LEMON BALM (*MELISSA OFFICINALIS* L.) LEAVES PRE-DRYING BY USING LOW ENERGY LASER BEAM

ORIGINAL SCIENTIFIC PAPER

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DOI: 10.5281/zenodo.4540094

RECEIVED 2020-07-20 **ACCEPTED** 2020-09-04

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ABSTRACT:
A laboratory laser beam drying method for lemon balm (*Melissa officinalis L.*) is presented. The aim of this study was to determine the possibility of using lasers as a pre-treatment for drying the lemon balm leaves and also to determine the variation of water content during the treatment. Leaves were illuminated from one side during a period of 180 s with 100 mW and 200 mW lasers. Both sources of coherent light were in the red part of the visible spectrum with wavelengths of 650 nm. Freshly harvested lemon balm leaves with 75.64% of water content were used for the analysis. Low-energy laser beam treatment for a period of 180 s resulted in the reduction of water content of 0.307% for 100 mW laser treatment and 0.31% for the 200 mW laser treatment. Amounts of energy emitted by low energy lasers are relatively small. Therefore, lasers thermal influence is negligible so it can be concluded that laser activity on lemon balm leaves is based solely on biostimulation. The proposed method allows effective reduction of water content without causing damage to the plant material. For practical application, dryers with integrated laser diode network were proposed. Low energy coherent radiation treatment represents an inexpensive and environmentally safe method that does not pollute the environment. This method also provides close control of the process, and in spite of the greater cost of energy, the overall increase in drying efficiency and throughput can bring about significant economic savings.

KEYWORDS: pre-treatment, drying, laser power, water content, lemon balm

INTRODUCTION

Lemon balm (*Melissa officinalis L.*) is a well-known medicinal plant. Leaves of this plant have been also widely used in cooking to add flavour to dishes and for the preparation of water infusions due to its pleasant aroma [1]. Lemon balm leaves are a rich source of various bioactive compounds that have strong antioxidant activity [2]. Lemon balm has been highly researched due to its many potentially therapeutically desirable effects such as sedative, antispasmodic, antibacterial, antiviral, anti-inflammatory, and sedative effect [3]. Therefore, the plant has been used for the treatment of mental diseases, various cancers, cardiovascular and respiratory problems, and as a memory enhancer, cardiac tonic, antidepressant, sleeping aid and antidote [4].

Leaves or top parts of the plant are picked before flowering when they contain the largest amount of essential oil [5], which due to its aromatic properties is used in aromatherapy, cosmetics, fragrance industry, and as a spice in the preparation of beverages and various sweet and salty foods [6].

Drying of plant material is a most important pre-processing step before storing for a longer time period but this process requires large financial costs. Non-invasive technique such as laser can be applied as pre-treatment of drying. Previous research on low energy lasers has shown that their application causes more positive reactions to plant material, which provides opportunities for their widespread use in agriculture and processing of agricultural products [7]. The use of pre-treatment in the drying process effectively shortens the drying time, and also contributes to the preservation of bioactive compounds. According to Danilov and Leontchik [8] and Mujumdar [9] only 20 to 60% of the heat supplied to the dryer is used for water evaporation, 5 to 25% for material heating, the rest are heat losses. One of the ways to achieve energy savings is application of different physical principle for drying process, such as use of radio frequency, laser radiation, NIR, microwave and vacuum drying. Starzycki et al. [10] indicates that alternative energy sources such as low energy lasers could be a feasible tool to perform the pre-drying process. Mujumdar [9] indicates that energy during the electromagnetic radiation drying is transferred directly to the material that is heated. Therefore, the energy is not expended by heating the air, or parts of equipment as in conventional drying methods, so this kind of drying leaves enough space for energy savings. According to Jović et al. [11], Nenadić et al. [12] and Nenadić et al. [13] beside water content removing, laser beam can also be successfully applied in fungi removing process. This is also an important fact because by reducing the number of undesirable microorganisms, the possibility of infection with the toxic products of their metabolism is also reduced. However, exposing the material to higher power lasers can remove too much water and cause serious damage to the plant even if exposure period is very short [11].

