RESEARCH IN SOME MEDICAL PLANT DRYING PROCESS

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Abstract. The drying process by free convection of six different medical plants (flowers of garden marigold (*Calendula officinalis*), leaves of lemon balm (*Melissa officinalis*), origanum (*Origanum vulgare*), common agrimony (*Agrimonia eupatoria*), common lavender (*Lavandula angustifolia*), and common sage *(Salvia officinalis*)) is compared. The constant and changing drying coefficients are determined using the gravimetric methods of measurement and a special mathematical evaluation methodology. Theoretical and experimental results are compared. The experimental results show that the drying coefficient of a plant at the first 10 hours of drying is changing linearly until it becomes constant. The corresponding linearity is strong, characterized by high coefficients of determination. The changes of speeds of sample drying rate are approximately equal, except lemon balm, which is more than twice greater than the others.

Keywords: drying coefficient, free convection, medical plant.

Introduction

Requirements of worldwide progress in cultivation of medicinal and aromatic herbs, plant drugs, different biological materials and their products require also new theoretical foundations and knowledge about their processing and safety storage. The need for high quality raw is increasing. This phenomenon is proven by number of cultivation results and registration procedures, concerning medicinal and aromatic plant cultivars, recently reported from different countries. The achieved progress in cultivation is obvious, in spite of the fact that different strategies and methods are used country by country [1].

In pharmacy, plant raw materials are important sources of new medicines and their substitutes. Natural medicines of plant origin have a wider therapeutic spectrum, milder action and less frequent side effects compared with synthetic substances. According to the data of the World Health Organization, about 70 000 plant species are currently used for medicinal purposes; about 1000 species are used in the European pharmaceutical industry.

Preservation of production is a very important problem to be solved by producers of these products. One of the ways of preservation of products is drying. Medicinal plants can be dried in a number of ways: in the open air (shaded from direct sunlight); placed in thin layers on drying frames, wire-screened rooms or buildings; by direct sunlight; in drying ovens/rooms and solar dryers; by indirect fire; microwave; or infrared devices [2]. When possible, temperature and humidity should be controlled to avoid damage to the active chemical constituents. The method and temperature used for drying may have a considerable impact on the quality of the resulting medicinal plant materials. Chemical changes are the most important in the post-harvest of medicinal plants and can be influenced by drying. Moreover, drying can promote changes in the product appearance (color) and smell, modifying the final quality.

Drying research is an outstanding example of a very complex field, where it is necessary to look comprehensively on the simultaneous energy and mass transfer process that takes place within and on the surface of the material. In order to get the full view of the drying process, researches have to incorporate and deal with highly non-linear physical phenomena inside drying agricultural products, non-homogenous distribution of temperature and humidity inside dryers, equipment selection, product final quality. That is the reason why a unique theoretical setting of drying has to be determined through the balance of the heat flow, temperature changes and moisture flow.

In order to find the optimal drying regime it is necessary to understand the transport mechanisms which take place within and on the surface of the product. The drying process is characterized by the existence of transport mechanisms such as surface diffusion, pure diffusion, capillary flow, evaporation, thermo-diffusion, etc.

Many studies were done to process medical plant drying by small heated air. The researchers investigated the influence of some process parameters (temperature, sample thickness, layer thickness, air flow rate, etc.). The effect of the used airflow and drying air temperature on the drying kinetics was

studied in [3; 4]. Influence of pre-treatment on the drying rate of chili pepper at various air temperatures was investigated in [5]. Solar energy usage in plant drying technologies was studied in [4].

Drying is the most common and fundamental method for post – harvest preservation of medicinal plants. Natural drying can be considered only for drying of small quantities. In case of mass production the use of technical drying applications is indispensable. For preservation of active ingredients of plant material low drying temperature is recommended. It means long drying duration. Drying represents 30-50 % of total costs in medicinal plant productions [6]. Energy demand of drying represents is a significant cost factor. It is largely due to the high moisture content of the leaves, flowers, berries or roots to be dried. Different parts of the plant and their drying aspects were considered in [2].

