DRYING OF INSHELL WALNUTS AND WALNUT KERNELS UNDER DIFFERENT CONVECTION CONDITIONS

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Abstract. Walnuts are among foods with a significant health-preventive effect. Walnuts significantly improve cardiovascular activity, they are a rich source of minerals, vitamins and proteins, and their consumption helps reduce cholesterol and have a number of other health-related preventive effects. The high season of walnut harvest is in late September and early October. At this time, however, rainy weather and moisture often make worse the quality of nuts, so it is necessary to know the appropriate drying methods, specifically to prevent mould formation. This research is focused on drying inshell walnuts and walnut kernels under different convection conditions. A special device for convection drying with air flow passing through the material from the bottom through supporting trays with a sieve by constant temperature (average 24.5 ºC) and relative humidity (41 %) was used for drying when the air velocity was 1.2 $m \cdot s^{-1}$. The results were compared with natural convection drying by the same temperature and humidity, but with zero air velocity. The dry matter content was measured gravimetrically after drying in a hot air dryer at 105 ºC. The evaluation of the measurement results was focused on the progress and course of the drying rate, changes in the water content and changes of moisture depending on the time and their mutual relations. The increased air velocity for convection influenced the drying process positively. Drying air velocity 1.2 $m \cdot s^{-1}$ increased the drying rate of walnuts (inshell as well kernels) approximately 1.7 times. Drying of walnut kernels allowed a reduction of moisture by 3 %, the final moisture of inshell walnuts was about 6.8 %. The drying time of kernels was about five times shorter than that of the inshell walnuts. The experimental data create the background for calculation of the main parameters useful for description and modelling of the drying process, which can be helpful, e.g., for decision of the optimum drying time.

Keywords: forced drying, natural drying, moisture, temperature.

Introduction

The walnut is a kind of nut, essentially a fruit of the royal walnut fruit (*Juglans regia* L.). It consists of an edible core surrounded by a solid woody shell. The fruit on the tree are wrapped in a protective layer, in which they ripen. At the beginning, this case (husk) is green and darkens, and cracks during ripening. When the walnut is mature, it falls out of the protective husk to the ground or falls down with the husk. Nuts mature in the Czech Republic usually from the end of August to September.

Walnuts are very nutritious, they have high content of oil (60 to 70 %) and other ingredients, approximately 15 % protein, 13 % carbohydrates, 5 % of water, 2 % fibre and 2 % minerals [1]. After the harvest, the nuts are dried, to reduce the moisture, which ensures that nuts are not attacked by moulds. As the walnuts are an important commodity, there is attention paid to the nut properties and moulds growing during the storage, e.g., in [2-4]. Especially the reduction of moisture is very important [5].

The importance of the research focused on the influence of the changed properties of air mentioned also in literature [6]. A shorter period of drying can be a method for reduced mould growing. Hot air can be used for this process [7]. The problem of this solution is higher consumption of energy and in some cases also rather a complicated construction of the technical equipment.

The aim of this work is to bring some new experimental and theoretical investigations focused on drying inshell walnuts and walnut kernels under different convection conditions. The results of this research can be useful for practical application in drying products and also as a theoretical background for further research.

Materials and methods

The laboratory measurements were carried out in the laboratory of the Faculty of Engineering at CULS Prague during October. The technical equipment used for the drying experiments was a forced convection system of own design [8;9]. Fully fresh walnuts were used for this research (Figure 1 left). Fresh nuts were peeled out of the green hulls. Part of these inshell nuts (Figure 1 centre) was placed on two sieve trays with a 3 x 4 mm mesh and another part was peeled out of the shell (Figure 1 right). The walnut kernels were placed on two sieve trays with a mesh 1 x 1 mm so that even small amounts of walnut kernels could not fall down. One sieve tray with inshell nuts and one sieve tray with walnuts kernels were placed in a drying chamber with an air flow rate of 1.2 m·s^{-1} and the remaining one sieve tray with inshell nuts and one sieve tray with walnuts kernels were used for control measurement with natural convection drying by the same air temperature 24.5 ºC and relative humidity 41 %, but with 0 m·s^{-1} air velocity.

Fig. 1. **Fresh walnuts (*Juglans regia* L.) (left), inshell nuts (centre) and walnut kernels (right) in convection drying sieve trays**

Air speed, air temperature and humidity, moisture content and dry matter were measured by instruments and sensors according to the methodology in [8;9]. Each measuring tray was weighed every 60 min. The total drying time 500 hours was adapted to the need for determination of the lowest moisture content, which can be achieved by convective drying. The following main parameters of the drying process are calculated from the measured values: water content u, moisture w_k and drying rate N according to literature [8;9].

Results and discussion

The kinetics of the drying process of walnuts inshell and walnut kernels caused by forced and natural convection with air velocities (1.2 m·s^{-1} and 0 m·s^{-1}) are described by the curves in Fig. 2-5.

