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Influence of osmotic dehydration on convective drying process of cherries

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Summary. The paper presents the results of convective drying process of cherries at the temperature of 70°C and at an air flow velocity of 0.5 m×s-1. Fruits were subjected to a pre-osmotic dehydration in 60% sucrose solution for durations from 4 to 24 hours, and the control raw material without dehydration. The results showed that the losses of total weight and water, and the increasing of dry matter during the osmotic dehydration of cherries were the highest at the first five hours of process. The osmotic dehydration over 15 hours had little influence on these parameters. The osmotic dehydration significantly decreases the total energy inputs for the drying of cherries, from 33 to 52% in relation to non-dehydrated raw material.

Key words: osmotic dehydration, convective drying, cherry.

Abbreviations

D*m* – loss of weight [%],
D*mw* – loss of water form dehydrated material [kg],
D*ms* – increase of dry weight (after dehydration) [kg],
mo – initial weight of the raw material [kg],
mt – weight of material after dehydration period *t* [kg],
mso – initial dry weight of the raw material [kg],
mst – dry weight of the raw material after time of dehydration *t* [kg],
u – absolute humidity [$kg_{H2O} \cdot kg_{s.s.}^{-1}$].

INTRODUCTION

Vegetables and fruits are on important aspect of the human diet because of their nutritional value. However they are usually in short supply because they are perishable crops, which deteriorate within a few days after harvest. Preserving these crops in their fresh form for long period has been a problem. A very common method of preservation for these agricultural corps is to dry them in order to conserve the perishable fruits, reduce storage volume and to extend their shelf life beyond the few weeks when they are in season [1]. Longer shelf-life, product diversity and substantial volume reduction are the reasons for popularity of dried fruits and vegetables, and this could be expanded further with improvements in product quality and process applications [14]. Drying can be done by many of methods such as sun drying or industrially through the use hot air drying or freeze drying. The most common drying method employed for food materials to date was hot air drying. However there are many disadvantages of this method. Among these are low energy efficiency and lengthy drying time during the falling rate period. This is mainly caused by rapid reduction of surface moisture and consequent shrinkage, which often results in reduced moisture transfer and, sometimes, reduced heat transfer. Several investigators of drying have reported that hot air drying, hence prolonged exposure to elevated drying temperatures, resulted in substantial degradation in quality attributes, such as colour, nutrients, flavour, texture, severe shrinkage, reduction in bulk density and rehydration capacity, damage to sensory characteristics and solutes migration from the interior of the food to the surface. Thus many of methods are used for pretreatment fruits and vegetables before drying. Before drying fruits and vegetables may be dehydrated or blanched as a pre-treatment to lessen changes in colour and reduce the total number of microorganisms in the food and improve the heat and mass transfer [5].

Food drying is one of the oldest methods of preserving food. Since drying reduces the moisture in foods making them lightweight and convenient to store, it can easily be used in place of other food preservation techniques. Besides, this moisture content decides about physical properties of food and determines the course of many processes [15, 16, 20].

Osmotic dehydration is a pre-treatment method used for food preservation before drying. This process enables fruits and vegetables to be stored for a longer period of time. The mechanism of the osmotic dehydration process is the difference in the concentrations of osmotic substance in the material and in the solution. Osmotic dehydration is a process that entails a partial removal of water from food items such as vegetables and fruits [2, 4, 11]. Due to the one-side diffusion of water from the drained material to the solution and the osmotic active substance in the opposite direction, the material after osmotic dehydration is characterized by lower absolute humidity and changed chemical composition [17, 18, 22]. Dehydration of sucrose solutions primarily contributes to changes in the surface layer of the material, thus reducing the adverse chemical reactions and losses of water-soluble substances, it also improves the organoleptic characteristics of the raw material [9, 10, 14]. The osmotic dehydration of fruits and vegetables significantly affects the shortening of the drying time, and thus reduces the drying energy requirements [1, 6, 5]. Fruits dried after the initial osmotic dehydration process are characterized by higher ratio of sugars content to organic acids contents in comparison to the raw material without osmotic dehydration. In most cases they retain the natural color and flavor and are preferred by consumers [3, 8, 13, 21].