For indoor drying, the duration of drying, drying temperature, humidity and other conditions should be determined on the basis of the plant part concerned (root, leaf, stem, bark, flower, etc.) and any volatile natural constituents, such as essential oils. The optimal combination of the dryer design, operation method, energy use, and product quality requires crucial managerial decision.

The aim of this research was to investigate and compare principal theoretical problems of drying by free convections for medical plants as flowers of garden marigold (*Calendula officinalis*), leaves of lemon balm (*Melissa officinalis*), origanum (*Origanum vulgare*), common agrimony (*Agrimonia eupatoria*), common lavender (*Lavandula angustifolia*), common sage *(Salvia officinalis)* and determining the drying coefficients.

Flowers of garden marigold (*Calendula officinalis*) have from ancient times large application. They are used against spasms, for better activity of gallbladder or against inflammatory diseases of the skin.

Leaves of lemon balm (*Melissa officinalis*) are used internally as a means of encouraging, calming and moderating pain, stimulating appetite and against flatulence.

Origanum (*Origanum vulgare*) is used internally for better digestion (digestive upsets) and externally as a gargle. Common agrimony (*Agrimonia eupatoria*) has an astringent effect, it helps digestion and gall bladder activity, positively regulates the activity of autonomic nerves and has anti-inflammatory effects.

Even in ancient Greece, common lavender (*Lavandula angustifolia*) was used as a cough medicine or appeasement. It is suitable against sleeping problems, suffer states of nervousness and anxiety, relieves muscle tension and promotes natural regeneration. Lavender accelerates wound healing and helps prevent the formation of scars.

Common sage (*Salvia officinalis*) is used internally against sweating, externally as an astringent agent, e.g., when rinsing during bleeding in the mouth. It also has anti-inflammatory effect.

The basis for reliable use of medicinal plants especially in medicine are often very complex and challenging chemical analyses, biological tests of isolated compounds on tissue cultures, animals, test cultures of bacteria, fungi, etc. For proper harvesting and collection of medicinal plants it is necessary to observe special procedures for both domestic consumption and particularly for industrial processing of drugs.

Generally, the medicinal plants should not be collected in wet and rainy weather or during dew, but when they are dry. During collection they must not be damaged, e.g., by breaking, but also contact with metals violates vitamin C and tannins. The plants should be collected as the whole, if possible, and cut after drying. Most plants should be dried in the shade, where they will not be soiled by dust, birds, insects etc. To the dried plants fresh plants must not be added, since the drug gets wet again and may degrade by mold.

Materials and methods

For studies of theoretical background of drying and comparison of different properties we have selected six subjects: flowers of garden marigold (*Calendula officinalis*), leaves of lemon balm (*Melissa officinalis*), origanum (*Origanum vulgare*), common agrimony (*Agrimonia eupatoria*), common lavender (*Lavandula angustifolia*), common sage *(Salvia officinalis)* Fig. 1.

a) **b)** **c)** **d)** **e)** **f)**

Fig. 1. **Plants in the nature (growing):** a – garden marigold (*Calendula officinalis*); b – origanum (*Origanum vulgare*); c – lemon balm (*Melissa officinalis*); d – common agrimony (*Agrimonia eupatoria*); e – common lavender (*Lavandula angustifolia*); f – common sage (*Salvia officinalis*)

The laboratory measurements were carried out at the Faculty of Engineering CULS Prague. The studied and measured material samples were put in white plastic bowls and dried by natural convection, Fig 2 and Fig. 3. During the experiment, the average ambient temperature was 25.3 ºC with a standard deviation STDEV = 0.7 ºC and the air humidity 50.6 % with a standard deviation STDEV = 4.7 %. The air temperature and humidity were measured by the sensor FHA646-E1C connected to the data logger ALMEMO 2690-8. The construction of the drying bowls and their placement enabled to control equal surrounding conditions for all plants and avoid the changes of tmhe parameters during the experiments.

The moisture content was identified by gravimetric measurement in regular time intervals. The samples were weighed on the digital laboratory balance KERN-440-35N with maximum load weight 400 g and with resolution 0.01 g. The total drying time was adapted to the need for determination of the final moisture content.

