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THE EFFECT OF OSMOTIC DEHYDRATION ON THE POLYPHENOLS CONTENT IN ONION

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ABSTRACT

Background. The onion is one of the most popular vegetables in the world, often used in the food industry. The purpose of this work was to determine the effect of osmotic dehydration of onions after storage in solutions containing various amounts of sucrose and sodium chloride on the course of osmoconcentration and the level of polyphenols in the dehydrated vegetables. The results could be useful to define the dehydration conditions under which a product retains the highest content of these health-promoting substances.

Materials and methods. Onions var. Robusta were used. The vegetables were stored for six months at 0°C (air relative humidity 75–80%). They were cut into quarters just before dewatering. Samples of 20 ±1 g were dehydrated for five hours in a 40–60°Bx sucrose solution and a 5–15% NaCl solution (25°C); the weight ratio of the sample to the solution was 1:5. The contents of polyphenols and dry matter were determined.

Results. The use of a mixture of two osmotic agents (sucrose, sodium chloride) was more effective in the increase of dry matter content than using only sucrose. Nearly 49% dry matter content in onion was obtained by using a 60% solution (50% sucrose + 10% NaCl) for five hours. The greatest differences in the content of total polyphenols occurred during the first hour. After this time, retention amounted to 48–90%, depending on the concentration of sucrose (40–60%) and sodium chloride (5–15%). The retention of diglycosides of quercetin (mainly quercetin-3,4'-diglucoside) was lower than that of monoglycosides (mainly quercetin-4'--glucoside). Following dehydration in a solution containing 60% sucrose and 10% NaCl, after three hours, there was about one third of the initial amount of the above-mentioned compounds in onion.

Conclusion. The increase in the concentration of the hypertonic solution, being a mixture of sucrose and sodium chloride, causes a reduction in the retention of total polyphenols in osmotically dehydrated onions. The smallest losses occur after applying a 40% sucrose solution with NaCl up to 10%.

Keywords: osmotic dehydration, polyphenols, monoglycosides, diglycosides, onion

INTRODUCTION

Osmotic dehydration is a technique of food processing that involves the removal of a portion of the water content as a result of immersing material with a tissue structure in a concentrated solution of an osmotic substance. These substances are most often saccharides and salts. The attractiveness of the method results from the lack of phase transformation of water, which allows the raw material to maintain its properties (for example nutritional value) to a large extent (García--Martínez et al., 2002). This technique is most often applied to fruit and vegetables.

The onion is one of the most commonly grown vegetables in the world. This fact, combined with its nutritional value and health-promoting effects (Suleria

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et al., 2015; Upadhyay, 2016), and at the same time its limited stability, make this vegetable an important raw material for use in osmotic dehydration (Alam et al., 2013). This technique is often combined with convective drying. Initial dehydration in concentrated solutions shortens the drying time with hot air and may improve the quality of the final product (Sahu et al., 2017; Shahade et al., 2015; Revaskar et al., 2014; Tsamo et al., 2006). Because large quantities of onions are stored for up to several months (time depending on many factors, Petropoulos et al., 2017), it is also advisable to use such material (after storage) in studies on the impact of processing on changes in the raw material.

The osmotic substance most often used for dehydrating fruits and vegetables is sucrose. Solutions of this sugar are also used for the dehydration of onion. In the case of this vegetable, the addition of sodium chloride is often used or pure (5–20%) salt solutions are applied (Ramya and Jain, 2017). Occasionally, osmotic substances other than sucrose have been used, e.g. maltose or trehalose (Ferrando and Spiess, 2001).

