COMPARISON OF MINT PLANT AND PINE CONE DRYING BY CONVECTION

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Abstract. Two different products (pine cones and peppermint plants) in the drying process by free convection are compared. Using the gravimetric methods of measurement and a special mathematical evaluation methodology the constant and changing drying coefficients are determined. Pine cones were dried in two different conditions (in bowl and on sieve); peppermint plants were placed in white and brown bowls. The results show that drying on the sieve goes quicker that drying in the bowl. Theoretical and experimental results are compared.

Keywords: drying coefficient, free convection, peppermint plant, pine cone, shape of product.

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 breeding results and registration procedures, concerning medicinal and aromatic plant cultivars, recently reported from different countries. The achieved progress in breeding is obvious, in spite of the fact, that different strategies and methods are used country by country [1].

Preservation of products is a very important problem to be solved by producers of these products. One of the ways of preservation of products is drying. The drying process is the use of products with low water activity, thereby inhibiting the production of microbial reproduction and enzyme activity, and can give the flavour of a good product to achieve long-term storage, easy to transport, easy to consumer spending. During drying, heat is supplied and the volatile component, mainly water, is eliminated from the material mixture.

Drying research is an outstanding example of a very complex field where it is necessary to look comprehensively on 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 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 cereals, carrots, apples and etc. 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 carrot slices on the drying kinetics was studied in [2; 3]. Influence of pre-treatment on the drying rate of chilli pepper at various air temperatures was investigated 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 the plant material low drying temperature is recommended. It means long drying duration. Drying represents 30-50 % of total costs in medicinal plant productions [5]. Energy demand of drying represents 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 its drying aspects were considered [6].

The method and temperature used for drying may have a considerable impact on the quality of the resulting medicinal plant materials. For example, shade drying is preferred to maintain or minimize loss of colour of leaves and flowers; and lower temperatures should be employed in the case of medicinal plant materials containing volatile substances. In the case of natural drying in the open air, medicinal plant materials should be spread out in thin layers on drying frames and stirred or turned frequently. In order to secure adequate air circulation, the drying frames should be located at a sufficient height above the ground. Efforts should be made to achieve uniform drying of medicinal plant materials and so avoid mould formation.

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 mint plant (peppermint) (*Mentha piperita* L.) and pine cone (*Pinus nigra* L.) drying by free convections and determining the drying coefficients.

Materials and methods

For studies of theoretical background of drying and comparison of very different properties we have selected two very different subjects: herb peppermint (*Mentha piperita* L.) and pine cones (*Pinus nigra* L.).

Peppermint has a long tradition of use in traditional medicine and aromatherapy. Peppermint is commonly thought to soothe or treat symptoms such as nausea, vomiting, abdominal pain, indigestion, etc. The use in culinary is very popular. It is the oldest and most popular flavour of mint-flavoured confectionery and is often used in tea and for flavouring ice cream, confectionery, chewing gum, and toothpaste.

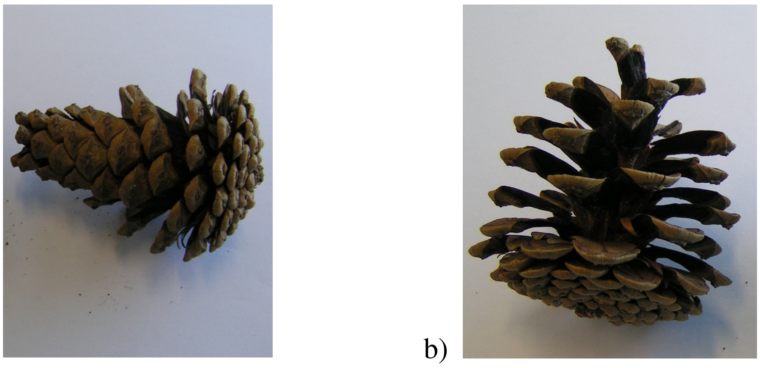
From the dried leaves and tops of the stems before flowering leached tea also is used in preparation of lamb or vegetables. Peppermint can also be found in some shampoos, soaps and skin care products. Peppermint has high menthol content. The oil also contains menthone and menthyl esters, particularly menthyl acetate. There are publications focused on breeding and determination of the content of the main substances. E.g., the biologically active substances have dominant presence of menthol at 72-75 %; at more quantities, menthone 12-16 % was determined in [7]. The control cultivar of “Perpeta” had 1.8 % essential oil content. In this cultivar, the major substance in essential oil is mentone at 30-42 %. Amount of menthol obtained was 30-34 %.

Fresh leaves can be harvested through the summer. The stems should be cut just before flowering, preferably at noon, because then they contain the most essential oils. By artificial drying the temperature must not exceed 35 ºC, because then oil is lost. Dried peppermint needs to be stored in an airtight container (therefore not to be wet) not to lose its aroma.