There are few works concerning the convective drying process of osmotic dehydrated cherries. The aim of the present work was to evaluate the influence the osmotic dehydration time of cherries on the convective drying process. Especially, the indices of osmotic dehydration were determined, the kinetic of the process was presented and the drying energy requirements were evaluated.

MATERIALS AND METHODS

The material for investigation were fruits of cherries (cv. Kelleris) at the stage of full technological maturity. The pits were removed from fruits and the initial moisture content and dry matter were evaluated. Studies of osmotic dehydration of cherries were performed at 20°C for 6 periods (4, 8, 12, 16, 20 and 24 hours). Osmotic dehydration was carried out in a solution of sucrose at the concentration of 60%. The ratio by weight of the raw material to the osmotic agent was 1:4. The process of osmotic dehydration, depending on its duration, was characterized on the basis of the following indices [23]:

– the total weight loss after dehydration:

$$\Delta m = \frac{m_o - m_t}{m_o} \cdot 100\%, \qquad (1)$$

– the loss of water from dehydrated material:

$$\Delta m_w = \frac{m_t(100 - m_{st}) - m_o(100 - m_{so})}{m_o \cdot m_{so}} \cdot 100\%, \qquad (2)$$

– the increase of dry matter after dehydration:

$$\Delta m_s = \frac{m_t \cdot m_{st} - m_o \cdot m_{so}}{m_o \cdot m_{so}} \cdot 100\%. \qquad (3)$$

The convection drying process of cherries was performed at the temperature of 70°C and the air flow velocity of 0.5 ms^{-1}. The convection was conducted using a vertical air-flow dryer. A detailed description of the measuring stand was presented by Krzykowski et al. [7]. The measuring stand was also equipped with a meter of electric power. The specific drying energy was calculated using the numerical integration method changes of power consumption as a function of time, related to the mass of the processed material. The measurements were replicated 5 times. The regression analysis was carried out on these data. All the statistical tests were carried out at the significance level of a = 0.05.

RESULTS

The greatest relative humidity loss was observed at the beginning of the process (the decrease form 85% to 76%, for the first five hours of the process), and then the relative humidity decreased with time (up to 68%). The relative humidity loss during the osmotic dehydration of cherries was described using the polynomial regression equation of the third degree (Fig. 1). The change in relative humidity during the osmotic dehydration results from two opposing processes: 1) passage of water and solutes from the dehydrated material to the solution, 2) passage of osmotic active substance to the dehydrated material.

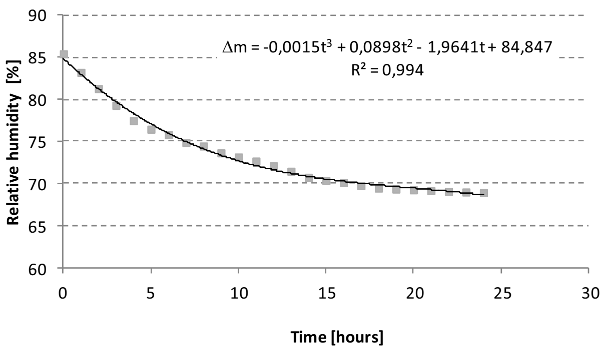

Fig. 1. The relative humidity loss as a function of osmotic dehydration time of cherries

Changes in the mass of water as a function of the duration of the osmotic dehydration process were described using the polynomial regression equation of the fourth degree (Fig. 2).

The largest loss of water by weight, reference on a kilogram of dry substance, occurred during the first five hours of osmotic dehydration. After 24 hours of the process, from the raw material containing one kilogram of dry matter more than 3.5 kilograms of water was discharged.

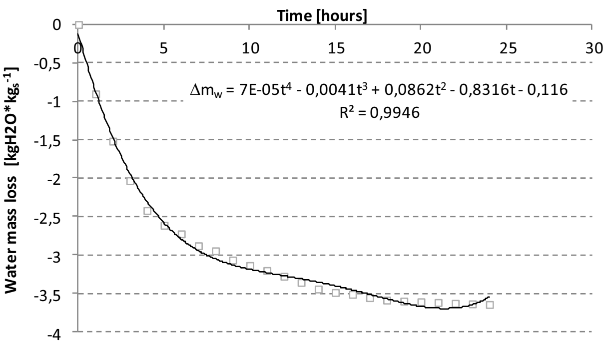

Fig. 2. The loss of water during osmotic dehydration of cherries in relation to time

Figure 3 presents the influence of osmotic dehydration time on an increase of dry matter in cherries. The relation was described by using the polynomial regression equation of the third degree. The highest increase of dry matter was observed at the beginning of the process (during first five hours of osmotic dehydration). After 24 hours of osmotic dehydration, dry weight of the material more than doubled.