Literature data on changes that occur during dewatering refer primarily to mass transfer; dry matter content, migration of osmotic substance to tissue, and water loss are presented (Baroni and Hubinger, 1998; Dabhi et al., 2016; Patil et al., 2012; Rane and Dabhi, 2017; Sutar and Gupta, 2007; Tsamo et al., 2005). Additionally, colour changes (Debnath et al., 2004), the microstructure of dehydrated tissue (Assani et al., 2009; Debnath et al., 2004; Ferrando and Spiess, 2001), and rheological properties of dehydrated material (Lewicki and Sitkiewicz, 1999) were studied. In some publications, the content of selected ingredients is given: vitamin C, magnesium, iron (Alabi et al., 2016), pyruvic and ascorbic acid (after combined process of osmotic dehydration and convective drying; Sahoo et al., 2015), pyruvic acid, and reducing and total sugars (after a combined process of osmotic dehydration and convective drying; Yadav et al., 2010). In the available literature, however, information on the retention of polyphenols in onions after processing is very limited. The presence of polyphenols in food is important due to the pro-health activities that are attributed to these substances, which may be involved in the prevention of, for example, atherosclerosis or cancer (Russo et al., 2017; Santhakumar et al., 2018).

The purpose of this work was to determine the effect of osmotic dehydration of onions after storage in solutions containing various amounts of sucrose and sodium chloride on the course of osmoconcentration and the level of polyphenols in the dehydrated vegetables.

MATERIAL AND METHODS

Material

In the experiments, onions (*Allium cepa* L.) var. Robusta (yellow) were used. The onions (20 kg) were purchased from the Research Institute of Horticulture in Skierniewice (from their field). They were stored for six months in refrigerated conditions (temperature 0°C, air relative humidity 75–80%) – this variety is recommended for long-term storage. Just before dewatering, the scale leaves were removed and the onions were cut into quarters.

Osmotic dehydration

Samples of 20 ±1 g (Radwag AS 220.R2; Radwag Wagi Elektroniczne, Radom, Poland) were placed in sealed containers. The following solutions of sucrose [S] (KSC Polski Cukier S.A., Dobrzelin, Poland) and NaCl (POCH S.A., Gliwice, Poland) were added to each container: 40°Bx S, 50°Bx S, 60°Bx S, 40°Bx S + 5% NaCl, 40°Bx S + 10% NaCl, 40°Bx S + 15% NaCl, 50°Bx S + 10% NaCl, 60°Bx S + 10% NaCl. The weight ratio of the sample to the solution was 1:5. Osmotic dehydration was carried out for five hours at 25°C with shaking (150 cycles/min); water-bath GFL 1086 (Gesellschaft für Labortechnik mbH, Burgwedel, Germany) was used. One technological repetition was carried out; two samples were taken every hour. The onion was separated from the solution in a sieve, dipped twice in distilled water, and dried on filter paper.

Dry matter content determination

Determination of the dry matter content was performed using a drying method at 70 ±1°C. Approximately 3 g of the sample (each sample in two repetitions) was weighed into weighing vessels and dried for nine hours under reduced pressure in a vacuum oven VO 400 (Memmert, Büchenbach, Germany). After cooling to room temperature, the sample was weighed.

The dry matter content was calculated based on the weight change.

Polyphenol determination

The sample was ground in liquid nitrogen (Linde Gaz Polska Sp. z o.o., Kraków, Poland) and approximately 0.5 g was weighed. Next, a three-time extraction was carried out using 70% methanol (POCH S.A., Gliwice, Poland) at room temperature for 15 minutes in an ultrasonic bath (IS 4; Intersonic S.C., Olsztyn, Poland). The content of polyphenols in the extracts was determined by HPLC-MS. A Dionex Ultimate 3000 liquid chromatograph (Diodex, Germering, Germany) coupled with a Q Exacutive Orbitrap mass detector (Thermo Fisher Scientific, Walthman, MA) was used (equipped with Chromeleon software) and a Kinetex column 2.6 µm C18 100 A, 150 mm × 2.1 mm (Phenomenex, Torrance, USA), PDA detector. The analysis was run in a gradient system: 0–1.44 min 5% B; 1.44–2.89 min 5–15%; 2.89–10.1 min 15–40% B; 10.1–11.55 min 40–73% B; 11.55–12.7 min 73% B; 12.7–13.28 min 73–5% B; 13.28–18 min 5% B. Phase A – 0.05% phosphoric acid (J.T. Baker, Deventer, Holland) in water, phase B – 0.05% phosphoric acid in 80% acetonitrile (LiChrosolv, Darmstadt, Germany). Standards: quercetin-3,4'-diglucoside, quercetin-4'--glucoside, quercetin (Extrasynthese S.A., Genay, France). Contents of other mono- and diglycosides were expressed as quercetin-4'-glucoside and quercetin-3,4'-diglucoside, respectively; total polyphenols is the sum of the individual polyphenolic compounds. The separation conditions were as follows: column temperature 35°C, flow rate 0.5 ml/min, injection volume 5 µl, and analysis time 18 min. Flavonol content was determined at 360 nm.

