Biblid: 1821-4487 (2011) 15; 3; p.146-148
UDK: 542.934.8:547.458.2

Original Scientific Paper
Originalni naučni rad

COUNTER-CURRENT OSMOTIC DEHYDRATION OF CARROT AND APPLE IN SUCROSE SOLUTIONS AND SUGAR BEET MOLASSES
PROTIVSTRUJNA OSMOTSKA DEHIDRATACIJA MRKVE I JABUKE U RASTVORIMA SAHAROZE I MELASI ŠEĆERNE REPE

Nevena MIŠLJENOVIĆ, Gordana KOPRIVICA*, Ljubinko LEVIĆ*, Svetozar STOJILJKOVIĆ**, Tatjana KULJANIN**
**Faculty of Technology, 21000 Novi Sad, Bulevar Cara Lazara 1, Serbia*
*** Fabrika šećera "Bačka" Vrbas, Kolonija Secerane 9, 21460 Vrbas*
e-mail: megamum@uns.ac.rs

ABSTRACT

Counter-current osmotic dehydration of carrot and apple in the sugar beet molasses (50, 60, 70 and 80%) and sucrose solution (40, 50, 60 and 70%) was examined. After dehydration in less concentrated solution, the sample of carrot/apple was transfered into the higher concentrated solution. Each phase lasted 15 minutes, and whole process of the dehydration lasted 1 hour. Experiments were carried out at atmospheric pressure and temperature of 65^{0}C. Dry matter content of apple was changed from 13.43 to 42.3% in sugar beet molasses, while in the sucrose solution dry matter content was increased from 15.05 to 43.89%. In case of counter-current dehydration of carrots, dry matter content was varied from 11.19 to 42.11% when sugar beet molasses was used as an osmotic solution, while in the case of sucrose solution dry matter content was changed from 11.43 to 43.21%.

Key words: *osmotic dehydration, sugar beet molasses, sucrose, carrots, apples*

REZIME

U radu je ispitana protivstrujna osmotska dehidratacije jabuke i mrkve u melasi šećerne repe (50, 60, 70 i 80%) i rastvorima saharoze (40, 50, 60 i 70%). Uzorak se nakon dehidratacije u rastvoru manje koncentracije ponovo unosi u rastvor veće koncentracije. Svaka faza traje po 15 minuta, a ceo proces protivstrujne osmotske dehidratacije sat vremena. Protivstrujna osmotska dehidratacija je izvedena na atmosferskom pritisku i temperaturi od 65^{0}C. Sadržaj suve materije u jabuci se povećava sa početnih 13,43 na 42,3% nakon dehidratacije u melasi šećerne repe, dok se u rastvoru saharoze sadržaj suve materije povećava sa 15,05 do 43,89%. Kada je u pitanju protivstrujne dehidratacija mrkve, sadržaj suve materije se menjao od 11,19 do 42,11% kada je kao osmotski rastvor korišćena melasa šećerne repe, dok se u slučaju saharoze sadržaj suve materije kretao od početnih 11,43 do 43,21%.

Ključne reči: *osmotska dehidratacija, melasa šećerne repe, rastvor saharoze, mrkva, jabuka.*

INTRODUCTION

Osmotic dehydration of fruits and vegetables is the process that has several advantages in comparison with other preservation methods. With this, less energy–intensive, method usually is not possible to produce products with low water content, but it is possible to reduce water content in a great extent and preserve nutritional and sensorial characteristics of the product, at the same time. Osmotic dehydration is very often used as pretreatment for further drying, canning, freezing, etc. *(Lenart and Lewicki, 1988; Pavkov et al., 2008).*

