DRYING PROCESS OF TWO SPECIAL PLANTS

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Abstract. The purpose of this work is determination of drying coefficient of porous material. Using the mathematical model of drying process of thick grain layer, a methodology of determination of drying coefficient of porous material in thin layer, using the experimental data, was done. Using the experimental data with natural convective drying method in the laboratory conditions there were calculated the theoretical drying coefficients, useful for description and modelling of the drying process, calculated theoretical results of moisture removal and compared with experimental results obtained from the measurements. The results of drying of typical traditional medicinal herbs which are *Tilia cordata* L. and *Sambucus nigra* L. are compared. The obtained results of this research are parameters, which can be used for other research work and for improvement of the whole drying process.

Keywords: *Sambucus nigra* L., *Tilia cordata* L., drying coefficient.

Introduction

Preservation of production is a very important problem to be solved by producer of this product. One of the ways of the preservation of products is drying. 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 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 heat flow, temperature changes and moisture flow.

In order to find optimal drying regime it is necessary to understand transport mechanisms which takes place within and on the surface of the product. 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, carrot, apples and etc. drying by small heated air. The researches 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 [1; 2]. The modelling of carrot cubes was made in [3; 4] where the author studied influence of air-flow rates and effect of temperature to drying curve for carrot cubes. Cocoa beans drying process was investigated at [5], where different semi-theoretical models are derived and tested. Influence of pre-treatment on drying rate of chilli pepper at various air temperatures was investigated in [6].

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 are recommended. It means long drying duration. Drying represents 30-50 % of total costs in medicinal plant productions [7]. 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 its drying aspects were considered [8].

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 dryer design, operation method, energy use and product quality requires crucial managerial decision.

The aim of this research was to investigate *Sambucus nigra* L. and *Tilia cordata* L. flowers drying by free convections and determining drying coefficient.

Materials and methods

For studies we have selected two plants: *Sambucus nigra* L. and *Tilia cordata* L. flowers. *Sambucus nigra* L., or European elder, is a tall tree-like shrub Fig.1. Various parts of the elder have long been used in traditional medicine as a diaphoretic, diuretic, astringent, laxative, and emetic. There are many aspects of beneficial effects of *Sambucus nigra* L. and extracts of berries [9].

Flowers was traditionally suggested as a remedy for diabetes. Extract of elder flower significantly increased glucose uptake, oxidation, and glycogenesis in rat abdominal muscle. Elder has been used for cough and cold, arthritis, and certain skin conditions. Traditionally elder used as a tea.

Linden (*Tilia cordata* L.) flowers are used in colds, cough, fever, infections, inflammation, high blood pressure, headache (particularly migraine), as a diuretic (increases urine production), antispasmodic (reduces smooth muscle spasm along the digestive tract), and sedative. The flowers were added to baths to quell hysteria, and steeped as a tea to relieve anxiety-related indigestion, irregular heartbeat, and vomiting.

Flowers of *Sambucus nigra* L. contains essential oils, flavonoids (rutin to 3 %), tannins, amines, sugars, organic acids and vitamin C, minerals and breakdown products of glycoside sambunigrin. Flowers of *Tilia cordata* L. contain very similar active ingredients, e.g. essential oils, flavonoids, glycocides, mucilaginous substances, tannins, phytosterols, compounds near vitamin E, organic acids, essential oils, sugars, and others.

a)

b)

Fig. 1. ***Sambucus nigra* L. flower:** a – in nature and b – in process of drying

When medicinal plant materials are prepared for use in dry form, the moisture content of the material should be kept as low as possible in order to reduce damage from mould and other microbial infestation. Linden flowers (*Tilia cordata* L.) were dried at average temperature 26.1 ± 0.4 ºC and relative humidity 57.9 ± 6.9 % during experiment. Flowers of European elder (*Sambucus nigra* L.) were dried at average temperature 23.9 ± 1.3 ºC and relative humidity 48.7 ± 3.1 %. The air speed was controlled several times during the measurement and the average value was 0.003 $m \cdot s^{-1}$, which was suitable for experiments in natural convention.

The laboratory measurements were carried out at the Faculty of Engineering CULS Prague during the June (last spring period and beginning of summer in Czech Republic), when these plants are in blossom. The technical equipment used for the experiments was very simple. The flowers of plants were put in plastic bowls and one part of samples also on the sieve with mesh 3x4 mm and dried by natural convection. The moisture content of the flowers was identified by gravimetric measurement in regular time intervals. 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 a determination of final moisture content. Air temperature and humidity were measured by the sensor FHA646-E1C connected to the data logger ALMEMO 2690-8. Air speed was measured by thermo anemometer ZA 9062-FS, model 8455-300 with measuring range from 0 to 2.5 $m \cdot s^{-1}$ a resolution 0.001 $m \cdot s^{-1}$, connected to the data logger ALMEMO 2590.9.