Different types of *Pinus* trees are famous partly also because of the application in special industries. Black pine (*Pinus nigra* L.) is a robust evergreen tree originally from southern Europe and the Mediterranean. In the Czech Republic it is an important substitute tree species planted in dry and warm sites on limestone and locations that are vulnerable to industrial pollution, e.g., in air pollution or reclaimed areas after extraction of raw materials. It is used as a fuel, building material or as a raw material for pulp. In recent times it is very often planted as an ornamental tree in parks and gardens.

The cones appear from May to June. The mature seed cones are 5-10 cm (rarely to 11 cm) long, with a rounded shape. The seeds are dark grey, 6-8 mm long, with a yellow-buff wing 20-25 mm long; they are wind-dispersed when the cones open. Collection of cones in seed orchards can be facilitated by simple technical equipment during suitable time. Because of their widespread occurrence, conifer cones have been a traditional part of the arts and crafts of cultures where conifers are common.

Due to the composition, high amounts of resin can be used, e.g., as a biofuel interesting prospective. Another application seems to be in pharmaceutical industry. Medicinal plants and culinary herbs with antiangiogenic and little toxicity properties have gained importance. The lipid fraction of *Pinus halepensis* L. seeds for a possible antiangiogenic activity has been investigated. No toxic and antiangiogenic phytochemicals are useful in combating cancer by preventing the formation of new blood vessels to support the tumor growth [8]. Because of the chemical composition and antibacterial activity of essential oil components extracted from the cones they can be used in the future more also in pharmaceutical and other special branches of chemical industry. Significant losses in the harvesting and collection of seeds are the problem.



a) b)

Fig. 1. **Pine cone a) in nature and b) in process of drying**

The laboratory measurements were carried out at the Faculty of Engineering CULS Prague. The technical equipment used for the experiments was very simple. The studied and measured material samples were put in plastic bowls and one part of the samples also on the sieve with mesh 3x4 mm and dried by natural convection. 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. Air temperature and humidity were measured by the sensor FHA646-E1C connected to the data logger ALMEMO 2690-8.

Results and discussion

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) depending only on the drying time t. Using the methodology described [2; 3] and the experimental data we obtained the drying rate expressions for pine cones (placed in a bowl and on sieve) and peppermint plant (placed in brown and white bowls) layer drying in room (air average temperature during drying was 23.6 ºC) by free convection.

1. Pine cone drying

Using the experimental data we calculated the changing drying coefficient [3] for pain cone drying situated on the sieve and in the bowl (Fig. 2, Fig. 3). Very special shape of pine cones was one of the reasons, why this material was chosen for the research.

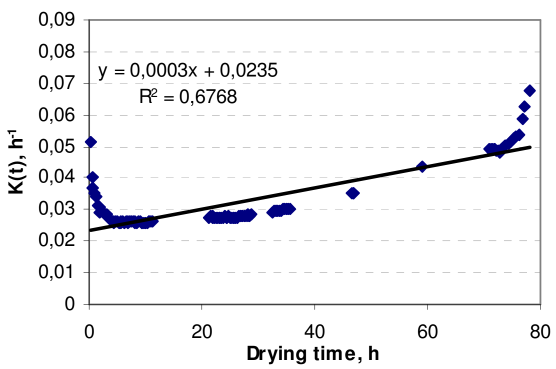


Fig. 2. **Linear drying rate *K*(*t*) calculation for pine cone drying placed in bowl**

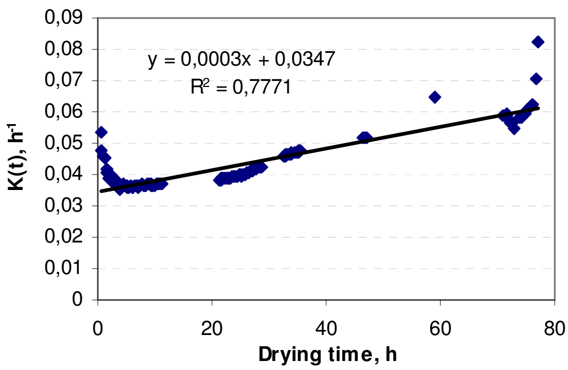


Fig. 3. **Linear drying rate *K*(*t*) calculation for pine cone drying placed on sieve**

Theoretical linear drying coefficients for cones placed in the bowl are:

$$K(t) = 3 \cdot 10^{-4} \cdot t + 23.5 \cdot 10^{-3} \quad (1)$$

with coefficient of determination R^2 = 0.677 and placed on the sieve:

$$K(t) = 3 \cdot 10^{-4} \cdot t + 34.7 \cdot 10^{-3} \quad (2)$$

with coefficient of determination R^2 = 0.777,
where t – drying time, h.

