AGRICULTURAL ENGINEERING
2013: Z. 4(148) T.2
S. 39-47
ISSN 1429-7264
Polish Society of Agricultural Engineering
http://www.ptir.org

INFLUENCE OF FREEZING TREATMENT, OSMOTIC DEHYDRATION AND STORAGE TIME ON THE REHYDRATION OF VACUUM DRIED STRAWBERRIES

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Abstract. Dried fruits – strawberries – were rehydrated by dipping them in water at room temperature and their rehydration characteristics were examined. The aim of this study was to analyze the influence of the preparation method (the impact of freezing treatment at -18ºC, osmotic dehydration in sucrose solution 61.5%) of raw material and storage (from 32 days to 399 days) on the rehydration of dried strawberries. Dried strawberries obtained by the vacuum method from frozen fruits have larger relative weight gain with prolongation of rehydration time than dried fruits obtained from raw strawberries. Osmotic dehydration of strawberries before vacuum drying did not cause a significant difference in rehydration of dried strawberries stored for a long period. Vacuum dried strawberries stored for about 360 days longer at ambient temperature obtained slightly lower relative weight gain and higher solids content.

Key words: rehydration, vacuum dried fruits, osmotic dehydration, storage

Introduction

Rehydration of dried food is a basic unit operation used in the food industry. Rehydration is a complex process which is oriented at preserving raw material properties by dipping dried material in water. Many factors such as freezing treatment, osmotic dehydration, method of drying, storage time have an effect on rehydration of dried fruits Lewicki 1998; Witrowa-Rajchert, 1999). Drying may cause tearing of internal cellular structure and affects the quality of the dried material. During rehydration three processes occur concurrently: 1) absorption of water by the dried material, 2) swelling and 3) leakage of the hydrated material. The rehydration process reflects changes that have occurred in the raw material tissue as a result of drying process as well as pretreatment before it. As a rule these changes caused that dried material did not achieve characteristics of raw material as a result of rehydration and indicated that drying was an irreversible process (Kaleta et al., 2008). The rate and range of the rehydration process of dried food depend on the damage of cellular structure and chemical changes appearing as a result of drying. Rehydration allows evaluating the degree of physical and structural changes occurring during the process of drying in the dried material (Rząca and Witrowa-Rajchert, 2007; Geware et al., 2010). Complex changes in moisture and solids content during rehydration are expressed in the literature by several coefficients (Marabi and Saguy, 2009; Markowski et al., 2009; Markowski and Zielińska, 2011). Rehydration properties are also an important indicator of the quality because much of the dried material is consumed or then processed industrially after initial hydration (Lemus-Mondaca et al., 2009; Marabi and Saguy, 2009). The storage conditions (e.g. in considered range from 4 to 40ºC) of dried fruits could had a greater influence on the rehydration and hygroscopic properties than the method of drying (Rząca and Witrowa-Rajchert, 2007; Nowacka and Witrowa-Rajchert, 2010).

The aim of this study was to analyze the influence of the preparation method of raw material and storage of dried fruits on the rehydration of dried strawberries. The study presents the impact of freezing treatment, osmotic rehydration and storage time on the rehydration of dried fruits.

Material and method

The experimental materials were strawberries of the Senga Sengana and Pandora varieties with a diameter of 24 and 27 mm respectively. Preparation of raw materials before drying consisted in:

1. washed strawberries with dried off surfaces were frozen down to -18ºC in a laboratory scale equipment, stored in a cabinet freezer with shelves at -18ºC, and before drying were thawed for approx. 2 hours 30 min.;
2. osmotic dehydration (washed strawberries were dipped in osmotic solution of sucrose (61.5%, a ratio of material to the solution 1:4 w/w) at 30ºC for 3 hours).

Vacuum drying at the setting temperature of 60 and 70ºC, under pressure of 4 and 10 kPa was applied for strawberries (Piotrowski et al., 2011). Fruits in a single layer were dried until a constant weight was reached, as indicated by a balance. The list of experiments analyzed in this work is presented in Table 1. Dried materials before research were stored from 32 days to 399 days at ambient temperature (21±3ºC) without exposure to daylight in sealed glass containers. Before the study began, equalization of moisture in the dried material was performed by holding it above the solution of lithium chloride at 25ºC for at least seven days.