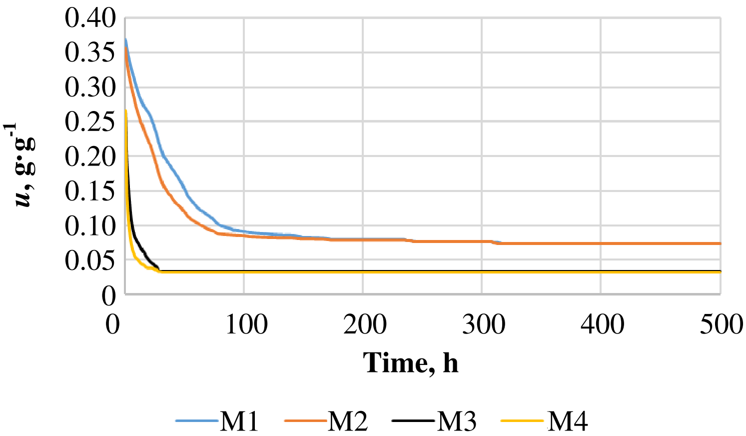

Fig. 2. **Water content *u* of inshell walnuts (M1, M2) and walnut kernels (M3, M4) samples during 500 h of convection drying with air velocities 0 m·s^{-1} (M1, M3) and 1.2 m·s^{-1} (M2, M4)**

The whole convection drying time 500 hours was sufficient for the maximal drop of the water content, which can be achieved by convection of air temperature 24.5 ºC and relative humidity 41 %. Fig. 2 shows that the water content u of walnut kernel samples (M3, M4) in comparison with the water content *u* of inshell walnut samples (M1, M2) was reduced since beginning of drying significantly. The final water content u of walnuts achieved by convection was about 0.07 g·g^{-1} and the water content of walnuts kernels was only about 0.03 g·g^{-1}. The convection drying process during 500 h is also obvious from the course of moisture w_k, presented in Fig. 3. The decrease of moisture of both samples of inshell walnuts is significantly slower (M1, M2) than in the case of the kernels moisture (M3, M4).

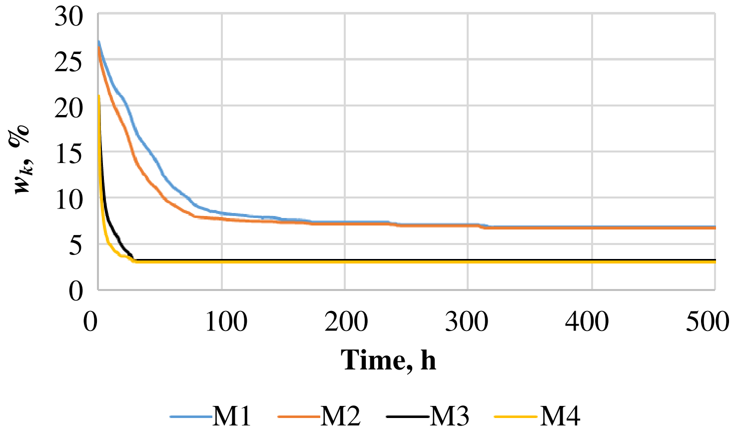

Fig. 3. **Moisture w_k of inshell walnuts (M1, M2) and walnut kernels (M3, M4) samples during 500 h of convection drying with air velocities 0 m·s^{-1} (M1, M3) and 1.2 m·s^{-1} (M2, M4)**

The course of moisture w_k during 100 h of convection drying is presented in Fig. 4. Moisture w_k of convection drying is significantly slower in the case of natural convection (v = 0 m·s^{-1}) samples (M1, M3) than with forced convection (M2, M4) with air velocity 1.2 m·s^{-1}. Increased air velocity helped reduce the moisture especially during the first 100 h of inshell walnuts drying (M2) and during the first 30 h of walnut kernels drying (M4).

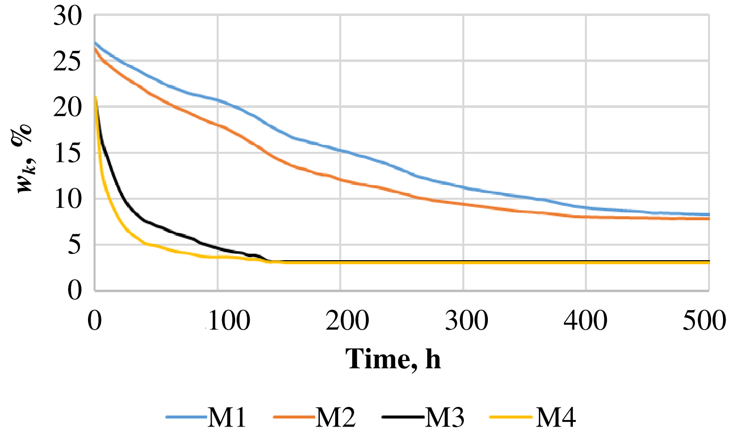

Fig. 4. **Moisture w_k of inshell walnuts (M1, M2) and walnut kernels (M3, M4) samples during first 100 h of convection drying with air velocities 0 m·s^{-1} (M1, M3) and 1.2 m·s^{-1} (M2, M4)**

The total drying time 500 hours adapted to the need for determination of the lowest moisture content, which can be achieved by convective drying, is very long, but the principal changes of the drying process have occurred during the beginning, therefore, the course of the drying rate *N* presented in Fig. 5 is focused only on the first 500 minutes of convection drying. The comparison of the curves shows that the highest drying rate was achieved in drying of the sample M4 (walnut kernel with air velocity 1.2 m·s^{-1}). It is obvious that the drying rate with natural convection (M1, M3) is very low in comparison with forced convection (M2, M4).