Fig. 2. **Medical plants before drying**

Fig. 3. **Medical plants after drying**

The aim of the post-harvest technology is to preserve the quality of the drugs, which is relevant to the plants also after drying. Just without the tests it is obvious from Fig. 2 and Fig. 3 that the plant color remained, but the bulk density decreased significantly during drying. It can be expected that the drying process was under conditions, which were adequate for the studied plants.

Results and discussion

Calculation was made per 100 g of material in order to compare the drying dynamics of different types and weights of medical plants. The results are shown in Fig. 4. Looking at the results it is seen that drying dynamics of all samples are similar except for garden marigold (M1), where longer sample drying is observed. Other examples dry 1 to 2 days, but M1 dries up to 6-7 days at the same

conditions. The difference between garden marigold and other plant drying can be explained by the fact that flowers of garden marigold are more thick and inside moisture diffusion affects the drying process more.

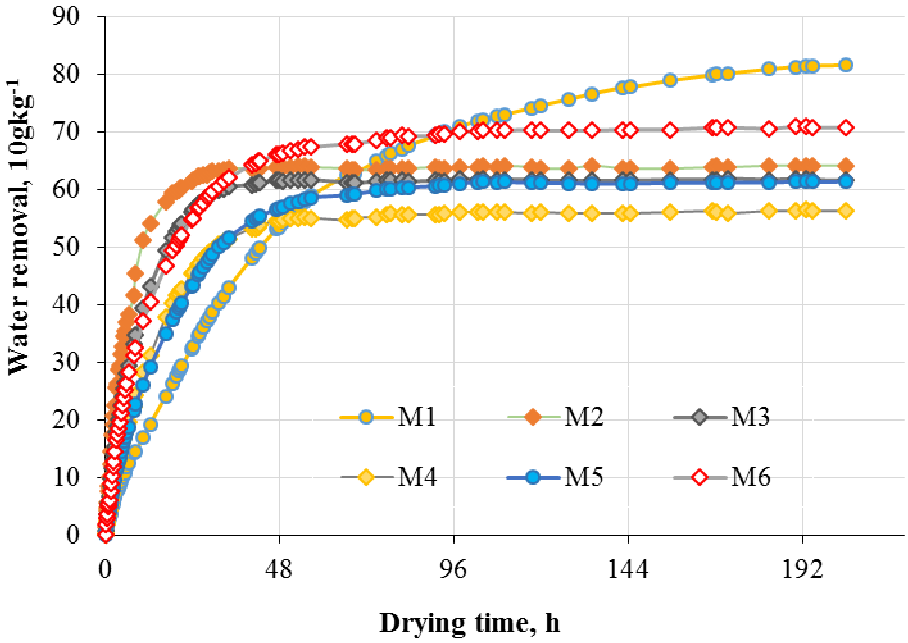

Fig. 4. **Different plant drying dynamics:** M1 – garden marigold; M2 – lemon balm; M3 – origanum; M4 – common agrimony; M5 – common lavender; M6 – common sage

One of the most important tasks is to find expression for the drying coefficient K. It depends on the dried product, drying equipment, conditions, etc. We assume (for thin product layer and constant boundary condition) that it is depending only on the drying time t. Using the methodology described [7] and the experimental data obtained the drying rate expressions can be obtained for the viewed plant (placed in white bowls) drying in room (air average temperature during drying was 25.3 ºC) by free convection.

Using the experimental data we calculated the changing drying coefficient [7] for the samples of each plant.

Garden marigold flower drying rate $K(t)$ dependence on the drying time is seen in Fig. 5. As it can be seen, starting with 12-hour drying, the drying coefficients remain constant. The changing drying rate can be calculated from the first 12 hours (Fig. 6). As follows from the calculations and the experimental data of the first 12-14 hours of drying the coefficient decreases linearly until it reaches the value 0.022.