Rehydration was determined by measuring the increase of water content in the dried fruit during the setting time (Piotrowski and Godlewska, 2011). Measurements were carried out in two replications for three rehydration times: 20, 60, 180 min. 100 ml of distilled water was poured into a prepared laboratory dishes at 25ºC, and next weighed strawberries were put into that dishes. After elapse of the setting time, strawberries with dried surface were weighed. Water and solids content of rehydrated strawberries was determined by drying method under atmospheric pressure at 60ºC.

Table 1
Drying codes, parameters of vacuum drying and solid content of dried strawberries

Material preparation	Drying parameters T (ºC)	Drying parameters P (kPa)	Drying code	Average solid content ± standard deviation (mass %)
Raw	60	10	r60C10kPa_24mmSenga_d399	97,15±0,20
raw	60	10	r60C10kPa_24mmSenga_d39	97,43±0,29
raw	70	4	r70C4kPa_27mmPand_d364	98,20±0,21
raw	70	4	r70C4kPa_27mmPand€_d358	98,05±0,15
osmotic dehydration	70	4	ro70C4kPa_27mmPand_d373	98,55±0,25
osmotic dehydration	70	4	ro70C4kPa_27mmPand€_d382	98,14±0,02
frozen	60	10	f60C10kPa_24mmSenga_d32	97,92±0,14

r - raw strawberries; ro - raw osmotically dehydrated strawberries; f – frozen and defrosted strawberries; Pand€ - the second repetition of the experiment carried out for the Pandora variety; _dxx – dried fruits stored xx days before rehydration

Relative weight gain during rehydration (ΔM) for dried strawberry was calculated from the formula (Piotrowski et al., 2010; Markowski and Zielińska, 2011):

$$\Delta M = \frac{(m_r - m_d)}{m_d} \qquad \left(\frac{\text{g water}}{\text{g dried fruit}}\right) \tag{1}$$

m_d – mass of a dried sample before rehydration (g),
m_r – mass of a dried sample after rehydration time (g).

In this study it was assumed that the relative weight gain after rehydration was calculated for dried material which was due to the stage of equalization of moisture in the material regardless of a minimal quantity of water (1,1-2,9%) (Tab. 1) was uniform.

The statistical interpretation of the mean values of mass gain and solid content for 20, 60 and 180 min. of rehydration was performed using IBM SPSS Statistics 20 (IBM Corp). A robust test of equality of means (Brown–Forsythe) without the assumption of homogeneity of variance at a given level of significance 0.05 was applied.

Results and discussion

Dried fruits stored for 32-39 days obtained from frozen strawberries for rehydration time 60 and 180 min. were characterized by higher average relative weight gain after rehydration than from raw strawberries (Fig. 1). However, despite the rehydration time, dried fruits obtained from frozen strawberries during the rehydration process leached a slightly greater quantity of soluble solids than from dried product obtained from raw material (Tab. 2). Differences of solids content for compared dried fruits were not statistically significant. Influence of freezing on relative weight gain of dried strawberries from frozen and raw material was statistically significant for rehydration time of 180 min. (Tab. 5). Ciurzyńska and Lenart (2010) also found that unfrozen strawberries before the drying process obtained a smaller increase of water after the rehydration process than for strawberries frozen and thawed before the drying process. Eshtiaghi et al. (1994) found that freezing of green peas, diced carrots and potatoes affected in a later stage to improve properties of rehydrated materials. These phenomena may be explained by the fact that in the case of frozen strawberries reduction of the water content was a consequence of following processes: freezing, thawing and drying. In such conditions a much greater loss of water from defrosted strawberries than from fresh strawberries could be estimated on the drying stage (Góral and Kluza, 2009; Pasławska et al., 2011; Kowalska et al., 2012).