We compared the experimental data with theoretical exploiting the variable drying rate and constant drying coefficient, calculated as the average of all interval corresponding coefficients Fig. 4, Fig. 5.

The average of absolute values of differences between the theoretical (with constant coefficient) and experimental data were 1.86 g (bowl) and 1.2 g (sieve) with standard deviations STDEV = 0.84 g and 0.58 g correspondingly. The average of absolute value differences between the theoretical ($K(t)$ from (1), (2)) and experimental data were 0.82 g (bowl) and 0.4 g (sieve) with standard deviations STDEV = 0.69 g and 0.31 g correspondingly.

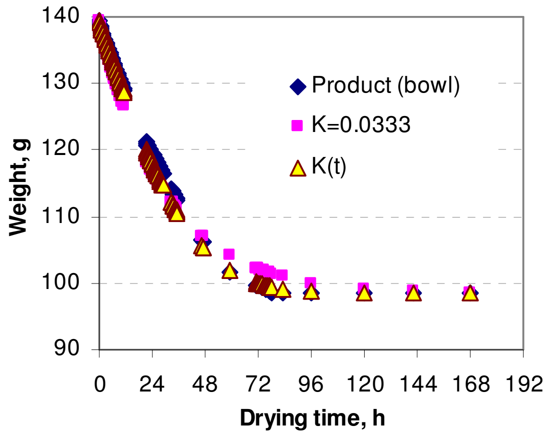


Fig. 4. **Pine cone weight change (experimental and theoretical calculated) during drying in a bowl**

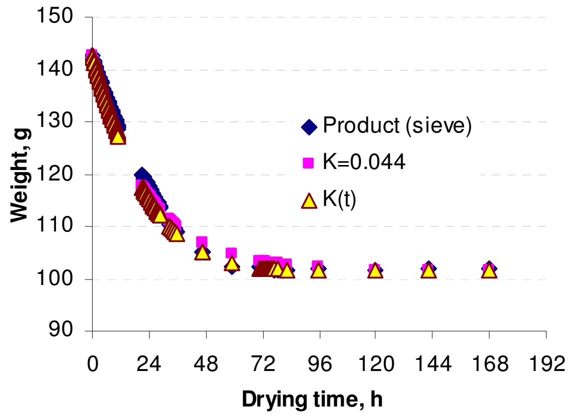


Fig. 5. **Pine cone weight change (experimental and theoretical calculated) during drying on a sieve**

After 80 hours of moisture pine cones are in balance with the environment and only in the cone moisture fluctuations occur. Drying on the sieve is faster; however, the rate of change is equal. This can be explained by the fact that the pine cones have a small surface contact with the bowl. Higher drying speed on the sieve can be explained by the possibility of ventilation. If the material is placed in a bowl, the air flowing and ventilation through it is difficult.

2. Peppermint drying

We compared the experimental data with theoretical exploiting the variable drying rate and drying constant factor, calculated as the average of all interval corresponding coefficients. Fig. 6. and Fig. 7 represent the weight changes of dried peppermint placed in a brown bowl and white bowl correspondingly. As it can be seen, product placement location influences the coefficient of drying.

The average of max absolute value difference between the corresponding theoretical and experimental data was 0.71 g ($K = 0.138$ h^{-1}) with standard derivation 0.46 g and 0.65 g ($K(t) = 148.7 \cdot 10^{-3} - 1.15 \cdot 10^{-3} \cdot t$) with standard derivation 0.44 grams correspondingly. For the white bowl average max absolute value difference was 0.78 g (for constant drying rate $K = 0.226$ h^{-1}) with standard derivation 0.55 g and 0.65 g (for changing drying rate $K(t) = 245 \cdot 10^{-3} - 3.1 \cdot 10^{-3} \cdot t$) with standard derivation 0.48 g.