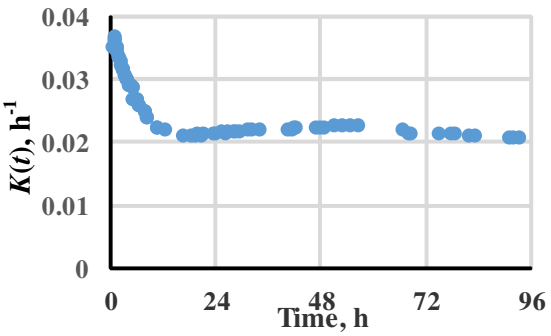

Fig. 5. **Garden marigold flower drying rate $K(t)$ changes during drying**

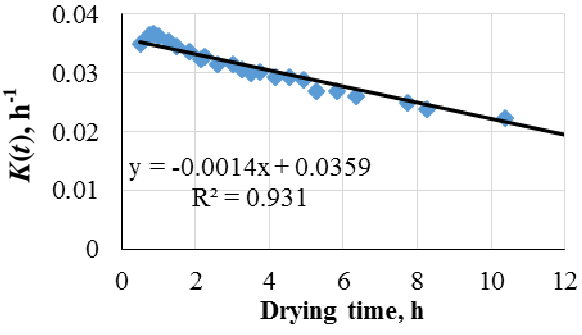

Fig. 6. **Linear drying rate $K(t)$ calculation for garden marigold flower**

As it is seen from the calculations, the linear drying coefficient well described garden marigold drying rate changes during the first 10 hours of drying (coefficient of determination $\eta^2 = 0.935$, see

Fig. 6). The comparison is made between the experimental and theoretical calculated data with variable and constant drying rates. Constant drying rate is taken as average value from the experimental data. The changing drying rate was taken as (Fig. 6):

$$K(t) = -1.4 \cdot 10^{-3} \cdot t + 0.036, \quad (1)$$

where t – drying time, h.

The average of max absolute value difference between the corresponding theoretical and experimental data was 0.126 g (K = 0.03088 h^{-1}) and 0.028 g for the changing drying coefficient (1). The differences between the experimentally measured and theoretically calculated sample weight changes with $K(t)$ = const are approximately five times greater that with the changing coefficient during the first 10 hours of drying. The drying coefficients were calculated for other 5 types of plants.

Theoretical linear drying coefficients for lemon balm in the first 10 hours of drying were:

$$K(t) = -4.9 \cdot 10^{-3} \cdot t + 0.1777 \quad (2)$$

with coefficient of determination η^2 = 0.83,

for oreganum was:

$$K(t) = -2 \cdot 10^{-3} \cdot t + 0.1165 \quad (3)$$

with coefficient of determination η^2 = 0.90,

for common:

$$K(t) = -1.5 \cdot 10^{-3} \cdot t + 0.0794 \quad (4)$$

with coefficient of determination η^2 = 0.68 ,

for common lavender:

$$K(t) = -2 \cdot 10^{-3} \cdot t + 0.10722 \quad (5)$$

with coefficient of determination η^2 = 0.92, and

for common sage was:

$$K(t) = -2.3 \cdot 10^{-3} \cdot t + 0.0945 \quad (6)$$

with coefficient of determination η^2 = 0.84.

Viewing expressions (1)-(6) it can be seen that the lowest drying rate at the beginning of the drying process was the drying rate of garden marigold flowers (1). It is more than twice lower than for the other types. The sample drying rate change speeds are approximately equal, except for lemon balm, which is more than 2 times greater than the others.

The research results correspond to *Sambucus nigra* flowers and *Tilia cordata* flowers [8] and peppermint (*Mentha piperita*) plants drying [9]. The drying rate change type and speed are the same. The drying rate difference at the beginning of the process could be explained by differences in the plant sample preparing and drying conditions (drying temperature was 2 degrees higher [9]).

Conclusions

1. The experimental results show that the drying coefficient of the plant at the first 10 hours of drying changes linearly until it becomes constant. The corresponding linearity is strong, characterized by high coefficients of determination.
2. The sample drying rate change speeds are approximately equal except for lemon balm, which is more than twice greater than the others.
3. Longer sample drying is observed for garden marigold flowers. Other examples dry 1 to 2 days, but garden marigold dries up to 6 - 7 days at the same conditions. The difference can be explained by the fact that the flowers of garden marigold are thicker and inside moisture diffusion affects the drying process more.
4. The drying process of the viewed plants corresponds with the results of drying similar herbs.

5. This methodology can be applied to find the drying rate of materials at different temperatures and combining the results to find the coefficient dependency on both the drying time and temperature.

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