Rather interesting is the dependence of the drying rate *N* on the water content *u* presented in Fig. 6, describing both very important parameters of the drying process. This figure shows the big difference between the course of the drying rate calculated for walnuts kernels and inshell walnuts during the whole drying process described by the calculated and transformed values without dependence on the time.

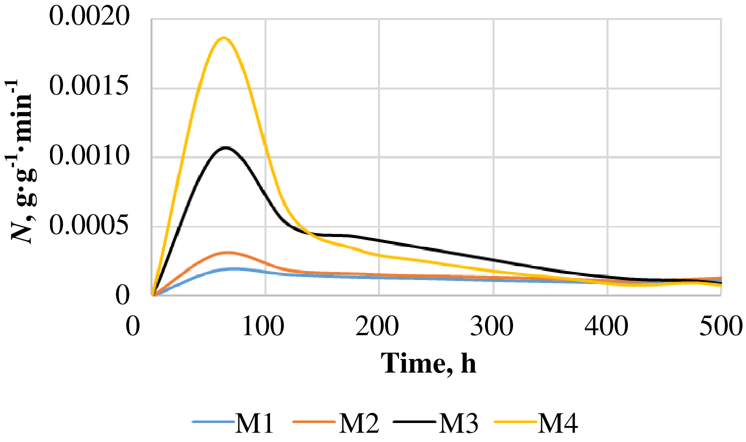

Fig. 5. **Drying rate *N* of inshell walnuts (M1, M2) and walnut kernels (M3, M4) samples during the 500 h of convection drying with air velocities 0 m·s^{-1} (M1, M3) and 1.2 m·s^{-1} (M2, M4)**

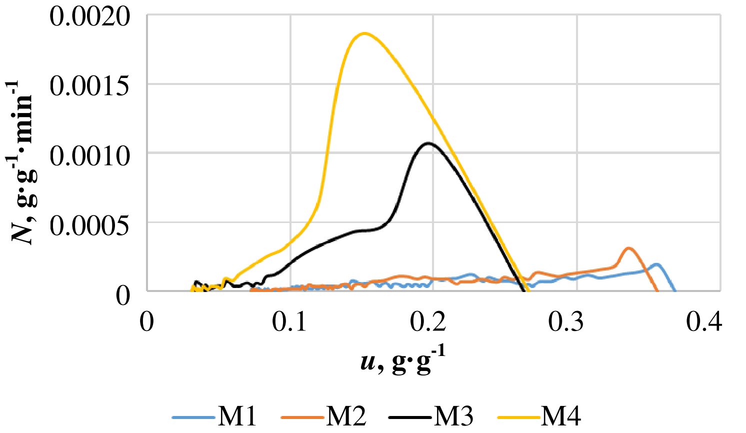

Fig. 6. **Drying rate *N* of inshell walnuts (M1, M2) and walnut kernels (M3, M4) samples during the 500 h of convection drying with air velocities 0 m·s^{-1} (M1, M3) and 1.2 m·s^{-1} (M2, M4) as function of water content *u***

The future research should be focused according to that idea on the study of a controlled process of drying with more tangible parameters including the temperature during the different periods of the drying process. The problems should be studied also with respect to the energy demands to find the optimal drying parameters of the whole process. The best relation between the drying rate and water content is achieved in forced drying of walnut kernels (M4).

Conclusions

1. This research is useful on the study of the influence of increased air velocity on the drying process of inshell walnuts and walnuts kernels.
2. It has been found that the forced convection has a positive influence on the drying time in comparison with drying under natural convection. Drying air velocity 1.2 m·s^{-1} increased the drying rate *N* of walnuts (inshell as well kernels) approximately 1.7 times. The drying time of walnut kernels was about five times shorter than that of inshell walnuts.
3. The increased air velocity recommended by this research would help accelerate the drying process and reduce the risk of mould formation (or to turn to be rancid) without higher energy requirements (in contrast to hot air drying of the kernels). This should be important for both small-scale production and processing in large industrial plants.

4. Drying of walnut kernels allowed a reduction of moisture by 3 %, the final moisture of inshell walnuts was only about 6.8 %. In order to achieve the suitable moisture optimization of the drying time should be provided and respected.
5. Future research in this area should be focused on the study of other factors influencing the drying process, especially in different air temperatures, partly described and expressed by the drying coefficient. The relations of the drying parameters should be based on optimisation and the drying time and energy demands.

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