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RESEARCH ON DRIED APPLE REHYDRATED WITH WATER AND MILK

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Abstract. Water absorption, swelling and the leaching of solubles during the rehydration of dried apple in water and milk were investigated in this work. Rehydration was done at 4, 25 and 40°C. The course of rehydration depends on temperature and the rehydration medium used.
Mass and volume increase was greater during rehydration in water; the higher the temperature, the larger the increase of mass and volume. The density of the material investigated increased during rehydration and was independent of the surrounding temperature. The density of apple rehydrated in milk was less.
Keywords: water absorption, leaching of solubles, swelling, density

INTRODUCTION

Rehydration is a complex process aimed at the restoration of the properties of the raw material when that material – in its dried state – comes into contact with water. The rehydration of dried plant tissue is composed of three simultaneous processes: water uptake into the dried material and the swelling and leaching of solubles [12]. Rehydration is influenced by several factors depending either on the lattice forces inside the plant tissue or on the interactions between the matrix and the immersion medium. Included in the second group of factors may be the composition of the immersion medium, the temperature and the hydrodynamic conditions.

Much information is available in the literature on the effects of temperature on the rehydration characteristics of food materials. Water absorption capacity was higher at higher temperatures for carrot and potato [13], blueberries [7], broccoli florets [2], onion [6].

Stirring and mixing the immersion medium improves the rehydration rate. Neubert et al. [9] reported that shaking and swirling mixtures of dried celery and water during rehydration increases the rate of water absorbtion. However, in general, the major resistance to water transfer lies within the food material itself, and thus mixing is not thought to play a major role.

Almost all the studies reported in the literature used water as the rehydration medium. However, although the characteristics of the immersion medium may affect both the rehydration rate and capacity, the number of investigations concerning this subject is insignificant.

The effects of different anions on the degree of rehydration of dehydrated carrots were measured by changes in tissue volume [3]. The carrots had signify-cantly greater rehydrated volumes when rehydrated in distilled water than in any of the salt solutions, while the carrots in the salt solution containing citrate had significantly lower rehydrated volumes than in other salt solutions. Because of its greater size, the citrate anion is probably less able to penetrate into the severely collapsed cell walls of the dehydrated carrots than the other anions. Therefore, water molecules that are orientated as a shell around the citrate anions are less available to rehydrate the polysaccharide gels of the dehydrated carrots than the water molecules orientated around the other anions. Del Valle et al. [1] found that the addition of carbonate salt to the soaking solution reduced water absorption and swelling in the beans, probably due to the water binding effect. On the other hand, Jadan et al. [4] found that beans coursed more quickly when soaking in sodium carbonate but more slowly when soaked in water.

Neubert et al. [9] studied the effects of the pH of the rehydration medium on the rehydration ability of dehydrated celery. They tested the pH range 2.6-11.5 and concluded that pH had no appreciable effect on the rehydration of celery. However according to Horn and Sterling [3] at pH values 2 and 12 the carrots rehydrated to the maximum extent. Greater hydration in solutions of extreme pH is probably due to their greater ability to hydrolyse the hemicelluloses and pectinates in the cell walls of the carrots - in particular those with a pH of 12.

Some dried fruit is mixed with breakfast cereal and consumed after immersing in milk. Thus rehydration in milk is also of interest; however this research was conducted by Oliveira and Ilincanu only [11]. They showed, based on the increase in mass, that rehydration is much smaller in whole milk than in water. The aim of this work was to accurately investigate water absorption, solubles leakage and swelling in convection-dried apple during rehydration in water and milk at different temperatures.

MATERIAL AND METHODS

Apple v. Idared cut in 1 cm cubes was the material under investigation.

Materials were dried in laboratory convection dryer at 70°C and air velocity 2 m s^{-1} in order to reach a constant mass. Trays were loaded 2 kg m^{-2}.

The dried material was rehydrated in water or in milk with a 0.5% and 3.2% fat content at a temperature of 4, 25 and 40°C for 5, 10, 15, 30, 60, 90 minutes and for 24 h. The re-hydrated material was strained, blotted with filter paper and weighed.

The dry matter content of the raw, dried and rehydrated material was measured according to Polish Standard PN-90/A-75101/03.