Osmotic dehydration is a process of the partial removal of water by direct contact of plant or animal tissue with a suitable hypertonic solution, i.e., highly concentrated sugar, salt, sugar/salt mixtures, etc. Mass transfer in osmotic dehydration is combination of simultaneous water and solute transfer processes. Due to pressure difference (as chemical potential) between the surrounding solution and the intracellular fluid, water flows from the product into the osmotic solution, while the solutes diffuse from the osmotic solution into the plant tissue. Together with these two mass transfer flows, third mass transfer phenomena, which is quantitatively negligible, takes place - leaching of product's own solutes (sugars, acids, minerals, vitamins) from plant tissue into the surrounding solution *(Ponting, 1973; Torreggiani, 1993; Rastogi et al., 2002).*

Mass transfer during the osmotic dehydration process depends on several factors: type and properties of the osmotic agents, concentration, temperature and agitation of the osmotic solution, material geometry, osmotic solution/material ratio, physicochemical properties of food materials, operating pressure and other forces *(Hawkws and Flink, 1978; Genina-Soto, et al., 2001; Lerici et al., 1985, Moreira and Sereno, 2003).*

Previous work of *Lević et al.* (2007) was shown that sugar beet molasses can be successfully used as a hypertonic solution in the osmotic dehydration of fruits and vegetables. *Mišljenović et al., (2010)* were compared effectiveness of the osmotic dehydration of apple in sugar beet molasses and sucrose solution, and concluded that dehydration in 80% sugar beet molasses provides best results, when WL/SG ratio has been taken into account. The most important advantage of sugar beet molasses application is nutritional improvement of the final product, primary the increased content of minerals and vitamins *(Koprivica et al., 2009).*

A numerous studies have been done to explore influence of gradually decreasing solution concentration (co-current material/solution flow), but opposite case, with increasing solution concentration (counter-current material/solution flow) has not been the subject of research with the exception of *Lazarides et al., (2007)*. Counter –current material/solution flow minimized solid gain and improved water loss in potato osmotically dehydrated in sucrose solutions.

In this paper changes in dry matter content of apple and carrot during counter-current osmotic dehydration in sugar beet molasses and sucrose solutions were shown.

MATERIAL AND METHODS

Principle of counter-current osmotic dehydration

Idea of counter-current osmotic dehydration is based on Silin's theory of extraction of sugar from sugar beet. In case of the osmotic dehydration, water was extracted from apple or carrot samples. Contacting between samples and solution is better explained on the scheme bellow.

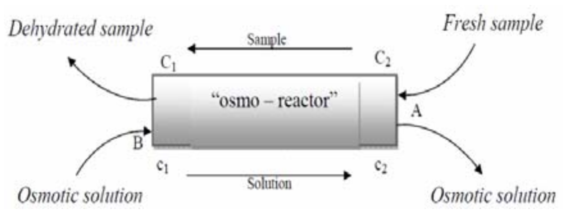

Fig. 1. Scheme of counter-current material/solution flow

In the apparatus with continuous counter-current flow, sample pieces are moving from one end to another, while the osmotic solution continuously flows in the opposite direction. Suppose that in such device enters fresh sample with water content (C2). At the other end of the device enters a certain concentration (c1) of the osmotic solution. Due to the diffusion, the sample gradually lose water and becomes dehydrate sample, with final water content (C1), while the solution accept water and becomes partially diluted and at the place where fresh material enters has lowest concentration (c2) (Šušić, 1966).

Material

Apples and carrots were purchased in a local market in Novi Sad, Serbia and stored at 4ºC until use. Initial moisture content of apples and carrots was 84.93±1.2 % and 89.51±0.99, respectively. Prior to the treatment, the apples and carrot were thoroughly washed and cut into cubes, dimension 0.7x0.7x0.7 cm.

Sugar beet molasses and sucrose solutions in different concentrations (50%, 60%, 70% and 80% for sugar beet molasses; 40%, 50%, 60% and 70% for sucrose solutions) were used as osmotic solution. Sugar beet molasses was obtained from the sugar factory Pećinci, Serbia. Initial dry matter content in sugar beet molasses was 81.14±0.15%. Solution of sugar beet molasses and sucrose were prepared with distilled water.

Experimental work

Solution to samples weight ratio was 5:1. Counter-current osmotic dehydration was carried out under atmospheric pressure, in the static conditions and at temperature of 650°C.

