affirmed that the chemical composition of a volatile oil, extracted from the same organ of the same plant species can vary significantly according to the harvest time, development stage, climate and soil.

## CONCLUSIONS

The drying air velocity effects were studied by the differences in the composition of the essential oils of lemon grass extracted by hydrodistillation. Drying air temperature was maintained at 50ºC and the air velocities investigated were 0.8, 1.3 and 1.8 m $s^{-1}$, with manual and automatic control. The differences between the air velocities and drying control did not influence the composition of the essential oils.

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