The volume of raw and dried cubes and material undergoing rehydration was measured by the volumetric method [8].

RESULT AND DISCUSSION

The rehydration of the dried materials resulted in an increase in mass and volume. The kinetics of the relative increase in mass is dependent on the immersion medium and the temperature of the rehydration (fig. 1). Regardless of temperature, more water was absorbed during rehydration with the water than with the milk. It was found that the different fat content of the milk (0.5 or 3.2%) had no effect on the course of mass increase. According to Oliveira and Ilincanu, [11] in milk, a layer composed mainly of lipids and micelles surrounds the fruit pieces, creating a major barrier to moisture transfer to the solid matrix, and the fruit piece better retains its structure after drying. This investigation showed that the layer of lipids on the surface of the apple pieces was the only reason for the smaller mass increase during rehydration with the milk. No differences in the course of water absorption during rehydration in milk of different fat quantities were found. Therefore all the results obtained for the different fat contents – which were provided for the analysis of the rehydration course – were determined as being due to rehydration with milk.

After rehydration, the mass of dried apple increased more than 3-fold during immersion in water and more than 2.6-2.9-fold, when processed in milk. The results showed that at the beginning of the rehydration process, the rates of increase in the mass were high. In the first phases of the process, reconstitution affected the dehydrated fruit pieces in different ways and involved mostly diffusive effects because the product had soaked up the liquid and, when diluted solutions were used, lost very high quantities of soluble solids (fig. 2). When cell walls become partially rehydrated, they act like semi-permeable membranes, absorbing water and exhibiting selective action towards soluble solids, depending on their molecular weights. When the concentration of the rehydration solution increased (milk), the dried apple cubes showed a decrease in the loss of soluble solids; the higher the temperature, the larger the loss of soluble solids. The loss of soluble solids after 90 minutes' rehydration in water was 44% at 4°C, 46% at 25°C and 59% at 40°C. Respective values for rehydration in milk were 23% at 4°C, 30 % at 25°C and 35% at 40°C. In the case of the rehydration in water, the driving force of soluble leaching (difference of chemical potential) is greater than during rehydration in milk and therefore this process was faster and was similar to water absorption.

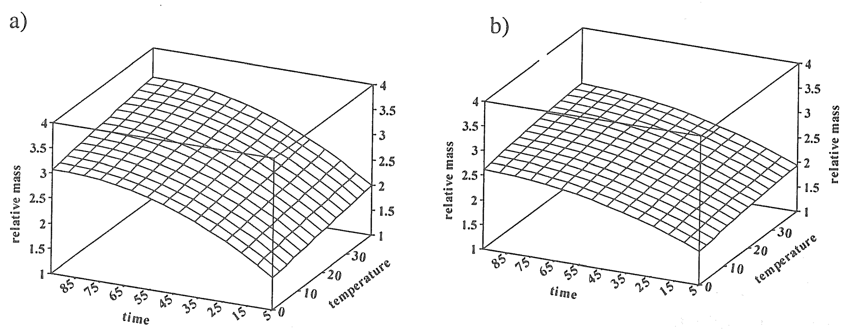

Fig. 1. The relative mass increase of apple in relation to time and temperature during rehydration in water (a) and milk (b)

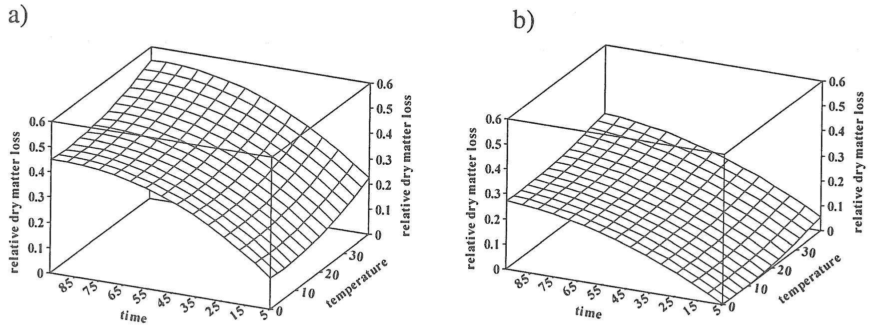

Fig. 2. Relative soluble leakage from apple in relation to time and temperature during rehydration in water (a) and milk (b)