In the experiments, followed instruments were used: the extractor, vessel, a hot plate to heat the solution and thermometer. Extractor is a specially designed vessel with a porous bottom and lids, which allow flow of the solution during the process. Extractor, filled with certain mass of samples, was dipped into the vessel, whose is a poured with certain amount of preheated solution of sucrose or molasses. At 15 min intervals, weight of the samples was noted and the extractor with sample was transferred to the solution with higher concentration in order to simulate counter – current conditions. Each phase lasted for 15 min and the entire process of counter-current osmotic dehydration lasted 1 hour. In Table 1 are shown solution concentrations and time intervals during counter-current material/solution flow.

After last phase, samples were washed with water and gently blotted to remove excessive water. The samples were weighed and analyzed for dry matter content. Dry matter content in the fresh samples, as well as in the samples after last phase of counter-current osmotic dehydration, was determined by the oven drying method according to AOAC (*AOAC, 2000*). The samples were kept in an oven (Instrumentaria Sutjeska, Serbia) at 105°C for 24 h until a constant weight was attained. Dry matter content was calculated from the samples weights before and after drying. Dry matter content in the samples after first, second and third step of the process was calculated by material balance where inputs were weight of the solution with known dry matter content and weight of the samples before and after each phase. The solid content of osmotic solutions was determined refractometrically (*AOAC, 2000*).

Table 1. Changes in osmotic solution concentration during 1 hour of counter - current osmotic dehydration

Phase	Osmotic solution concentration, %			
	1 (first 15 min)	2 (Next 15 min)	3 (Next 15 min)	4 (Last 15 min)
Sugar beet molasses	50	60	70	80
Sucrose solution	40	50	60	70

RESULTS AND DISSCUSION

Results obtained in this experiment (Fig. 2 and 3) show that, by counter-current osmotic dehydration, dry matter content in apple and carrot can be increased several times. Increasing of dry matter content was due to diffusion of water from the plant tissues into the surrounding osmotic solution.

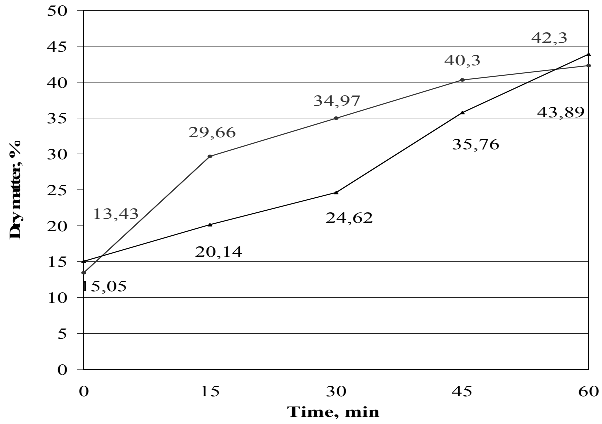

Fig. 2. Dry matter content in apple during counter – current osmotic dehydration (▲- suc. solution; ● – sugar beet molasses)

After the first 15 minutes of dehydration of apple in 40% sucrose solution, the dry matter content was increased from the initial 15.05% to 20.14%. After 4th phase, ie. 60 minutes of counter - current dehydration, the dry matter content in apple was 43.89%. In comparison with the results in previous research of Mišljenović et al., 2010., can be noted that in co – current osmotic dehydration this value of dry matter content was reached after 2.5 - 3 hours of dehydration in 70% sucrose solution, which certainly points out on the advantage of the counter – current way of performing of dehydration. Obviously, in this way is possible to reduce duration of the process and consequently save the energy necessary for the performing of the osmotic dehydration.

The dry matter content in apple, during 60 min of counter-current dehydration in sugar beet molasses, was changed from 13.43% to 42.3%. In the co – current apple/sugar beet molasses flow this value can be reached only after 3 hours. Apple with 42.3% dry matter content can be further exposed to convective drying to the desired dry matter content or can be used as raw materials in certain branches of the food industry (bakery, confectionery, dairy) (*Filipčev et al., 2009*).