Results and discussion

One of the most important tasks is to find expression for 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 drying time t. Using the methodology described [2; 10] and the experimental data obtained the drying rate expressions, for linden flowers (placed in black bowl Fig. 2 and on sieve Fig. 3) layer drying with air of 26.1 ºC by free convection. As can be seen, product placement location influences the coefficient of the drying. In the case of flowers placed on the sieve, moisture runoff occurs in all directions, but if the flowers are placed in a bowl, moisture runoff occurs only on the top. The determination of drying coefficient is much more accurate if the product is on the sieve, the coefficient of determination in our case was $\eta^2 = 0.9674$.

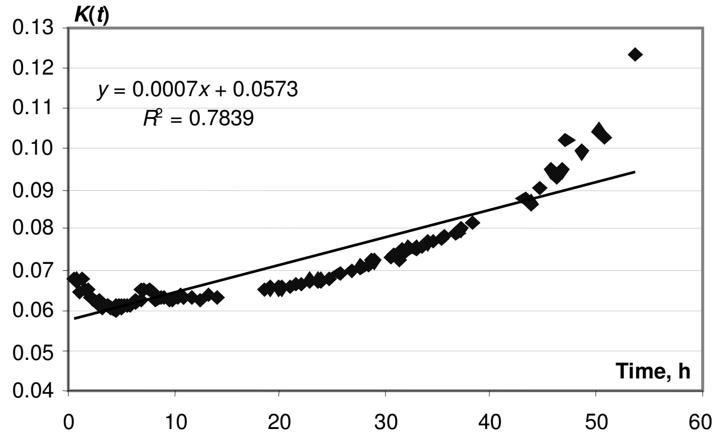

Fig. 2. **Linden (*Tilia cordata* L.) flowers' drying rate determination, drying it on a black bowl**

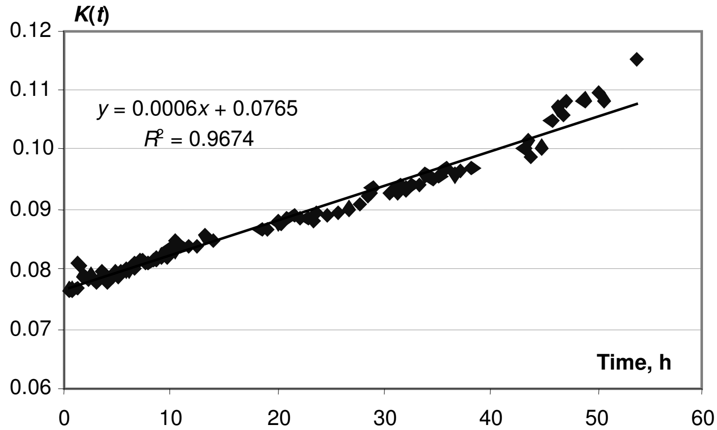

Fig. 3. **Linden (*Tilia cordata* L.) flowers' drying rate determination, drying it on a sieve**

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

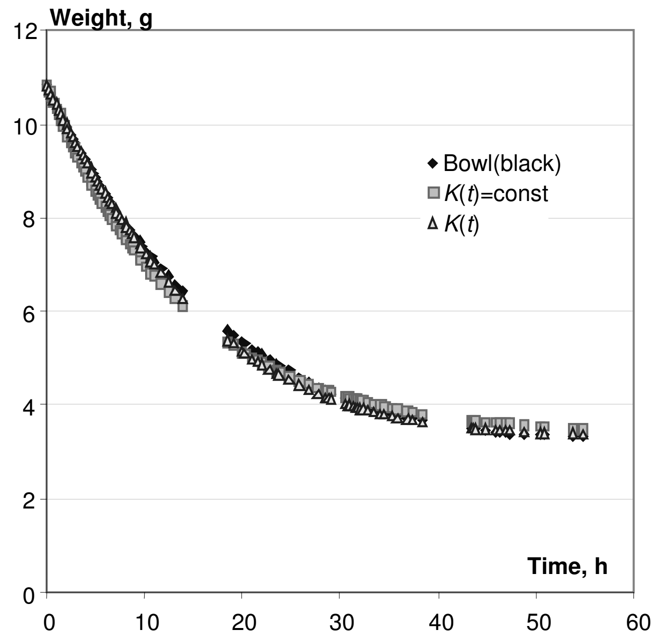

Fig. 4. **Linden (*Tilia cordata* L.) flowers' weight change (experimental and theoretical calculated) during drying on a black bowl**

The average of max absolute value difference between corresponding theoretical and experimental data was 0.18 grams ($K = 0.071\ h^{-1}$) with standard derivation 0.09 grams and 0.07 grams ($K(t) = 3.44 \cdot 10^{-4} \cdot t + 57.3 \cdot 10^{-3}$) with standard derivation 0.06 grams. For sieve average max absolute value difference was 0.15 ($K = 0.088\ h^{-1}$) and 0.02 ($K(t) = 2.9 \cdot 10^{-4} \cdot t + 76.5 \cdot 10^{-3}$) grams corresponding. Similarly, the experimental tests were carried out with *Sambucus nigra* L. flowers Fig. 1. Using experimental data we calculated the changing drying coefficient for flower drying situated on sieve and in bowl. We calculated theoretical flower changing drying coefficients placed flowers in bowl:

$$K(t) = -4.8 \cdot 10^{-4} \cdot t + 139.8 \cdot 10^{-3} \quad (1)$$

with coefficient of determination $\eta^2 = 0.6492$ and placed on sieve:

$$K(t) = -5.46 \cdot 10^{-4} \cdot t + 150.8 \cdot 10^{-3} \quad (2)$$

with coefficient of determination $\eta^2 = 0.5922$.