Table 2
Influence of freezing treatment on solid content of rehydrated strawberries

Rehydration time (min)	Average solid content ± standard deviation	
	f60C10kPa_24mmSenga_d32	r60C10kPa_24mmSenga_d39
0	97.900.05	97.34±0.29
2	6.20±3.36	70.93±2.00
60	42.38±23.98	47.80±6.91
180	17.60±3.86	29.37±2.24

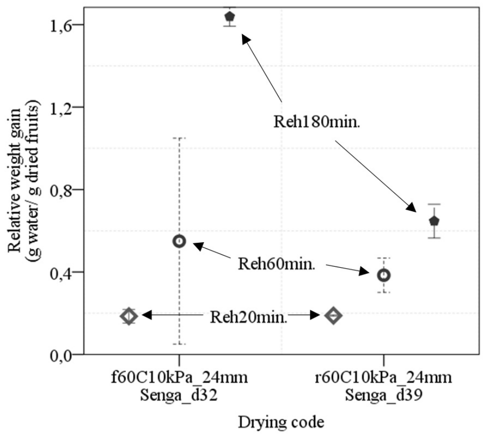

Figure 1. Influence of freezing treatment on relative weight gain

Ciurzyńska and Lenart (2009) observed that osmotic dehydration of fresh strawberries in a sucrose solution causes obtained higher water content of dried material in relation to samples not subjected to pretreatment but these differences were not statistically significant. Stępień (2009) found that samples of carrots subjected to osmotic dehydration were characterized by smaller weight loss and higher water content compared to the control sample (dried carrot samples not subjected to the pretreatment).The influence of osmotic dehydration carried out on raw strawberries of Pandora variety (storage time: 358-382 min.) for rehydration times of 20 and 60 min. was ambiguous in terms of relative weight gain (Fig. 2a, 2b) and solid content (Tab. 3a, 3b). It is expected that an osmotic substance will modify conditions of mass transfer, also making difficult the process of rehydration. For rehydration time 180 min. the relative weight gain for dried strawberries osmotically dehydrated compared to dried strawberries without osmotic dehydration did not differ statistically (Tab. 5). For the discussed dried materials, standard deviations for solid content partially overlap and the Brown-Forsythe test found average values to be statistically insignificant (Tab. 5).

Table 3a
Influence of osmotic dehydration on solid content (first repetition)

Rehydration time (min)	Average solid content ± standard deviation	
	r70C4kPa_27mmPand_d364	ro70C4kPa_27mmPand_d373
0	98.20±0.21	98.52±0.13
20	77.74±3.13	72.03±3.73
60	57.09±7.27	42.88±4.88
180	31.02±1.70	27.26±7.61

Table 3b
Influence of osmotic dehydration on solid content (second repetition)

Rehydration time (min)	Average solid content ± standard deviation	
	r70C4kPa_27mmPand€_d358	ro70C4kPa_27mmPand€_d382
0	98.05±0.15	98.14±0.02
20	60.58±1.05	48.42±4.89
60	44.31±4.79	52.07±1.72
180	28.85±7.39	25.42±4.00

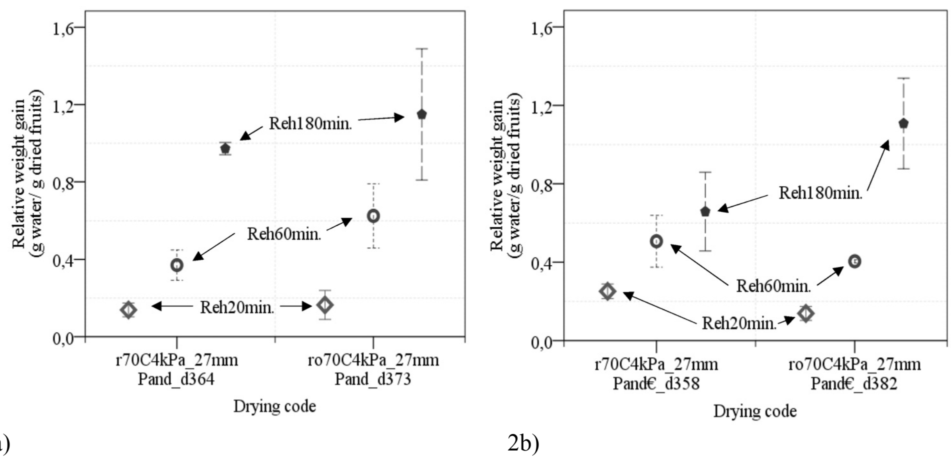

Figure 2. Influence of osmotic dehydration on relative weight gain: first (2a) and second (2b) repetition