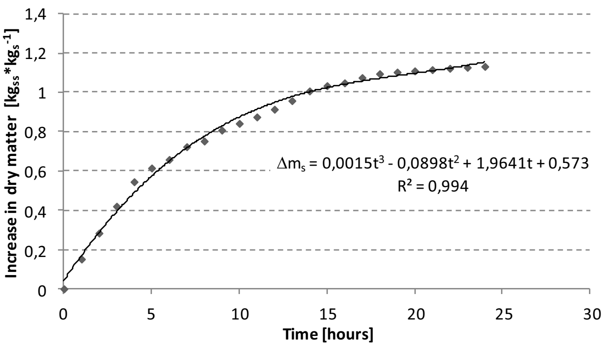

Fig. 3. The increase of dry matter during the osmotic dehydration of cherries

The osmotic dehydrated cherries (from 4 to 24 hours) and the control sample were subjected to convection drying. The drying kinetics of cherries was presented in Fig. 4. The drying curves of dehydrated and non-dehydrated cherries have the characteristic shape for the capillary-porous bodies. Depending on the duration of osmotic dehydration, the material subjected to the drying process was characterized by different initial moisture content. Drying curves of dehydrated material were similar in shape, regardless of the duration of the dehydration process. Drying curves obtained from the material dehydrated for 20 and 24 hours had almost the same characteristics. The regression equations describing the changes of absolute humidity in relation to drying time were of quadratic form (Table 1).

Table 1. The regression equations describing the changes of absolute humidity of dried material in relation to drying time

Dehydration time [h]	Regression equation	R^2
0	$u = 2E\text{-}05t^2 - 0{,}0206t + 5{,}6131$	0,9972
4	$u = 2E\text{-}05t^2 - 0{,}0164t + 3{,}4007$	0,9991
8	$u = 2E\text{-}05t^2 - 0{,}0155t + 2{,}8867$	0,9995
12	$u = 2E\text{-}05t^2 - 0{,}0149t + 2{,}5756$	0,9996
16	$u = 3E\text{-}05t^2 - 0{,}0147t + 2{,}296$	0,9983
20	$u = 3E\text{-}05t^2 - 0{,}0162t + 2{,}2168$	0,998
24	$u = 3E\text{-}05t^2 - 0{,}0161t + 2{,}192$	0,9983

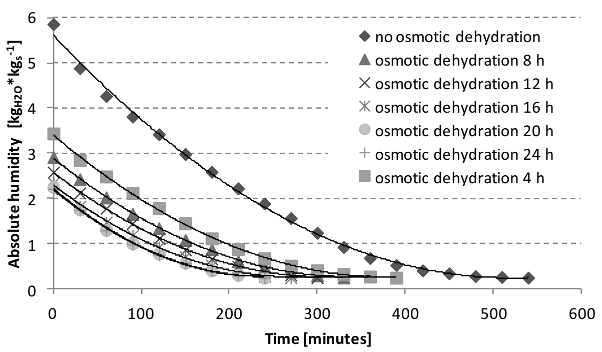

Fig. 4. Convection drying kinetics of osmotic dehydrated cherries and a control sample

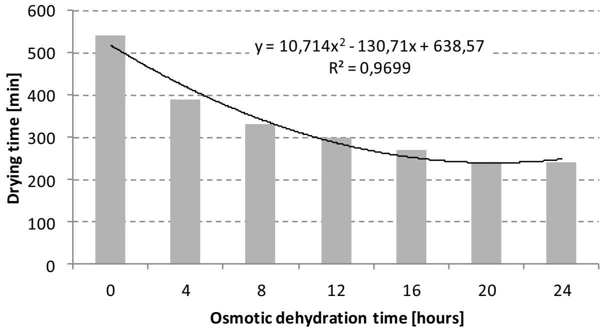

Fig. 5. The convection drying time in relation to osmotic dehydration time of cherries

The relation between the osmotic dehydration time and drying time was presented in Figure 5. The osmotic dehydration significantly decreased the duration of convection drying process. The longest drying time was found for non-dehydrated cherries (540 min). The shortest drying time (240 min) was obtained for fruits dehydrated for 20 and 24 hours.

