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Investigations on rehydration process of dried prunes, apples and strawberries obtained under industrial conditions

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Abstract: *Investigations on rehydration process of dried prunes, apples and strawberries obtained under industrial conditions.* The work aimed at investigating of the course of rehydration process of dried prunes, apples and strawberries. The dried material was produced in a chamber drier under industrial conditions. Drying process consisted of three cycles: drying a bit, two-stage drying and two-stage secondary drying. Dried material was rehydrated in distilled water of temperature 20ºC during 6 hours and in distilled water of 100ºC during 2 hours. It is evident from obtained results that the applied drying conditions are more suitable for apples in respect of their quality.

Key words: drying, rehydration, prunes, apples, strawberries.

INTRODUCTION

Rehydration is a complicated process aimed at restoring dried material's properties that were characteristic for a raw material prior to its initial processing and drying; it is achieved by the contact of dried material with water. During rehydration the following three processes occur simultaneously: absorbing of water by dried material tissues that results in an increase of its mass and volume, and rinsing out of water-soluble substances from material being rehydrated. The course of these processes depends on raw material properties and conditions of storage, preparation and the range of structural and chemical damage caused by drying [Krokida and Maroulis 2001; Lewicki 1998a]. Thus, the course of rehydration process reflects changes that occurred in the structure and composition of raw material plant tissues as a result of drying and preceded processing as well as a result of rehydration [Lewicki 1998b; Witrowa-Rajchert 1999]. These changes cause that product being dried does not achieve the raw material properties as a result of rehydration; it proves that drying process is irreversible [Krokida and Marinos-Kouris 2003]. Therefore, rehydration ability is one of the most important quality indices of dried food products.

This work aimed at investigating the course of rehydration process of dried prunes, apples and strawberries. The dried material was produced in a chamber drier under industrial conditions. In references one can find investigations on rehydration process of dried apples [Krokida and Marinos-Kouris 2003; Lee et al. 2006; Witrowa-Rajchert and Dworski 2006] and of strawberries [Woźnica and Lenart 2005a, b]. However, the dried material was obtained under conditions different from that of this work. No works on prunes' dried material rehydration were found in references.

MATERIAL AND METHODS

Prunes, apples and strawberries were dried in a chamber drier under industrial conditions. The drier cubic capacity amounted to 2 m^3 and drier was equipped with a membrane heater; a single charge of raw material amounted to about 110 kg. The drying process consisted of three cycles and occurred as follows:

- I cycle lasted 4 hours and involved drying a bit at temperature 30ºC. Drying air recirculation amounted to 10% and its volume flow was equal to 1800 m^3/h.
- II cycle lasted 8 hours and involved two-stage drying. The first stage lasted 4 hours and was performed at temperature 60ºC. Drying air recirculation amounted to 50% and its volume flow was equal to 1200 m^3/h. The second stage of drying lasted 4 hours also, but was performed at 55ºC. Drying air recirculation amounted to 50% and its volume flow was equal to 1400 m^3/h.
- III cycle lasted 6 hours and involved two-stage secondary drying. The first 3-hour stage was performed at 45ºC. Drying air recirculation amounted to 60% and its volume flow was equal to 1900 m^3/h. At the second 3-hour stage drying air temperature was equal to 35ºC; air recirculation amounted to 60% and its volume flow was equal to 2000 m^3/h.

Whole strawberries were dried, prunes with removed stones were divided into halves, while apples were cut into slices of thickness 12 mm.

Obtained in this way dried prunes, apples and strawberries were subjected to rehydration process in distilled water of temperature 20ºC. Dried material of prunes and apples was additionally subjected to rehydration in distilled water of temperature 100ºC. A kinetics of rehydration process at 20ºC was investigated for 6 hours. At intervals of 0.5, 1, 1.5, 2, 3, 4, 5, and 6 hours the rehydrated sample was separated from water, dried with an absorbent paper and weighed with accuracy 0.01 g. For each time there was determined a relative mass increment of rehydrated dried material, as a ratio of current sample mass to initial mass of dried material used subjected to rehydration. Determination of relative mass increment was repeated three times. The kinetics of rehydration process in distilled water of temperature 100ºC was investigated for 2 hours and the measurements were carried out after 10, 20, 40, 60 and 120 minutes.