Polyphenol retention

Retention was calculated according to the formula:

$$R = (C_D / C_0) \times 100\%$$

where:

C_0 – sample mass before dehydration [g] × polyphenol concentration in the sample before dehydration [mg/100 g of fresh weight],

C_D – sample mass after dehydration [g] × polyphenol concentration in the sample after dehydration [mg/100 g].

Statistical analysis

Statistical analysis was conducted using Statistica 6.1 software (StatSoft, Tulsa, OK). Data were analysed using one-way analysis of variance and the Duncan test to find significant differences at $p < 0.05$.

RESULTS AND DISCUSSION

Figure 1 presents the changes in the content of dry matter in onions osmotically dehydrated in solutions of sucrose or containing a mixture of sucrose and sodium chloride (two popular osmotic factors). In the first case, the maximum content of dry matter (d.m.) reached nearly 38% (after five hours in 60% sucrose solution). Changes in the content of dry matter during dewatering are higher than those for NaCl. Baroni and Hubinger (1998) obtained 22% d.m. after four hours of dehydration (Baia Periforme variety) in 15% NaCl solution. In turn, Shahade et al. (2015) conducted dewatering for one hour in 10% and 15% NaCl solutions; they obtained, respectively, 18% and 20% d.m.

Comparison of data obtained using sucrose alone with results for sucrose mixtures with sodium chloride (Fig. 1b and 1c) clearly indicates that the use of two osmotic factors at the same time is more effective from the point of view of increasing the dry matter content. The use of a 60% solution, in which 10% sucrose was replaced with sodium chloride (50% sucrose + 10% NaCl), made it possible to obtain a dry matter content of almost 49% after five hours (29% higher than after using pure 60% sucrose). The phenomena of water loss and migration of the osmotic factor, which make up the observed change in the content of dry matter, were described in publications on onion dehydration from the mass transport point of view (Tsamo et al., 2005); therefore, our research focused on the retention of polyphenols affecting the health-promoting properties of the product. The content of the main polyphenols in the starting material are presented in Table 1. Changes in retention during osmotic dehydration were presented for the most effective variant in terms of osmoconcentration, i.e. using a mixture of sucrose and sodium chloride as an osmotic agent.

Figure 2a shows the results obtained using a 40% sucrose solution to which 5, 10, or 15% sodium chloride was added. The highest concentration of hypertonic solution resulted in the greatest loss (about 40%)