The dried apple cubes soaked up the water and a volume increase was observed. The swelling depended more on the kind of rehydration medium used and less on temperature. The volume increase in the material rehydrated in water was faster than that observed where the apple had been soaked in milk (tab. 1). The volume of one cube after 90 minutes of rehydration in water was 4% at 4°C and 11% at 25 and 40°C greater than that for rehydration in milk. The rehydration temperature during rehydration in water influenced the volume increase. The water temperature increase from 4 to 40°C caused about 19% of volume increase. The respective value for rehydration in milk was about 12%. Regardless of the rehydration environment or temperature, the dried material had not regained its original volume even after 24 h of rehydration (tab. 2).

Table 1. Values of apple volume and density after 90 minutes of rehydration

Temperature (°C)	Water		Milk	
	Volume (cm^3)	Density ($g\ cm^{-3}$)	Volume (cm^3)	Density ($g\ cm^{-3}$)
4	0.566 ± 0.013^{a}	0.618 ± 0.038^{A}	0.542 ± 0.037^{a}	0.555 ± 0.016^{B}
25	0.631 ± 0.009^{b}	0.614 ± 0.009^{A}	0.559 ± 0.031^{a}	0.563 ± 0.027^{B}
40	0.675 ± 0.001^{c}	$0.598\pm0.029^{A,C}$	0.605 ± 0.021^{a}	$0.570\pm0.024^{B,C}$
dried cube	0.327±0.029	0.359±0.013	0.327±0.029	0.359±0.013
raw cube	1.250±0.050	0.766±0.038	1.250±0.050	0.766±0.038

Table 2. Values of apple volume and density after 24 h of rehydration

Temperature (°C)	Water		Milk	
	Volume (cm^3)	Density ($g\ cm^{-3}$)	Volume (cm^3)	Density ($g\ cm^{-3}$)
4	0.769 ± 0.027^{d}	0.699 ± 0.001^{D}	0.667 ± 0.034^{e}	0.637 ± 0.027^{E}
25	0.775 ± 0.018^{d}	0.705 ± 0.025^{D}	0.652 ± 0.033^{e}	0.645 ± 0.033^{E}
40	0.822 ± 0.040^{d}	0.691 ± 0.019^{D}	0.613 ± 0.027^{e}	$0.572\pm0.010^{E,F}$
raw cube	1.250±0.050	0.766±0.038	1.250±0.050	0.766±0.038

The influence of temperature on the apple volume was insignificant, but the difference between the material rehydrated in water or milk was statistically significant. The volume of the apple cubes reached 63% of the raw apple volume during rehydration in water and 52% of that where the material had been in milk.

The differences between rehydration in water and milk after lengthy rehydration indicate that a layer forms on the surface of the apple, composed of milk constituents – especially proteins – and that these create a major barrier to the transfer of moisture into the solid matrix. Moreover, the layer can be created from the pectins contained in the apple, which in the presence of calcium ions (from the milk) undergo gelation and thus the flow of water and solubles is impeded.

The rates of relative mass increase and relative volume change during rehydration were calculated. It was observed that the relative mass increase was faster (fig. 3), signifying that the water soaking up into the material fills up the pores and does not result an equivalent increase in volume. Sometimes, the situation is the reverse, especially for small material of limited porosity. The volume increases with hydration are greater than the weight of the water soaked up for soybeans and corn [5] as well for potato [12]. Water probably penetrates material through its solid part causing the bio-polymers to swell.

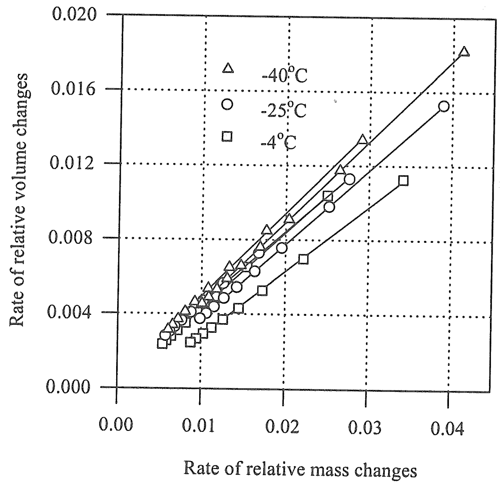

Fig. 3. Relationship between rates of relative mass increase and relative volume increase during rehydration of dried apple in water (blank symbols) and milk (shaded symbols)