Approximation of experimental data (in three repetitions) was performed with the use of following equations [Kaleta et al. 2008]:

$$m_\tau / m_0 = \mathrm{a} + \mathrm{b}\left[1 - \frac{1}{(1 + \mathrm{b} \cdot \mathrm{c} \cdot \tau)}\right] \quad (1)$$

$$m_\tau / m_0 = \mathrm{A}\left[\mathrm{B} - \exp(-\mathrm{C} \cdot \tau)\right] \quad (2)$$

where:

m_τ – dried material mass being rehydrated at moment τ, kg,

m_0 – initial mass of dried material, kg,

τ – time, h.

Empirical constants a, b, c, A, B, C were matched with the use of Statistica program.

Basing on the obtained equations there were calculated the balanced values of relative mass increments of dried material, that would have been achieved if rehydration process had lasted infinitely long. These values amounted to $(m_\tau / m_0)_r =$ $= a + b$, $(m_\tau / m_0)_r = A \cdot B$ respectively.

RESULTS OF INVESTIGATIONS AND THEIR ANALYSIS

Figure 1 presents diagram of changes in relative mass increment of strawberries dried material during rehydration in distilled water of temperature 20ºC. It is evident from the diagram that both empirical formulae (1) and (2) used for approximation of the obtained results of relative mass increment of strawberries dried material give good results, since determination coefficient for both equations amounted to 0.993. Both equations also approximated the remaining results with good accuracy and determination coefficient values ranged: for (1) formula 0.989–0.997, for (2) formula 0.989–0.998.

Figure 2 presents the course of changes in relative mass increment of dried material during rehydration. All investigated samples show the highest relative mass increment at the initial rehydration stage, then at further stage a water absorption by dried material slows down gradually due to approaching of hydrated samples to a state of equilibrium. The initial fast increment of absorption can be found especially during rehydration

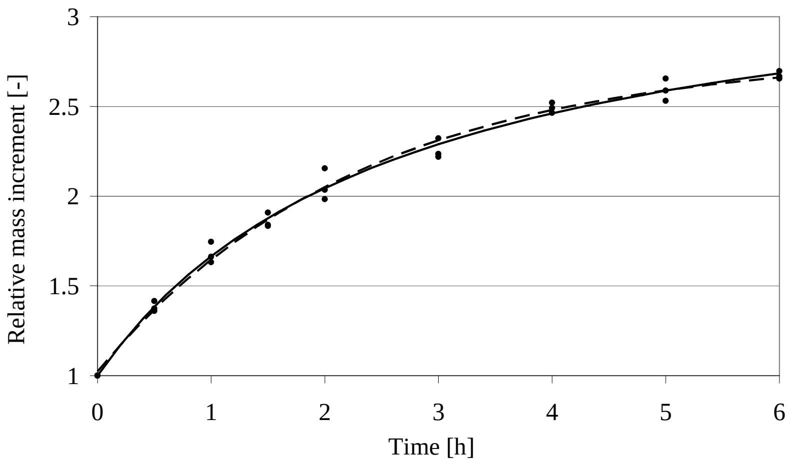

FIGURE 1. Relative mass increment of strawberries dried material during rehydration at temperature 20ºC: (——) approximation with equation (1), (— —) approximation with equation (2)

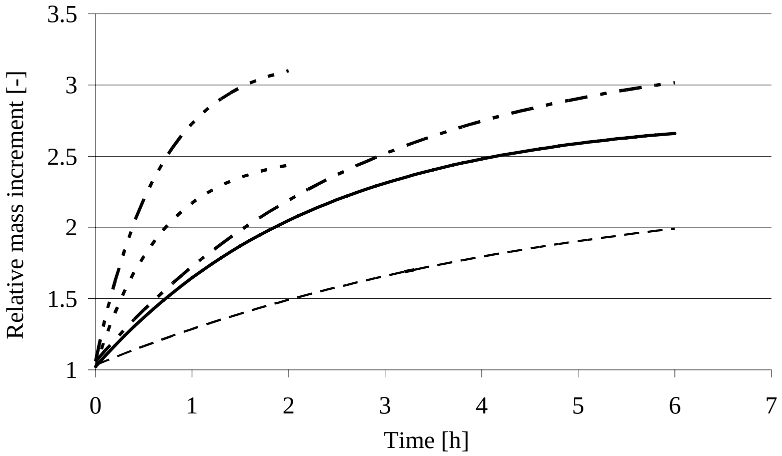

FIGURE 2. Relative mass increment of dried material during rehydration: (— —) prunes, 20ºC, (– – –) prunes, 100ºC, (—·—) apples, 20ºC (—··—) apples, 100ºC, (——) strawberries, 20ºC