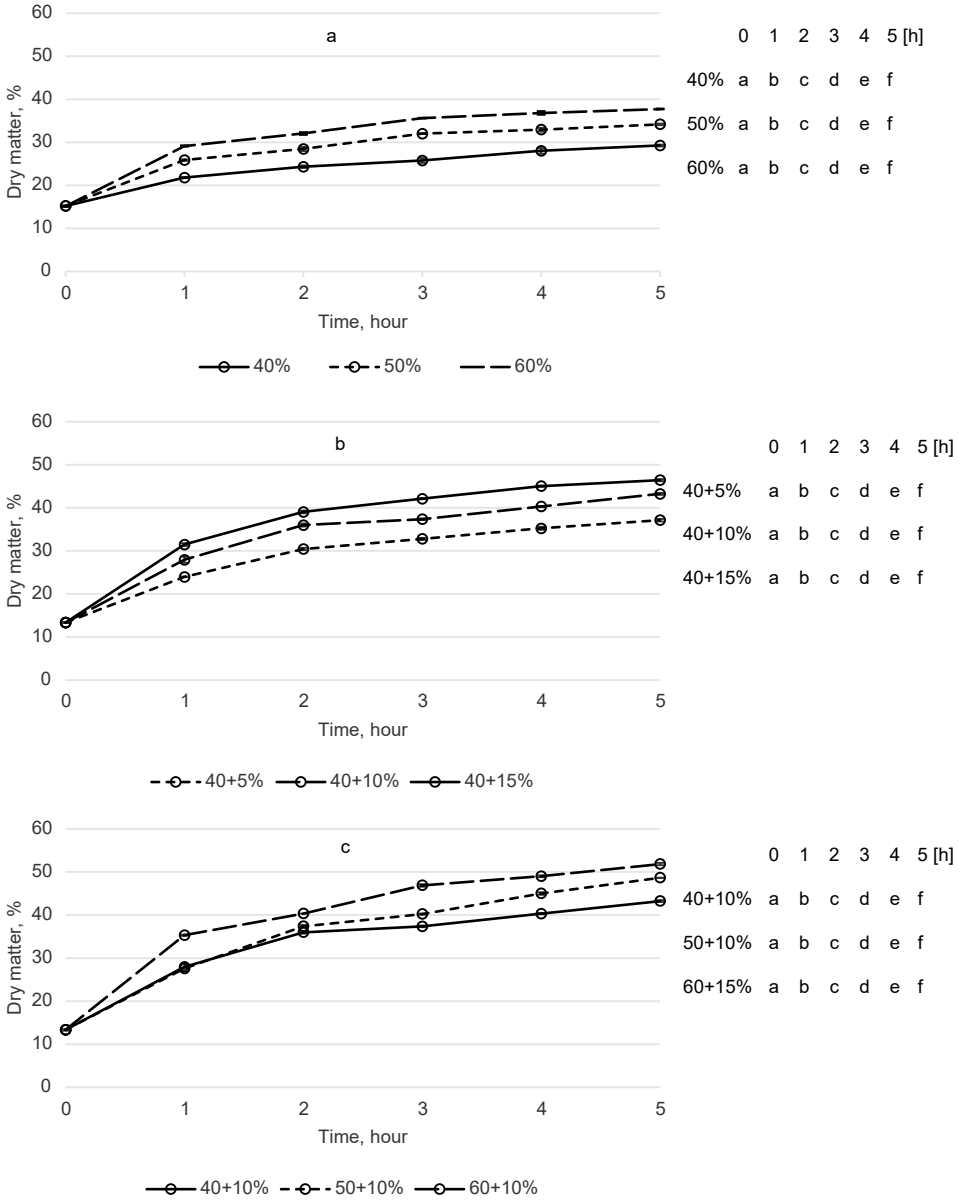

Fig. 1. Dry matter content in onion osmotically dehydrated in: a – sucrose solution of different concentrations, b – 40% sucrose solution containing NaCl of different concentrations, c – sucrose solution of different concentrations containing 10% NaCl; temperature 25°C, mass ratio solution/material 5/1. The same letter for a given concentration means no significant differences (95% confidence level)

of polyphenols up to the third hour of osmoconcentration. Lower concentrations caused about 20% loss. From the fourth hour, in all three variants, the polyphenol retention was about 60%. Figure 2b shows the results obtained using solutions with increasing sucrose concentration (from 40 to 60%) with 10% NaCl addition. Also in this case, the dependence of polyphenol retention on the concentration of the hypertonic

Table 1. Content of the main polyphenols in onion before dehydration (mean value ±standard deviation)

Compound	mg/100 g of fresh weight
Quercetin-3,4'-diglucoside	38.57 ±1.55
Quercetin-4'-glucoside	43.94 ±0.90
Quercetin	0.77 ±0.07
Total monoglycosides	47.29 ±3.06
Total diglycosides	39.16 ±1.58
Total polyphenols	87.63 ±4.76

Total monoglycosides expressed as quercetin-4'-glucoside; total diglycosides expressed as quercetin-3,4'-diglucoside.

solution is evident in the first phase of osmoconcentration (especially during the first hour). After three hours of the process, it ranged from 51% for the 60+10 variant (sucrose + NaCl) to 75% for the 40+10 variant. Staring from the fourth hour, the differences decreased significantly.