There are unambiguous results of Woźnica and Lenart (2005), who stated in their work that strawberries dried previously osmotically dehydrated in 61.5% sucrose solution were characterized by a smaller increase in the water content after rehydration than strawberries not treated with osmotic dehydration. In studies by Piotrowski et al. (2010) for freeze dried strawberries stored for a short period, osmotic pretreatment resulted in a slight decrease in relative weight gains during rehydration. Osmotic dehydration before the indicated drying causes increasing losses of dry matter during rehydration, which is consistent with the determinations of dry matter for the present study. Prolonging time of osmotic treatment causes increasing losses of dry matter during rehydration. For freeze dried strawberries dehydrated in solutions of sucrose or glucose rehydration was harder to carry out than for freeze dried strawberries dehydrated in corn syrup or without osmotic dehydration. Osmotic dehydration of plant materials tissue changed size and shape of the cells and the intercellular spaces. This contributed to a significant quantity increase of small cells and caused an increase in intercellular spaces circuit. The cells characterised by smaller size have a larger capacity of water uptake than greater cells (Janowicz et al., 2009; Stępień, 2009).

At the beginning of the rehydration process, for dried strawberries of the Senga Sengana variety stored for 399 days, average relative weight gain was lower than for dried material stored for 39 days (Fig. 3). If the rehydration time was longer, dried material stored for long period had a relative weight gain of 136.5 and 437.6% which was still lower than for reference dried material. For 20 min. rehydration time differences in solid content were small (5.1%) (Tab. 4).

Table 4
Influence of storage time on solid content of rehydrated strawberries

Rehydration time (min.)	Average solid content ± standard deviation	
	r60C10kPa_24mmSenga_d39	r60C10kPa_24mmSenga_d399
0	97.34±0.29	97.15±0.02
20	70.93±2.00	76.02±4.95
60	47.80±6.91	62.62±12.16
180	29.37±2.24	40.52±4.95

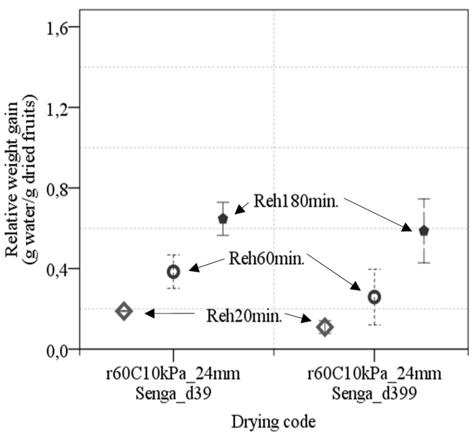

Figure 3. Influence of storage time on relative weight gain

If the rehydration time was longer, dried material stored for long period remained higher solids content of 14.8 and 11.1%. The differences in the two parameters of rehydration of dried material were not statistically significant (Tab. 5). In contrast to studies on vacuum dried fruits, Rząca and Witrowa-Rajchert (2007) observed that prolonged storage of dried apple slices obtained by the convection method caused greater relative weight gain during rehydration in comparison to short stored dried material. However, only for convective dried apples stored at 40ºC for a period of 140 days was the difference in relative weight gain statistically significant. Krzykowski (2008) found that long-term storage of dried peppers caused a decrease of rehydration ratio (relative weight gain) with comparison to the dried vegetables rehydrated without long-term storage. Regardless of quantitative losses, causing decrease of individual components content, qualitative changes during apples storage occurred and lowered consumers' and nutritional value of fruits (Łapczyńska-Kordon and Krzysztofik, 2008).

