Effect of convective drying on quality of lemon balm (Melissa officinalis L.)

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Abstract

The effect of the conditions of drying air on the quality of lemon balm (Melissa officinalis L.) leaves such as colour, rosmarinic acid and essential oil content was investigated in this research. Fresh leaves with a moisture content of approximately 80% wet basis were dried to a final moisture content of 10% wet basis. The thin-layer drying experiments were conducted in a high precision through flow laboratory dryer at air temperatures of 30, 35, 40, 45, 50, 60 and 70 °C and the corresponding relative humidity by maintaining 10 g water per kg of dry air. The effect of the increased humidity of drying air was also investigated at 15, 20, 25 and 30 g/kg specific humidity. For all drying trials the air velocity flowing through the sample was kept constant at 0.2 m/s. Although drying of leaves at 30 °C preserved their medicinal qualities and colour, the duration of the process was comparably long. On the contrary, high drying air temperatures caused considerable colour degradation, a decrease in rosmarinic acid content and significant essential oil losses. The effect of relative humidity of drying air on the overall quality was found to be insignificant. A temperature limit of 40 °C can be imposed for convective drying of lemon balm in order to protect the heat-sensitive active ingredients and maintain the green colour of the leaves.

Keywords: Melissa officinalis L.; convective drying; hue; essential oil; rosmarinic acid

1. Introduction

Lemon balm (Melissa officinalis L.) is a perennial herb of the family Lamiaceae, cultivated for its characteristic lemon-scented leaves. It is implemented for several purposes in the food, pharmaceutical and cosmetic industries due to its flavouring and therapeutic properties. The most common method for post-harvest processing of medicinal plants is by hot air drying because it allows a quick conservation of the medicinal qualities of the plant material in an uncomplicated manner [1]. The conventional hot air drying of medicinal plants typically involves low drying temperatures between 30 and 50 °C in order to protect the heat-sensitive active ingredients. However, improper application of the method affects the
quality of the dried product. For instance, a high drying temperature or a prolonged drying time can cause colour deterioration and significant essential oil losses [2, 3].

Colour is considered to play a significant role in the acceptability of medicinal, aromatic and spice plants since it has a great influence on their appearance. Usually, when the herb is used as seasoning or tea, the colour of the leaves is of prime importance to the consumers as a product quality criterion who prefer leaves with a natural green colour. During convective air-drying discoloration of leaves from bright green to pale green occurs mainly due to loss of chlorophyll, which is sometimes accompanied by browning. The essential oil of *M. officinalis* is a well-known antibacterial and antifungal agent [4]. However, the total content in the herb is relatively low, usually 0.06-0.39% V/m [5] increasing its production cost and consequently its commercial price. The leaf also contains phenolic acids, mainly rosmarinic acid in large proportions. Rosmarinic acid has been identified as the main compound related to the antioxidative and antiviral activity of *M. officinalis* [6].

Although the whole lemon balm herb is frequently utilized to develop drugs, European Pharmacopoeia defines the leaf as the main source of the medicinal principles [7]. Therefore, in the current study the effect of convective air drying on quality of *M. officinalis* leaves was investigated by examining the influence of the conditions of drying air on colour, rosmarinic acid and essential oil content of the dried material.

2. Materials and Methods

2.1. Plant material

Plants of lemon balm (*Melissa officinalis* L.) cultivar Citronella were collected before flowering from an organic farm in Magstadt, approximately 20 km west of Stuttgart (Germany). The samples were obtained by cutting the herb manually to a height of about 20 cm above the ground. Material was stored at 2 °C and 90% relative humidity in a refrigerator and used for subsequent drying trials. Prior to drying experiments the leaves were separated from the stems. The fresh leaves were analyzed in terms of moisture content, colour and essential oil yield.

2.2. Laboratory dryer

The thin layer drying experiments were conducted using a high precision hot-air laboratory dryer designed at the Institute of Agricultural Engineering, University of Hohenheim (Stuttgart, Germany) which allowed the control of the desired drying conditions over a wide range of operating parameters. A detailed description of the experimental system (Fig. 1) has been given by Argyropoulos et al. [8].