The above conditions had different effects on the retention of polyphenols of the two main groups found in onions: mono- and diglycosides. After three hours of the process in solutions with increasing NaCl content, monoglycosides (mainly represented by the glucose derivative of quercetin) were preserved at 84, 68, and 58% for the 5, 10, and 15% salt addition, respectively (Fig. 3a). In the case of increasing sucrose content in the hypertonic solution (Fig. 3b), the greatest losses were recorded in the 60+10 variant (sucrose + NaCl), in which about half of the monoglycosides were lost after one hour. However, by using a 40% sucrose solution with the addition of 10% salt, it is possible to retain nearly 80% of these compounds; after three hours the retention was about 70%. Higher losses were noted in the diglycoside group (Fig. 4a and 4b), in particular in experiments with increasing sucrose concentrations. In the 60+10 variant (sucrose

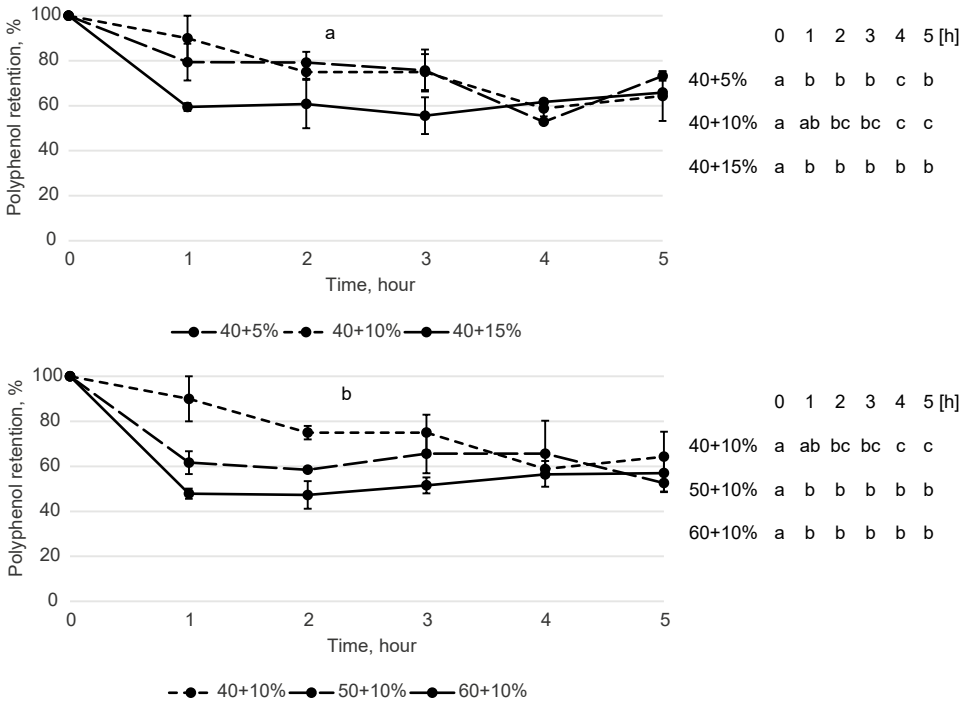

Fig. 2. Polyphenol retention in onion osmotically dehydrated in: a – 40% sucrose solution containing NaCl of different concentrations, b – sucrose solution of different concentrations containing 10% NaCl; temperature 25°C, mass ratio solution/material 5/1. The same letter for a given concentration means no significant differences (95% confidence level)