Table 5
Results of a robust test of equality of means (Brown – Forsythe) for relative weight gain and solid content of vacuum dried strawberries

Compared experiments / influence of	Rehydration time (min.)	Test Brown – Forsythe, significance	
		Relative weight gain	Solid content
freezing	20	0.914	0.163
f60C10kPa_24mmSenga_d32/	60	0.721	0.805
r60C10kPa_24mmSenga_d39	180	0.011	0.090
osmotic dehydration (Pand)	20	0.718	0.243
r70C4kPa_27mmPand_d364/	60	0.237	0.166
ro70C4kPa_27mmPand_d373	180	0.596	0.611
osmotic dehydration.(Pand€)	20	0.091	0.163
r70C4kPa_27mmPand€_d358/	60	0.470	0.234
ro70C4kPa_27mm Pand€_d382	180	0.176	0.637
storage time	20	0.048	0.216
r60C10kPa_24mmSenga_d39/	60	0.294	0.181
r60C10kPa_24mmSenga_d399	180	0.620	0.045

Conclusions

For dried fruits obtained by the vacuum method from frozen strawberries in comparison to dried fruits from raw strawberries with prolongation of rehydration time, larger relative weight gain was obtained, wherein for the time of 180 min. differences were statistically significant. Osmotic dehydration of strawberries before vacuum drying for rehydration time of 20 or 60 min. did not cause a significant difference in rehydration of dried strawberries stored for a long period. However, despite rehydration time, solid content in dried material from osmotically dehydrated strawberries was lower than for the dried fruits obtained from raw strawberries. Vacuum dried strawberries stored for about 360 days longer at ambient temperature obtained slightly lower relative weight gain and higher solids content, but the differences were not statistically significant.

References

Ciurzyńska, A.; Lenart, A. (2009). Influence of freezing and osmotic dehydration in various types of osmotic solutions on chosen properties of freeze-dried strawberries. *Acta Agrophysica, 14*(3), 577-590 (*in Polish*).
Ciurzyńska, A.; Lenart, A. (2010). Rehydration and sorption properties of osmotically pretreated freeze-dried strawberries. *Journal of Food Engineering, 97*(2), 267-274.
Eshtiaghi, M. N.; Stute, R.; Knorr, D. (1994). High-Pressure and Freezing Pretreatment Effects on Drying, Rehydration, Texture and Color of Green Beans, Carrots and Potatoes. *Journal of Food Science, 59*(6), 1168-1170.
Gaware, T. J.; Sutar, V.; Thorat, B. N. (2010). Drying of tomato using different methods: comparison of dehydration and rehydration kinetics. *Drying Technology, 28*(5), 651-658.
Góral, D., Kluza, F. (2009). Cutting test application to general assessment of vegetable texture changes caused by freezing. *Journal of Food Engineering, 95*, 346-351.
Janowicz, M.; Domian, E.; Lenart, A. (2009). Changes in internal structure of apple tissue dried using the convection process, induced by osmotic dehydration. *Inżynieria Rolnicza, 2*(111), 67-73 (*in Polish*).
Kaleta, A.; Górnicki, K.; Wierzbicka, A.; Pacak-Żuk, S. (2008). Investigation of the course of rehydration of dried parsley root slices. *Acta Agrophysica, 12*(3), 689-698 (*in Polish*).
Kolniak, J. (2008). Effect of freezing and thawin methods and cryo-protective supplements added on the content of total polyphenols, anthocyanins, and antioxidant capacity in frozen strawberries. *Żywność. Nauka. Technologia. Jakość, 5*(60), 135-148 (*in Polish*).
Kowalska, H.; Marzec, A.; Omen, K. (2012). Effect of osmotic pretreatment on selected rehydration properties of dried apples. *Acta Agrophysica, 19*(1), 65-76 (*in Polish*).
Krzykowski, A. (2008). The influence of blanching of pepper on the energy-consumption during its freeze drying and on rehydration of dried paprika during storage. *Acta Sci. Pol., Technica Agraria, 7*(3-4), 11-17 (*in Polish*).
Lemus-Mondaca, R.; Miranda, M.; Andres Grau, A.; Briones, V.; Villalobos, R.; Vega- Galvez, A. (2009). Effect of osmotic pretreatment on hot air drying kinetics and quality of Chilean Papaya (Carica pubescens). *Drying Technology, 27*(10), 1105-1115.
Lewicki, P.P. (1998). Effect of pre-drying, treatment, drying and rehydration on plant tissue properties: a review. International *Journal of Food Properties, 1*(1) 1-22.
Łapczyńska-Kordon, B.; Krzysztofik, B. (2008). Effects of the storing methods and storing time on selected physical properties of apples. *Inżynieria Rolnicza, 2*(100), 179-185 (*in Polish*).
Marabi, A.; Saguy, I. S. (2009). *Rehydration and reconstitution of foods*. In: Advances in Food Dehydration. C. Ratti, (ed.). CRC Press Taylor & Francis Group, Boca Raton, 237-284.
Markowski, M.; Bondaruk, J.; Błaszczak, W. (2009). Rehydration behavior of vacuum- microwave-dried potato cubes. *Drying Technology, 27*(2), 296-305.
Markowski, M.; Zielińska, M. (2011). Kinetics of water absorption and soluble-solid loss of hot-air-dried carrots during rehydration. *International Journal of Food Science and Technology, 46*(6), 1122-1128.
Nowacka, M.; Witrowa-Rajchert, D. (2010). Changes of hygroscopic properties of dried apples during storage. *Acta Agrophysica, 15*(2), 359-370.
Pasłowska, M.; Stępień, B.; Surma, M.; Jałoszyński, K. (2011). Colour durability of berry fruit stored in a frozen state. *Inżynieria Rolnicza, 9*(234), (*in Polish*).
Piotrowski, D.; Godlewska, A. (2011). Influence of vacuum drying method on the rehydration process of dried strawberries. *Zeszyty Problemowe Postępów Nauk Rolniczych, 569*, 251-263, (*in Polish*).