It essentially consists of four units: (i) an air flow control unit, (ii) an air conditioning unit with a thermostat-controlled water bath and sprayed Raschig-ring bed, (iii) a heating control unit with primary and secondary heating elements and (iv) two drying compartments to provide either through-flow or overflow air stream for convective drying of products. Each unit is electronically controlled by PID control. The weight measuring system comprised different load cells (type PC6, Flintec Ltd, Vasteras, Sweden) for each drying chamber. The dryer is connected to an industrial computer using PLC software allowing pre-programming of the set drying conditions and monitoring of temperature, humidity, velocity and mass data during the drying process.
2.3. Thin-layer drying

Fresh leaves with a moisture content of approximately 80% wet basis were dried to a final moisture content of 10% wet basis, which is the recommended value for the safe storage of *M. officinalis* [7]. The dryer was warmed up for 30 minutes to reach the defined set points. The thin-layer (30 mm) drying experiments (2.2 kg/m²) were conducted using the through flow drying compartment of the dryer at air temperatures of 30, 35, 40, 45, 50, 60 and 70 °C and the corresponding relative humidity by maintaining 10 g/kg of specific humidity. Additional trials were carried out at 15, 20, 25 and 30 g water per kg dry air to investigate the effect of the increased humidity of air. The air velocity flowing through the sample was maintained constant at 0.2 m/s. During the drying process the weight change was recorded in ten minute time intervals for the determination of the drying curves and estimation of total drying time. The experiments were replicated three times for each drying condition.

2.4. Moisture content

The moisture content of the leaves was determined by the oven method (103 ± 2 °C for 24 h) in triplicate and the average value was recorded.

2.5. Colour measurement

The colour of fresh and dried leaves was determined by a reflectance Minolta colorimeter (model CR-400 Minolta Co, Ltd., Japan). The instrument was calibrated with a standard white plate at D65 illumination before taking measurements (Y=93.7, x=0.3158, y=0.3324). The material was spread over a sampling plate and twelve measurements were performed at random locations by placing the colorimeter head directly above the sample. The colour parameters were expressed as L* describing lightness (L*=0 for black, L*=100 for white), a* describing intensity in green-red (a*<0 for green, a*>0 for red), b* describing intensity in blue-yellow (b*<0 for blue, b*>0 for yellow). Nevertheless, for the colour evaluation of medicinal and aromatic plants the C* and h* parameters are frequently calculated. Chroma (C*) was calculated as $C^* = (a^{*2} + b^{*2})^{1/2}$ and indicates colour saturation, which is proportional to its
intensity. The hue value was calculated as $h^* = \tan^{-1}(b^*/a^*)$. An angle of 0° or 360° indicates red hue, while angles of 270°, 180° and 90° indicate blue, green and yellow hue respectively.

2.6. Distillation

The essential oil of the leaves was isolated by hydro-distillation using a Clevenger apparatus. About 50 g of fresh and 40 g of dried leaves were added to a round-bottom flask filled with 500 ml of distilled water. The flask was then heated for 3 hours estimated from the time after condensation of the first drop of vapour in the calibrated tube. The amount of extracted oil was measured and expressed in ml per 100 g dry matter.

2.7. Rosmarinic acid determination

The hydroxycinnamic acid derivatives were expressed as rosmarinic acid. A quantitative determination of rosmarinic acid was carried out by the photometric method using a UV-Spectrophotometer (Shimadzu GmbH, Germany).

2.8. Statistical analysis

One-way analysis of variance (ANOVA) was performed using the OriginLab (OriginPro v. 8.0 SR2) software. Differences among the mean values of the experimental data for each quality parameter were evaluated by Tukey’s test at $p<0.05$ significance level.

3. Results and Discussion

3.1. Drying time

The effects of temperature and relative humidity of drying air on the time required to reach the final moisture content of 10% wet basis are shown in Fig. 2. It is obvious that the total drying time decreased significantly with an increase in temperature of drying air (Fig. 2A). Consequently, the total drying time for 40 °C was about 60% shorter as compared with the drying time at 30 °C. The influence of the increased humidity of drying air was considered as lower than that of air temperature, however, the drying time was increased from 10 h at 40% to 20 h at 60% relative humidity when drying was performed at a temperature of 40 °C (Fig. 2B).