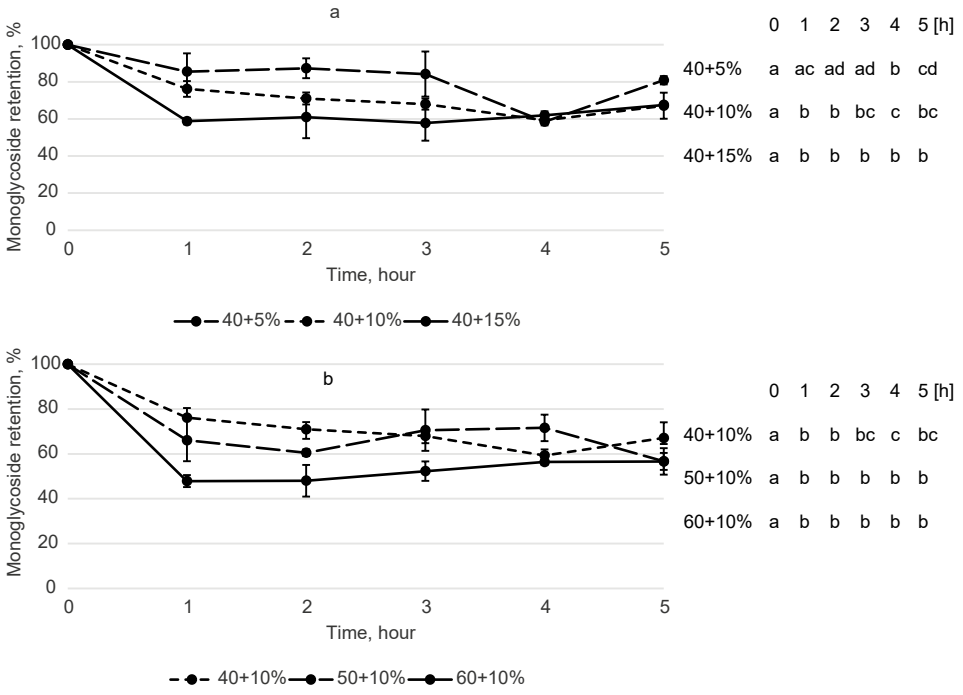

Fig. 3. Monoglycoside retention in onion osmotically dehydrated in: a – 40% sucrose solution containing NaCl of different concentrations, b – sucrose solution of different concentrations containing 10% NaCl; temperature 25°C, mass ratio solution/material 5/1. The same letter for a given concentration means no significant differences (95% confidence level)

+ NaCl), retention fell to about 35% after three hours. Most of these compounds (over 60%) were preserved when using the least concentrated hypertonic solution (40+10). There was no clear relationship between the amount of salt added to the 40% sucrose solution and the diglycoside retention (Fig. 4a).

The above-described effect of the decrease in retention as the hypertonic solution concentration increases can be related to the intensification of water migration from dehydrated tissue to the hypertonic solution caused by the increase of the osmotic pressure of the solution. The phenomenon of increasing the amount of water transferring from onions (and other plant material) in higher concentrated solutions has already been described in numerous publications (Alam et al., 2013; Patil et al., 2012; Sahu et al., 2017). The water that migrates from the tissue takes polyphenolic compounds with it.

The limited availability of data on the polyphenol retention in the osmotically dehydrated material does not only apply to onions, as mentioned before, but to vegetables generally. Among the few available data are those relating to ginger (García-Toledo et al., 2016), which dehydrated in 35–65% sucrose solution (raw material/solution ratio 1/15) for 220 minutes at 25°C and lost from 25 to 33% of total polyphenols. Singla et al. (2010) studied the effect of a combined dehydration technique (osmotic dehydration in 5% NaCl for five minutes + vacuum drying at 45°C for 2.5 hours) on total polyphenol and flavonoid levels in mushrooms. According to the authors, there was no loss of polyphenolic compounds due to processing (the authors did not provide separate information on the increase in the content of dry substance after dehydration and the resulting increase in the concentration of polyphenols). Cvetković et al. (2019) carried out dehydration of white cabbage in beet molasses (ambient temperature, 5 h). They reported an increase in the polyphenol content.