Therefore, the aim of this study was to determine the possibility of using lasers as a pre-treatment for drying the lemon balm leaves and also to determine the variation of water content during the laser treatment.

MATERIALS AND METHODS

PLANT MATERIAL

Lemon balm plants were grown according to the standard procedure in the experimental field of the Department of Vegetable Crops, Faculty of Agriculture University of Zagreb. Lemon balm leaves was harvested in the early morning hours and immediately after harvesting fresh material was delivered to the laboratory of the Department of Agricultural Technology, Storage and Transport at Faculty of Agriculture, University of Zagreb where all the analyses were performed. Leaves were manually cleaned up from impurities. Only whole, healthy and undamaged leaves were considered for treatment. Water content of fresh leaves was determined by a standard AOAC [14] procedure in laboratory dryer INKO ST40T (Croatia) in the temperature range of 105 °C and at atmospheric pressure until the mass of the substance remains constant.

LASER TREATMENT

Two main parts laser treatment equipment are laser beam source and micro-objective. Two laser beam sources with 100 mW (model HLM1845) and 200 mW (model HLP18130) (China) output power were used to expose lemon balm leaves to beam energy. Both laser beam sources have the same output wavelength of 650 nm. Different power outputs were used to determine whether there is any effect of power to the water content removal process.

In order to perform pre-drying the dryer with integrated laser diode net (3 × 5) lasers were proposed. Dryer consists of drying chamber with inspection window, air output and input. Measuring instruments were wet thermometer, dry thermometer and electronic balance. The drying chamber is made of polyurethane insulation panels, coated on both sides with stainless steel (X6CrNiTi18-10) sheets, which ensures quality thermal insulation. Drying chamber internal dimensions are 300 × 300 × 400 mm. For testing purposes in presented study laboratory tests were performed on one segment of the laser diode net. The experiment was set up, as shown in Figure 1.

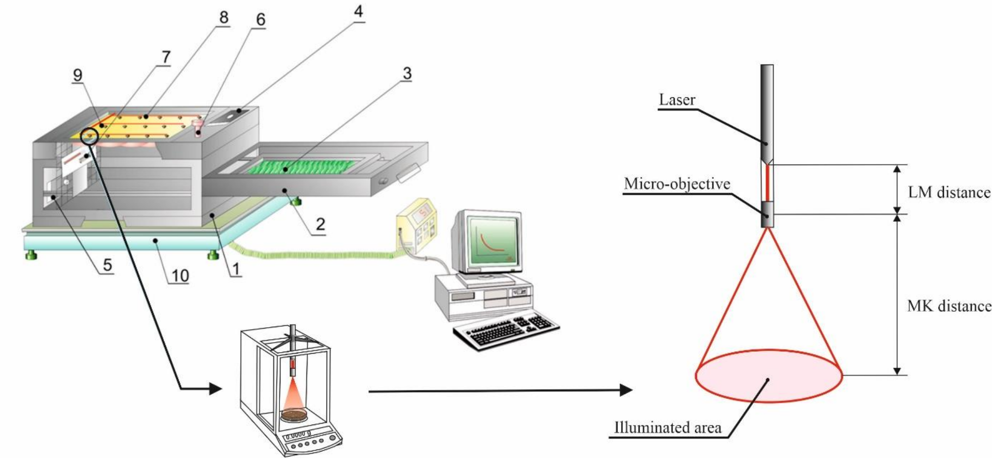

Figure 1. Experimental set-up of the drying process with laser beam
(where: 1 – dryer, 2 - frame for biological material, 3 – biological material (lemon balm leaves), 4 – air output, 5- air input, 6 - thermometer (dry), 7 - thermometer (wet), 8 – inspection window, 9 - laser diode net (3 x 5 lasers), 10 - electronic balance) [7].