If we take only the first 2 days, then the drying rate $K(t)$ expression is a high linear correlation. For flowers in bowl drying coefficient was $K(t) = -1.5 \cdot 10^{-4} \cdot t + 167.8 \cdot 10^{-3}$ with coefficient of determination $\eta^2 = 0.933$ and on sieve $K(t) = -1.9 \cdot 10^{-4} \cdot t + 186 \cdot 10^{-3}$ with coefficient of determination $\eta^2 = 0.888$.

This can be explained by the fact that the drying in the period of time strictly linear, but increases the drying time the material moisture asymptotically tends to equilibrium moisture.

We compared the experimental data with theoretical exploiting the variable drying rate and constant drying coefficient, calculated as the average of all intervals corresponding coefficients Fig. 5, Fig. 6.

The max absolute value of difference between corresponding theoretical (with constant coefficient) and experimental data was 2.7 grams (bowl) and 2.3 g (sieve). The corresponding maximal absolute value of difference between theoretical ($K(t)$ from (1),(2)) and experimental data was 1.9 g (sieve) and 2.3 g (bowl).

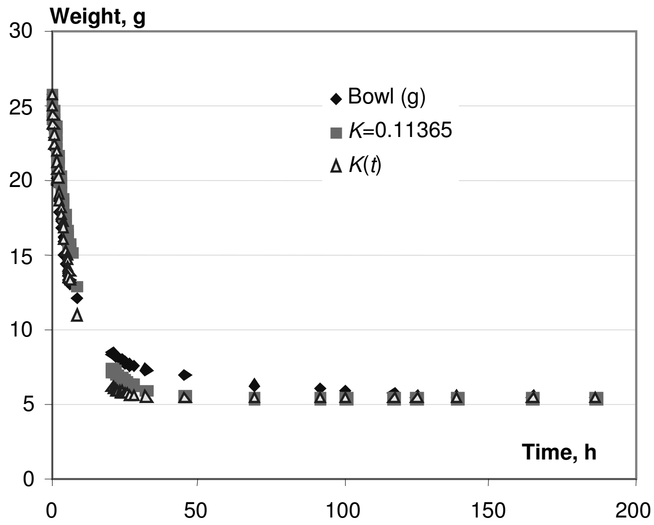

Fig. 5. ***Sambucus nigra* L. flower weight change (experimental and theoretical calculated) during drying in a black bowl**

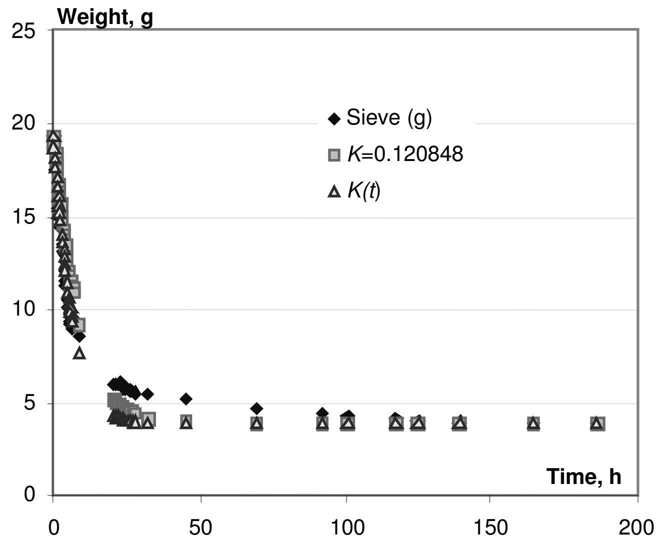

Fig. 6. ***Sambucus nigra* L. flower weight change (experimental and theoretical calculated) during drying on a sieve**

Conclusions

1. The proposed methodology, originally used for determination of drying coefficient of thick grain layer, is applicable in thin layer of light porous material, like flowers or herbs as well.
2. The developed mathematical model for determination of drying coefficient of flowers of trees can be applied to other porous materials.
3. Theoretically the necessary drying time with constant conditions and linear drying rate is defined.
4. Drying of on the sieve was faster in the first period of drying than on the solid tray (bowl) without holes.
5. Drying of Tilia cordata L. flowers is faster than *Sambucus nigra* L., which is obvious especially in more suitable temperature conditions. It can be explained by the smaller and lighter parts of flowers of *Tilia cordata* L. than flowers of *Sambucus nigra* L.
6. Using this methodology can be applied to find the drying rate of the material at different temperatures and combining the results to find the coefficient depends on both the drying time and temperature.

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