in water of temperature 100ºC, while rehydration at temperature 20ºC is more uniform and slower over the entire process than at 100ºC. This effect of water temperature during rehydration can be caused by an increase in water diffusion rate with temperature rise and, probably, by affected by temperature changes in the structure and chemical composition of dried material during rehydration. Connections between rehydration rate and water temperature call for additional explanations and will be further investigated. It is also evident from carried out investigations that among three investigated materials dried apples are characterized by a highest relative mass increment during rehydration at a given temperature, while prunes by a lowest one. It can suggest that the applied drying conditions were more favourable for apples in respect of their quality.

Figure 3 presents the measured values of relative mass increment of dried material after 6-hour rehydration in water of temperature 20ºC and after 2-hour rehydration at temperature 100ºC, and also the values of balanced relative mass increment of dried material assessed on the basis of equations (1) and (2) (different due to application of extrapolation). It is evident from the diagram that none of investigated samples reached an equilibrium state. Dried material of prunes and apples rehydrated for 6 hours in water at temperature 20ºC was the most remote from that state. It is also evident from the diagram that apples dried material is characterized by the highest values of balanced relative mass increment; this corresponds to the suggestion of Figure 2 – the applied drying conditions are more suitable for apples.

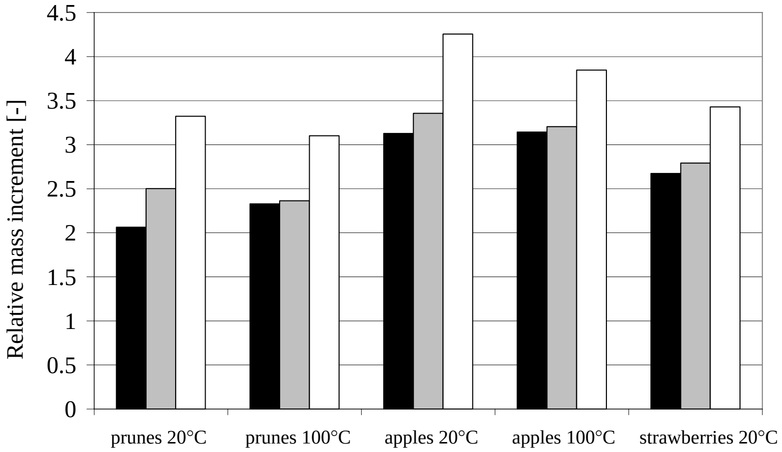

FIGURE 3. Relative mass increment of dried material after 6-hour rehydration at temperature 20ºC, after 2-hour rehydration at temperature 100ºC and balanced relative mass increment of dried material: █ after 6 h (20ºC), after 2 h (100ºC), ░ balanced of (2), □ balanced of (1)

CONCLUSIONS

1. Approximation with formulae (1) and (2) of experimental data of relative mass increment of dried material of prunes, apples and strawberries during rehydration gives good results: determination coefficient ranged from 0.989 to 0.998.
2. Water temperature used for rehydration influence the course of that process – at higher temperature the dried material is moistened very quickly, especially at initial stage, while at lower temperature the process is uniform and slower.
3. Dried apples are characterized by highest relative mass increment during rehydration at a given temperature, while prunes by the least. It can suggest that the applied drying conditions are more suitable for apples in respect of their quality.

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Streszczenie: *Badanie przebiegu procesu rehydratacji suszu ze śliwek, jabłek i truskawek otrzymanego w warunkach przemysłowych*. Celem pracy było badanie przebiegu procesu rehydratacji suszonych śliwek, jabłek i truskawek. Susz został wyprodukowany w suszarce komorowej w warunkach przemysłowych. Proces suszenia składał się z trzech cykli: obsuszania w temperaturze 30ºC, dwuetapowego suszenia w temperaturze kolejno 60 i 55ºC i dwuetapowego dosuszania (45 i 35ºC). Susz rehydratowano w wodzie destylowanej o temperaturze 20ºC przez 6 godzin i w wodzie destylowanej o temperaturze 100ºC przez 2 godziny. Aproksymacja danych doświadczalnych względnego przyrostu masy suszu podczas rehydratacji formułami empirycznymi dała dobre wyniki. Z uzyskanych rezultatów wynika, że zastosowane warunki suszenia są bardziej sprzyjające dla jabłek ze względu na ich jakość.

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