Approximately 1.5 g of leaves per repetition were placed in elementary (thin) layer on illuminated area, 100 mm in diameter under the laser source. Illuminated area surface is calculated by using following formula:

$$A = r^2\pi \quad (1)$$

Distance (LM) between laser source and micro-objective was 70 mm and distance (MK) between micro-objective and leaves was 320 mm.
Intensity of laser radiation within the illuminated area for a 100 mW laser is calculated using the following equation:

$$Intensity = \frac{E_{laser}(W)}{Illuminated\ area\ (m^2)} \times treatment\ period\ (s) \quad (2)$$

The energy of individual photon is calculated by following equation:

$$E_{individual\ photon} = h\upsilon = \frac{hc}{\lambda} \quad (3)$$

where:

- h – Planck's constant (6.626 x 10^{-34} Js),
- υ – photon frequency for semiconductor laser (4.61538 x 10^{15} s^{-1}),
- c – speed of light (2.99 x 10^8 ms^{-1}),
- λ – wavelength (650 nm).

Numbers of photons from the individual laser sources are calculated by using equation:

$$n_{photons} = \frac{E_{laser}}{E_{photon}} \quad (4)$$

In addition to the above knowing the laser output power and period of treatment, total energy emitted by the source of laser light during 180 seconds is calculated by using equation:

$$E_{laser} = E_{ivdividual\ photon} \times n_{photons\ 100mW} \times treatment\ period \quad (5)$$

Plate with prepared leaves is placed on the laboratory analytical balance (Sartorius BP 221S, Göttingen, Germany) with measurement accuracy class I scale interval 0.1 mg. Leaves are illuminated only from one side during 180 seconds. During the pre-drying process, reduction in the weight of the samples was measured and recorded every 30 seconds. During the drying process, laboratory environment humidity was between 80-84% and atmosphere pressure was in the mean 1014 hPa.

RESULTS AND DISCUSSION

According to Dinoev et al. [15] physiological changes occurring in the treated plant material mostly depend on the laser wavelength and intensity of radiation. Illuminated area surface of 100 mm in diameter according to equation (1) was 7.85 $\times 10^{-3}$ m^2.

According to equation (2) intensity of laser radiation for 100 mW laser were 2292.99 Wsm^{-2} and 4585.98 Wsm^{-2} for a 200 mW laser.

The energy of individual photon calculated by equation (3) were 3.06×10^{-18} J.

Numbers of photons from the individual laser sources calculated from the equation (4) were 3.27×10^{16} photon s^{-1} for 100 mW laser and 6.54×10^{16} photon s^{-1} for 200 mW laser.

Total energy emitted by the lasers during 180 seconds calculated using equation (5) were 18.01 J for 100 mW laser and 36.02 J for 200 mW laser.

According to the results, it is obvious that the amounts of energy emitted by lasers are relatively small. Therefore, lasers thermal influence is negligible so it can be concluded that laser activity on lemon balm leaves is based solely on biostimulation.

Beside wavelength of electromagnetic radiation and intensity of radiation, interaction between laser light and plant material also depends on the water content and the structure of plant material. The initial water content of lemon balm leaves was 75.64%. The loss of water content during laser pre-treatment is shown in Figure 2. The results are presented as mean values of 30 repetitions (n=30).