Figure 3 shows result of the counter – current osmotic dehydration of carrot in sugar beet molasses and sucrose solutions. In both cases, dry matter content was being increased after each phase, but the largest increasing was observed after first 15 minutes, even though a osmotic solution with a lowest concentration has been used. After the first phase of dehydration in 40% sucrose solution, content of dry matter was increased for 13.7%. After the last cycle, i.e. after 60 minutes of counter- current osmotic dehydration, dry matter content in carrot was 42.11%.

In sugar beet molasses, dry matter content in carrot was increased from 11.43 to 43.21%. After the first cycle the content of dry matter was changed from 11.43 to 26%. If we compare these results with the previous experiments, we can note that by co - current osmotic dehydration, 43.21% of dry matter content was reached after 2.5 hours (*Koprivica et al., 2010*).

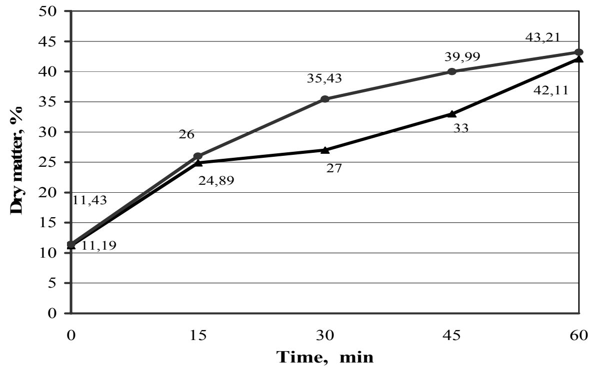

Fig. 3. Dry matter content in carrot during counter – current osmotic dehydration (▲- sucrose solution; ● – sugar beet molasses)

Table 2. Concentration of the osmotic solutions before and after each phase of the counter – current osmotic dehydration (OD)

	Apple			
	Sugar beet molasses		Sucrose solution	
Phase	Before OD	After OD	Before OD	After OD
1	52.5	47.47	40.96	38.94
2	61.86	59.94	50.86	49.47
3	71.92	69.96	60.95	59.36
4	81.25	79.92	69.35	68.44
	Carrot			
1	51.55	47.09	41.10	37.83
2	60.66	58.78	48.53	46.41
3	72.03	68.17	62.15	61.15
4	81.04	80.59	69.00	67.56

Based on already presented, the priority can be given to counter –current way of performing of the osmotic dehydration. Additionally, the fact that the dry matter content in the osmotic solution was just slightly changed enables multiple usage of the osmotic solutions (*Mišljenović et al., 2010*). In the Table 2, concentrations of osmotic solutions before and after each phase were shown. Changes in the concentrations of molasses after processes were very small, which indicate the already mentioned possibility of multiple usage of molasses in the process of osmotic dehydration, as well as row material for the bioethanol production (*Lević et al., 2008*).

CONCLUSION

Counter – current material/solution contacting appears to be an excellent way of performing of the osmotic dehydration, primarily due to the high content of dry matter in the samples reached after 1 hour of immersion, while by co – current osmotic dehydration that value was reached after 2,5 - 3 hours. That consequently leads to reduction of the immersion time, as well as energy consumption and costs of the process.

ACKNOWLEDGMENT: This research is part of the project supported by the Ministry of Science and Technological Development of the Republic of Serbia, TR – 31055, 2011-2014

REFERENCES

AOAC (2000). Official Methods of Analysis. Washington, USA

Filipčev, Bojana, Lević, Lj., Bodroža-Solarov, Marija, Mišljenović, Nevena, Koprivica, Gordana (2010). Quality characteristics and antioxidant properties of breads supplemented with sugar beet molasses-based ingredients. International Journal of Food Properties, 13 (5), 1035-1053.