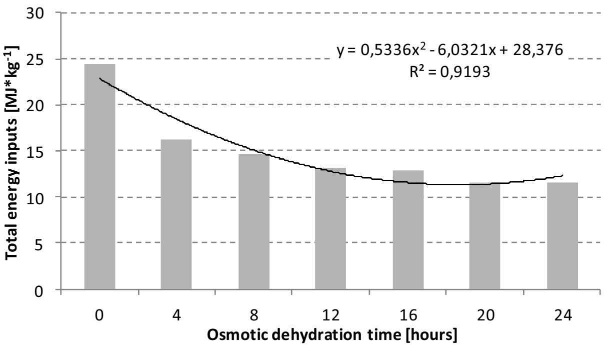

Fig. 6. The total energy inputs for drying of cherries

The total energy inputs required to dry one kilogram of osmotic dehydrated cherries and control sample were presented in Figure 6. The results showed that as the osmotic dehydration time increased, a decrease of total drying energy was observed (average from 24 $MJ \cdot kg^{-1}$ to 12 $MJ \cdot kg^{-1}$).

CONCLUSIONS

On the basis of the obtained results, the following conclusions can be formulated:

1. The losses of total weight and water, and the increasing of dry matter during the osmotic dehydration of cherries were the highest at the first five hours of process. The osmotic dehydration over 15 hours had little influence on these parameters.
2. The osmotic dehydration caused a decrease of drying time of cherries in comparison to non-dehydrated fruits (from 150 min to 300 min for 4 hours and 24 hours of osmotic dehydration, respectively).
3. The osmotic dehydration caused a decrease of total energy inputs for drying of cherries from 33 to 52% in relation to non-dehydrated raw material.

4. Taking into account the time of drying and the total energy inputs, it is recommended to dry cherries at 70°C after osmotic dehydration in 60% sucrose solution for 20 hours.