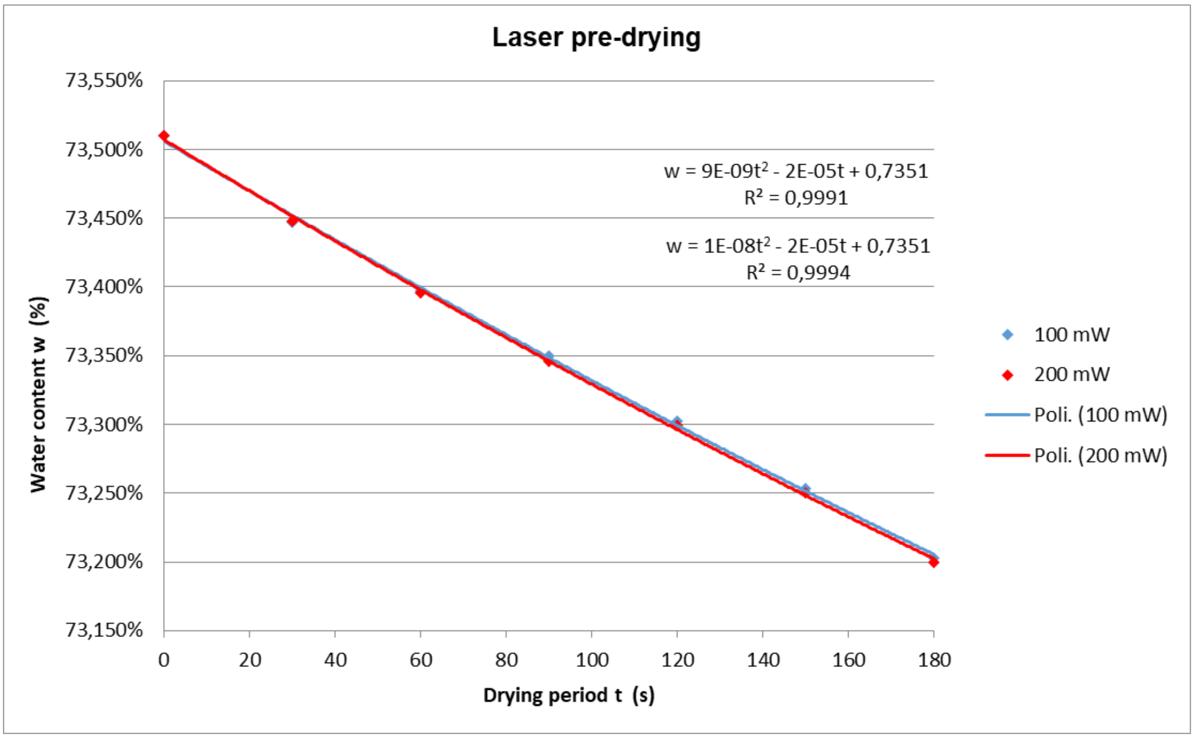

Figure 2. Effect of 100 mW and 200 mW laser pre-treatment on water content of lemon balm leaves

Based on the obtained data, second order polynomial equations were calculated. Pre-drying by 100 mW laser takes place according to the equation $w = 0.7351 - 2\times10^{-5}t + 9\times10^{-9}t^2$ with a very high coefficient of determination $R^2 = 0.9991$. Pre-drying by 200 mW laser takes place according to the equation $w = 0.7351 - 2\times10^{-5}t + 1\times10^{-8}t^2$ with also a very high coefficient of determination $R^2 = 0.9994$.

By deriving second order polynomial equations the slopes of the lemon balm leaf drying curves were determined and the following expressions were shown in table 1.

Table 1. Derivations of second order polynomial equations

Pre - treatment	**Derivations of second order polynomial equations (*dw/dt*)**
100 mW	$dw/dt = -2\times10^{-5} + 18\times10^{-9}t$
200 mW	$dw/dt = -2\times10^{-5} + 2\times10^{-8}t$

The derivatives of the equations have a negative sign, which indicates a decreasing function, and confirms that this is a process of drying. It is also evident from the derivations that the slopes of the drying curves differ from each other depending on the method of treatment. Therefore, the results of both 100 mW and 200 mW lasers show positive aspects in water removing process. By comparing the above equations, *i.e.* their coefficients, it can be reliably concluded that the application of a 200 mW laser results in a somewhat faster release of water from the lemon balm leaves. According to Moore et al. [16] reason for this water removing process is a better energy transfer during laser treatment than in convective drying, probably due to Förster - Dexter's energy transmission in dipole molecules. In addition, these processes need further careful investigated in order to find balance between laser power and its biological effect on treated materials.

Laboratory tests carried out on a single section of laser diode network shows that proposed dryer with integrated laser diode net (3 × 5 lasers) can be successfully used for pre-drying purposes.

CONCLUSION

Experiments have shown that a low energy laser can be used for the pre-drying of lemon balm leaves. Treatment with a low energy laser beam for 180 seconds caused a decrease in the water content by 0.307% with 100 mW laser and 0.31% with 200 mW laser. Obtained results indicate a realistic possibility of applying laser radiation in a technological process that precedes conventional drying. Application of laser drying needs to be considered as cheap and environmentally friendly method that does not pollute the environment and at the same time allows significant energy savings. Also this method of pretreatment creates favourable conditions for the automation of process.

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