Piotrowski, D.; Lenart, A.; Berner, W. (2010). Loss of soluble dry matter from initially osmotically dehydrated freeze-dried strawberries during rehydration. *Zeszyty Problemowe Postępów Nauk Rolniczych, 552,* 169-179 (*in Polish*).
Piotrowski, D.; Janowicz, M.; Sitkiewicz, I.; Ciurzyńska, A.; Lenart, A.(2011). Influence of temperature and pressure in the vacuum-dryer chamber on drying process and shrinkage of strawberries. *Zeszyty Problemowe Postępów Nauk Rolniczych, 558*, 197-206 (*in Polish*).
Rząca, M.; Witrowa-Rajchert, D. (2007). The influence of drying technique and storage conditions on dried apples reconstitution and hygroscopic properties. *Acta Agrophysica, 9*(2), 471-479 (*in Polish*).
Stepień, B. (2009). *Modification of mechanical and rheological properties for selected vegetables occurred during drying using different methods*). Wydawnictwo Uniwersytetu Przyrodniczego we Wrocławiu, 23-34, (*in Polish*).
Witrowa-Rajchert, D. (1999). *Rehydration as an index of changes occurring in plant tissuues during drying*. Rozprawa habilitacyjna, Fundacja „Rozwój SGGW", Warszawa.
Woźnica, A.; Lenart, A. (2005). Rehydration and water adsorption of freeze-dried strawberries. *Inżynieria Rolnicza, 11*(71), 523-530, (*in Polish*).

WPŁYW OBRÓBKI ZAMRAŻALNICZEJ, ODWADNIANIA OSMOTYCZNEGO I CZASU PRZECHOWYWANIA NA REHYDRACJĘ PRÓŻNIOWO WYSUSZONYCH TRUSKAWEK

Streszczenie. Suszone owoce – truskawki – poddano rehydracji poprzez zanurzenie w wodzie o temperaturze otoczenia i zbadano ich rehydracyjne właściwości. Celem pracy była analiza wpływu metody obróbki wstępnej (wpływ zamrożenia w -18°C, osmotyczne odwodnienie w roztworze sacharozy 61,5%) surowca i przechowywania (od 32 dni do 399 dni) na rehydrację wysuszonych truskawek. Próżniowo wysuszone truskawki z mrożonych owoców uzyskują większy względny przyrost masy wraz z wydłużaniem czasów rehydracji w porównaniu do suszy z truskawek surowych. Osmotyczne odwodnianie truskawek przed suszeniem próżniowym nie spowodowało znaczącej różnicy w rehydracji suszu truskawkowego długo przechowywanego. Wysuszone próżniowo truskawki przechowywane o około 360 dni dłużej w temperaturze otoczenia uzyskały nieznacznie niższy względny przyrost masy i wyższą zawartość suchej substancji.

Słowa kluczowe: rehydracja, suszone próżniowo owoce, mrożenie, osmotyczne odwodnienie, przechowywanie

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