REFERENCES

1. **Chua K.J., Mujumdar A. S., Hawlader M.N.A., Chou S. K., Ho J. C. 2001:** Batch drying of banana pieces effect of stepwise change in drying air temperature on drying kinetics and product colour. Food Research International, 34, 721–731.
2. **Corzo O. Go´ mez, E. R. 2004:** Optimization of osmotic dehydration of cantaloupe using desired function methodology. Journal of Food Engineering, 64, 213–219.
3. **Dixon G. M., Jen J. J. Paynter, V. A. 1976:** Tasty apple slices result from combined osmotic-dehydration and vacuum- drying process. Food Process Development., 10, 634-638.
4. **Fito, P. 1994:** Modeling of vacuum osmotic dehydration of food. Journal of Food Engineering, 22, 313–328.
5. **Kozak P., Dziki D., Krzykowski A., Rudy S. 2011:** Optymalization of energy consumption in the freeze drying process of champignon (*Agaricus bisporus* L.). TEKA Commission of Motorization and Energetics in Agriculture nr XIc., 134–141.
6. **Krzykowski A., Rudy S., Kozak P., Dziki D., Serwatka Z. 2011:** Influence of blanching and convective drying conditions of parsley on process energy consumption TEKA Commission of Motorization and Power Industry in Agriculture, XIC., 142-150.
7. **Krzykowski A., Dziki D., Polak R., Rudy S. 2012:** Influence of heating plates temperature on freeze drying energy requirements and quality of dried vegetables. TEKA Commission of Motorization and Power Industry in Agriculture 2(2), 129-131.
8. **Lazarides, H. N., Katsanidis, E., Nickolaidis, A. 1994:** Mass transfer kinetics during osmotic preconcentration aiming at minimal solid uptake. Journal of Food Engineering, 25, 151-166.
9. **Lenart, A, Lewicki P. 1995:** Osmotic dehydration of fruits and vegetables Warsaw: Warsaw Agricultural University Press, 99–111.
10. **Lenart A. 1991:** E€ect of saccharose on water sorption and rehydration of dried carrot. In A. S. Mujumdar, & I. Filkova, Drying'91. Amsterdam: Elsevier, 489–498.
11. **Lenart A. 1995:** Osmotic dehydration of foods before convection drying. In A. Lenart, & P. P. Lewicki, Osmotic dehydration of fruits and vegetables Warsaw: Warsaw Agricultural University Press, (pp. 99–111.
12. **Lenart A., Cerkowniak M. 1996:** Kinetics of convection drying of osmodehydrated apple. Polish Journal of Food and Nutrition Sciences, 5/46, 73–82.
13. **Lenart A., Flink J. M. 1984:** Osmotic concentration of potato. II. Spatial distribution of the osmotic effect. Journal of Food Technology, 19, 65–89.
14. **Lenart A., Lewicki P.P., Mlynarczyk, G. 1987:** Effect of osmotic dehydration on the physico-chemical properties of dried apples. In Annals of Warsaw Agricultural University ± SGGW. Food Technology and Nutrition, 17, 55–63.
15. **Mitrus M., Oniszczuk T., Mościcki L. 2011:** Changes of specific mechanical energy during extrusion-cooking of potato starch TEKA Commission of Motorization and Power Industry in Agriculture, XIC, 200–207.
16. **Mitrus M, Wójtowicz A. 2011:** Extrusion-cooking of wheat starch TEKA Commission of Motorization and Power Industry in Agriculture, XIC, 208–215.
17. **Prokharkar S.M., Prasad S., Das H. 1997:** A model for osmotic concentration of bananas slices. Journal Food Science and Technology, 34, 230–232.
18. **Raoult-Wack A.L. 1994:** Advances in osmotic dehydration. Trends in Food Science and Technology 5, 255–260.
19. **Rastogi N.K., Niranjan K. 1998:** Enhanced mass transfer during osmotic dehydration of high pressure treated pineapple. Journal of Food Science, 63, 508–511.
20. **Rydzak L., Andrejko D. 2011:** Effect of different variants of pretreatment of wheat grain on the particle size distribution of flour and bran. TEKA Commission of Motorization and Power Industry in Agriculture, XIC, 283–290.
21. **Salvatori D., Andres, A. Chiralt A., Fito, P. 1999:** Osmotic dehydration progression in apple tissue. I. Spatial distribution of solutes and moisture content. Journal of Food Engineering, 42, 125- 132.
22. **Simal S., Benedito J., Sa´nchez E.S., Rosello C 1998:** Use of ultrasound to increase mass transport rate during osmotic dehydration. Journal of Food Engineering, 36, 323–336.
23. **Pękosławska A., Lenart A. 2008:** Wpływ powlekania na przebieg odwadniania osmotycznego dyni, Postępy Techniki Przetwórstwa Spożywczego, 1, 9–14.

WPŁYW CZASU OSMOTYCNZEGO ODWADNIANIA NA PROCES KONWEKCYJNEGO SUSZENIA WIŚNI

Streszczenie. W pracy przeprowadzono badania konwekcyjnego suszenia owoców wiśni w temperaturze 70°C i przy prędkości przepływu 0,5 m×s^{-1}. Owoce zostały poddane procesowi wstępnego odwadniania osmotycznego w 60% roztworze sacharozy dla sześciu czasów trwania tego procesu – od 4 do 24 godzin oraz dla surowca nie poddanego zabiegom wstępnym. Na podstawie uzyskanych wyników badań stwierdzono, że całkowite straty masy oraz wody, jak również wzrost suchej substancji były największe przez pierwsze pięć godzin odwadniania osmotycznego wiśni. Po 15 godzinach trwania tego procesu zmiany tych parametrów były już niewielkie. Odwadnianie osmotyczne powodowało skrócenie czasu suszenia oraz zmniejszenie całkowitych nakładów energii na ten proces (od 33 do 52%) w porównaniu do surowca nie poddanego odwadnianiu.

Słowa kluczowe: odwadnianie osmotyczne, suszenie konwekcyjne, wiśnia pospolita.