The literature provides much more information on the retention of polyphenols in fruits after osmo-

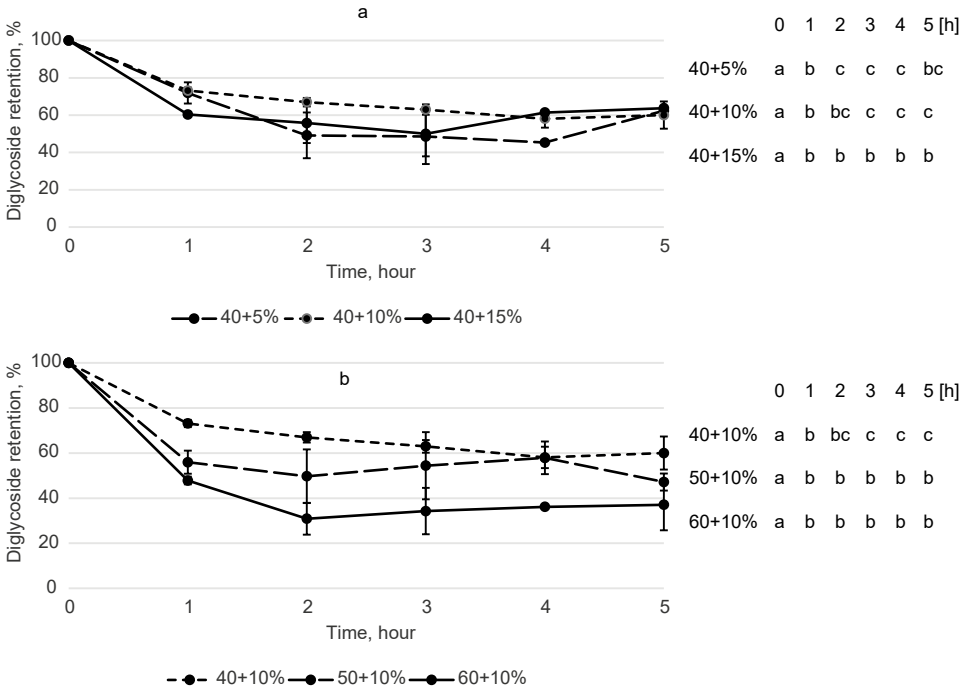

Fig. 4. Diglycoside retention in onion osmotically dehydrated in: a – 40% sucrose solution containing NaCl of different concentrations, b – the sucrose solution of different concentrations containing 10% NaCl; temperature 25°C, mass ratio solution/material 5/1. The same letter for a given concentration means no significant differences (95% confidence level)

concentration. Here are some examples of using fruits that, like onions, are cut into parts before osmotic dehydration. Mango is indicated as a stable material from the polyphenol retention point of view (Nagai et al., 2015). No loss of polyphenols was observed during osmotic dehydration in a 40–60% sucrose solution at 25°C for 1–3 hours in the presence of ascorbic acid. Almeida et al. (2015) determined retention of total polyphenols in bananas dehydrated in a sucrose solution (30°C). After 60 and 180 minutes, using a 45% solution, the retention was close to 98%. The use of a 65% solution resulted in a reduction in the amount of polyphenols to 89.8% of the original value (after 60 minutes) and 77.7% (120 minutes). Devic et al. (2010) studied the effect of dehydration on the level of polyphenols in apples (45°C, 60% sucrose solution). They determined losses of monomeric catechins, procyanidins, and hydroxycinnamic acid. For a Marie Menard variety, after 90 minutes there were, respectively: 25, 18, and 42%, and after three hours: 46, 28, and 58%. The raw material characterised by significant loss of polyphenols during osmotic dehydration is pear. This material was tested by Kopera and Mitek (2007). They showed that the total polyphenol level in fruit after one hour of holding in 65% sucrose solution at 20°C decreased by 8–21%, depending on the variety used; after three hours, this value fluctuated between 31 and 42%, and after six hours 45–62%.

CONCLUSIONS

An increase in the concentration of hypertonic solution, being a mixture of sucrose and sodium chloride, causes a reduction in the retention of total polyphenols in osmotically dehydrated onions.

At 25°C, the greatest differences in the total polyphenol content occur during the first hour of the process. After this time, the retention ranges between 48 and 90% depending on the concentration of sucrose (40–60%) and sodium chloride (5–15%); after three

hours the value varies between 50 and 80%. The smallest losses occur after applying a 40% sucrose solution with NaCl up to 10%.

In the diglycoside group, there are higher losses than in the monoglycoside group. In the 60+10 variant (sucrose + NaCl), after three hours of osmotic dehydration, only about one third of the initial amount of diglycosides is present in the onion.

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