Genina-Soto, P., Barrera-Cortes, J., Gutierrez-Lopez, G., Nieto, E. A. (2001). Temperature and concentration effects of osmotic media on OD profiles of sweet potato cubes. Drying Technology, 19 (3-4), 547-558.

Hawkes, J., Flink, J. M. (1978). Osmotic concentration of fruit slices prior to freeze dehydration. Journal of Food Processing and Preservation, 2, 265–284.

Koprivica, Gordana, Mišljenović, Nevena, Lević, Lj., Jevrić, Lidija, Filipčev, Bojana (2010). Osmotic dehydration of carrot in sugar beet molasses: Mass transfer kinetics. Acta Periodica Technologica, 41, 47-55.

Koprivica, Gordana, Mišljenović, Nevena, Lević, Lj., Kuljanin, Tatjana (2009). Influence of nutrients present in sugar beet molasses and saccharose solution on the quality of osmodehydrated carrot. Journal on Processing and Energy in Agriculture, 13 (2), 178- 180.

Lazarides, H. N., Mitrakas, G. E., Matsos, K. I. (2007). Edible coating and counter-current product/solution contacting: A novel approach to monitoring solids uptake during osmotic dehydration of a model food system. Journal of Food Engineering, 82, 171–177.

Lenart, A., Lewicki, P. P. (1988). Energy consumption during osmotic and convective drying of plant tissue. Acta Alimentaria Polonica, 14 (1), 65-72.

Lerici, C. R., Pinnavaia, G., Della Rosa, M., Bartolucci, L. (1985). Osmotic dehydration of fruit - influence of osmotic agents on drying behavior and product quality. Journal of Food Science, 50 (5), 1217.

Lević, Lj., Filipović, V., Kuljanin, Tatjana (2007). Osmotski tretman oblikovanog korena mrkve u saharozi i melasi. Journal on Processing and Energy in Agriculture, 11 (3), 132 - 134.

Lević, Lj., Razmovski, Radojka, Vučurović, Vesna, Koprivica, Gordana, Mišljenović, Nevena (2008). Primena melase šećerne repe nakon osmotske dehidratacije za proizvodnju bioetanol. Journal on Processing and Energy in Agriculture, 12 (4), 219-221.

Mišljenović, Nevena, Koprivica, Gordana, Lević, Lj. (2010). Comparison of the kinetics of osmotic drying apples in sugar beet molasses and sucrose solutions. Journal on Proccesing and Energy in Agriculture, 14 (1), 32-35.

Mišljenović, Nevena, Koprivica, Gordana, Lević, Lj., Jevrić, Lidija, Kuljanin, Tatjana (2010). Reusing of hypertonic solution during osmotic dehydration of carrot. 11th International Symposium "Interdisciplinary Regional Research", Szeged, Hungary, Book of Abstracts.

Moreira, R., Sereno, A. M. (2003). Evaluation of mass transfer coefficients and volumetric shrinkage during osmotic dehydration of apple using sucrose solutions in static and non-static conditions. Journal of Food Engineering, 57, 25–31.

Pavkov, I., Babić, Ljiljana, Babić, M., Radojčin, M. (2008). Changes in physical properties of apple (Malus domestica) throughout combined drying technology. Journal on Processing and Energy in Agriculture, 12 (3), 127-131.

Ponting, J. D. (1973). Osmotic dehydration of fruit – recent modifications and applications. Process Biochemistry, 8, 18-20.

Rastogi, N.K., Raghavarao, K.S.M.S., Niranjan, K., Knorr, D. (2002). Recent developments in osmotic dehydration: methods to enhance mass transfer. Trends in Food Science & Technology, 13, 48–59.

Šušić, S. K., Guralj, E. M. (1965). Ekstrakcija soka iz repe – difuzija, Glava 4 in "Osnovi tehnologije šećera", Naučna knjiga, Beograd.

Torreggiani, Danila (1993). Osmotic dehydration in fruit and vegetable processing. Food Research International, 26, 59-68.

Received: 28.02.2011. Accepted: 10.05.2011.