The above results were used to follow the changes in density of the material investigated during rehydration. Changes in relative mass which were faster than those for relative volume resulted in density which increased with rehydration time. The density of apple increased from 0.359 to about 0.610 g cm^{-3} in water and to about 0.563 g cm^{-3} in milk, after 90 minutes of rehydration (tab. 1). The influence of temperature on the density of the material was statistically insignificant, but it is worth noting that an increase in water temperature caused a decrease in density, whereas for an increase in milk temperature there was an increase in density after 90 minutes of the process. Greater density was found for apple rehydrated in water after 24 hours of the process (tab. 2). The relative mass increase during rehydration (24 h) in milk was about 30% smaller than that for rehydration in water, while the respective value for the relative volume increase was about 18%. Therefore differences in apple density became apparent. The situation is the reverse where changes in apple density in relation to water content are presented (fig. 4). For the same water content, the density was greater for the material being rehydrated in the milk. The water content reached for the apple soaked in milk was always smaller than that for the fruit in water. This was due to the smaller amount of water soaking up into the material during rehydration in milk and the constituents of milk, which diffused into the material. The relationship between density and water content was described by the following equations:

- rehydration in water: $\rho = 0.25 + 0.22 \cdot u^{0.27}$, $r^2 = 0.863$
- rehydration in milk: $\rho = -1.73 + 2.24 \cdot u^{0.02}$, $r^2 = 0.860$

The values of coefficients in the above equations testify that changes of apple density vary during rehydration in water and milk. The majority of calculated densities were within an error margin of ±10 %. The respective lines presenting the ±10 % error are drawn on figure 4.

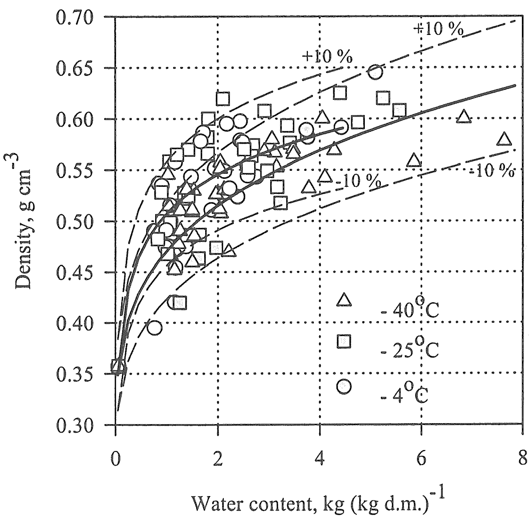

Fig. 4. Changes of dried apple density during rehydration in water (blank symbols) and milk (shaded symbols)

CONCLUSION

The results collected in this work show that rehydration is a complex process. The conclusion may be drawn that rehydrating dried apple in water is different to rehydrating it in milk. The influence of the temperature of the immersion medium was of less importance than the surroundings in which rehydration took place. The rate of water uptake, the leaching of solids, volume increase and density of rehydrated apple were found to have increased with temperature and soaking time. It is possible to modulate the water uptake and the soluble solid balance of the reconstituted fruit pieces by controlling the duration of the process, the temperature and the type of reconstitution medium used.

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BADANIE REHYDRACJI SUSZONYCH JABŁEK W WODZIE I MLEKU

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Streszczenie. W pracy badano procesy przyrostu masy i pęcznienia oraz wypływu suchej substancji, wywołane wchłanianiem wody podczas rehydracji suszonego jabłka w wodzie i mleku w temperaturach 10, 25 i 40°C. Przebieg rehydracji był uzależniony od temperatury procesu i rodzaju środowisk. Przyrost masy i objętości materiału był większy w czasie rehydracji prowadzonej w wodzie oraz w wyższych temperaturach. Gęstość badanego materiału zwiększała się w czasie uwadniania i była niezależna od temperatury procesu, ale wpływ środowiska rehydracji był istotny. Gęstość suszu rehydrowanego w mleku była mniejsza.

Słowa kluczowe: absorpcja wody, wypływ suchej substancji, pęcznienie, gęstość