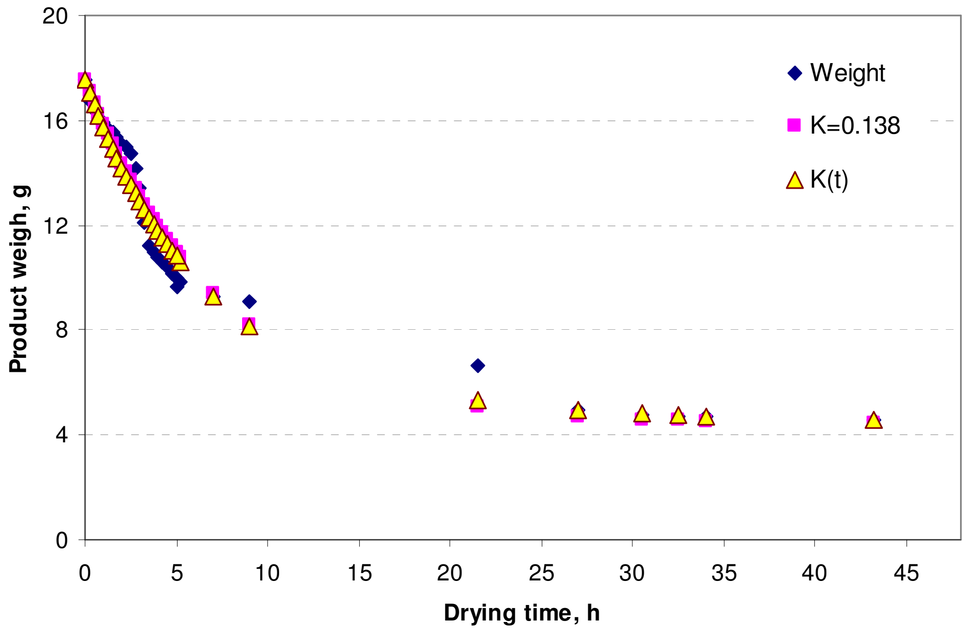


Fig. 6. **Peppermint (*Mentha piperita*) plant weight change (experimental and theoretical calculated) during drying on a brown bowl**

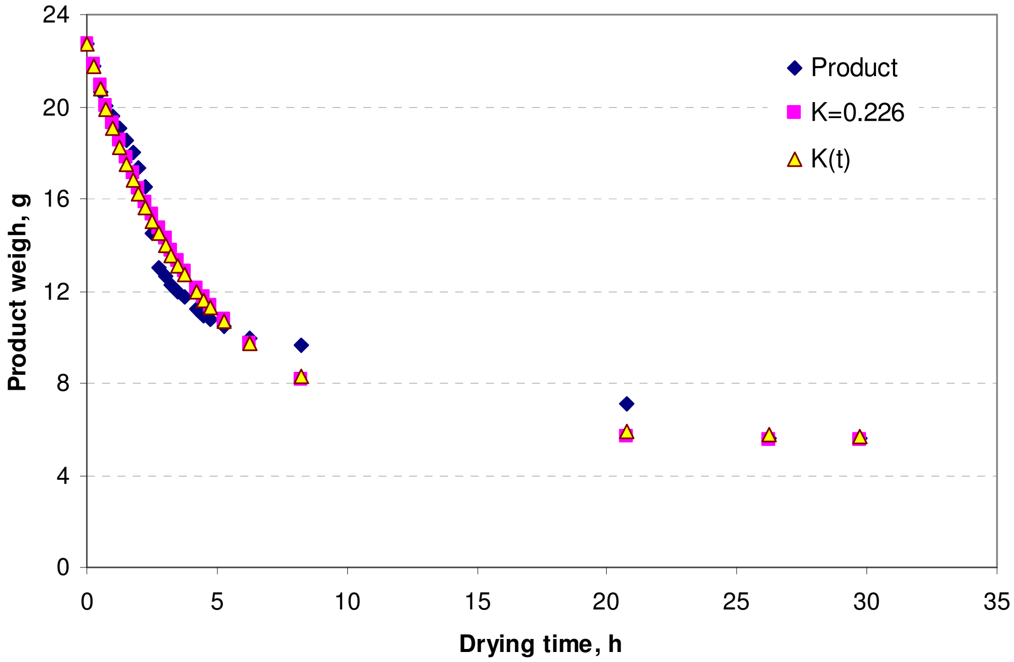


Fig. 7. **Peppermint (*Mentha piperita* L.) plant weight change (experimental and theoretical calculated) during drying on a white bowl**

The peppermint plant variable drying coefficient is descending regardless of placement. This corresponds to a *Sambucus nigra* L. flower and *Tilia cordata* L. flower drying [9]. In the experiment the observed bowl colour effects on the drying process. The plants in the white container dry faster than in dark-coloured containers by free convection. There was not sufficient number of experiments to confirm these results. It could be studied also by drying of other plants.

The linear correlation (for $K(t)$ expressions) determination coefficient was only R^2 = 0.26. It means that the drying rate is not so accurate if the product is in a bowl.

Conclusions

1. The developed mathematical model for determination of the drying coefficient can be applied to porous materials.
2. Drying of pine cones at the beginning and end of the drying period is obviously influenced by strongly and quickly changed shape of the product (Fig. 2 and Fig. 3).
3. Drying on the sieve was faster but the rate of change is similar than on the solid tray (bowl) without holes.
4. The drying process of peppermint corresponds with the results of drying of similar herbs.
5. This methodology can be applied to find the drying rate of the material at different temperatures and combining the results to find that the coefficient depends on both the drying time and temperature.

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