Fig. 2. Influence of drying conditions on drying time for Melissa officinalis. (A): influence of temperature of drying air on drying time. (B): influence of relative humidity of drying air on drying time
3.2. Colour

The overall colour quality based on the CIELAB system for *M. officinalis* leaves has been assessed in a previous study published by Argyropoulos et al. [9]. In this work only the hue value is presented since it has been proven as the best parameter to depict the visual impression of browning on plant leaves effectively [3]. Convective drying influenced significantly the colour of lemon balm leaves as expressed by the h* value (Fig. 3). The h* value of fresh leaves was 123 degrees which decreased with an increase in temperature of drying air. According to the statistical analysis there is a significant effect of the progressive increase in temperature up to 70 °C on the hue (Fig. 3A).

Samples dried at 30 and 40 °C exhibited the highest h* values. This implies that the dried leaves were greener in colour and therefore closer in appearance of the fresh leaves. Noticeable colour degradation was documented at temperatures above 45 °C. In particular, at air temperatures of 50 and 60 °C the h* value decreased from 93 to 91 degrees and the leaves turned yellow indicating undesirable colour changes. Moreover, for drying at 70 °C, drastic browning reactions were observed by a further decrease in h* value to 84 degrees. Clearly in this case the hue angle was moving from the green to the red quadrant indicating visible effect of browning. The influence of relative humidity of drying air at a temperature of 40 °C on the h* value is shown in Fig. 3B. Statistically identical h* values were obtained at 20, 30 and 40% of relative humidity. This means that the influence of relative humidity was insignificant below 40%, however, a gradual decrease of the h* value was recorded for an increase in relative humidity from 40 to 50 and finally to 60%. The mean h* values at 50 and 60% of relative humidity were not statistically different (p>0.05).
constituents found in essential oils. High drying temperatures strongly affected the oil glands and resulted in significant losses due to rapid evaporation of oil from the leaf.

![Fig. 4](image_url)

**Fig. 4.** Influence of drying conditions on essential oil content of *Melissa officinalis*. (A): influence of temperature of drying air on essential oil content. (B): influence of relative humidity of drying air on essential oil content

Similar influence of the drying temperature on essential oil was also reported for several plants of the Lamiaceae family such as *Salvia officinalis*, *Rosmarinus officinalis*, *Ocimum basilicum*, *Origanum majorana* and *Satureja hortensis* [13, 14]. On the contrary, a study published by Arabhosseini et al. [2] for *Artemisia dracunculus* indicated that the oil losses may fluctuate with an increase of drying temperature. Concerning the effect of relative humidity of drying air on the total oil recovery, the statistical analysis revealed no significant differences between the values of relative humidity tested.

3.4. Rosmarinic acid

Fig. 5 shows the impact of temperature and relative humidity of drying air on the content of rosmarinic acid. Leaves dried at temperatures of 30 and 40 °C indicated the highest amount of rosmarinic acid content and their values were statistically identical (p>0.05). The effect of drying temperature is considered to be significant above 45 °C. More specifically, the content of rosmarinic acid decreased significantly when higher drying temperatures were applied (Fig. 5A). Drying of leaves at different values of relative humidity at a constant temperature of 40 °C implied an insignificant influence of the increased humidity of drying air on rosmarinic acid content (Fig. 5B). In a comparative study conducted by Bomme et al. [15] on rosmarinic acid of *M. officinalis*, a noticeable variation of the total content (7.1-14.8%) was documented between the plants.
4. Conclusion

The effect of the conditions of drying air such as temperature and relative humidity on quality of *M. officinalis* leaves was investigated in this study. Although drying at a temperature of 30 °C preserved both the medicinal qualities and colour of leaves, the duration of the process was comparably long. On the other hand, high drying air temperatures caused considerable colour deterioration, a decrease in rosmarinic acid content and significant essential oil losses. The effect of relative humidity of drying air at a temperature of 40 °C on the overall quality was found to be insignificant. A temperature limit of 40 °C can be imposed for the convective drying of *M. officinalis* in order to protect the heat-sensitive active ingredients and maintain the green colour of the leaves.

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