The Quality Indicators of Osmotic Dried Apricot (*Prunus armeniaca*)

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Summary

Apricot (*Prunus armeniaca)* osmotic drying set of tests was conducted under controlled condition in laboratory. Current mean values of samples moisture content were obtained by measurement equipment and were used as data base for further statistical analysis. ANOVA statistical analysis proved that solution temperature and concentration are influential factors of osmotic drying. Empirical equation which predicts the changes of apricot halves moisture content in the time as a function of solution temperature and concentration was derived by the means of regression analysis. This equation was evaluated for solution temperatures of 45°C and 55°C, as well as for solution concentrations of 70% and 85% of saturated solution for chosen solution temperature. Results of chemical analyses results for "Keckemetska ruza", "Novosadska rodna" and "Ambrosia" apricot varieties are also presented in this paper. The significant changes in phosphorous and calcium were not observed, but the contents of total sugar in samples changed during soaking in sugar solution, as a result of solids gain in apricot halves.

Key words

apricot *(Prunus armeniaca),* osmotic drying, solution's temperature and concentration

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Introduction

Dewatering impregnation soaking in concentrated solution (Torreggiani and Bertolo, 2001) or osmotic dehydration was promoted at the end of 19-th century (Stefanovic and Urošević, 1995). Interest for this process appeared more than seventy years later by the scientists in many countries. The removal of water by soaking biomaterials in a concentrated solution is the basic "function"of this preservation method. Osmotic dehydration is a simultaneous water and solute diffusion process (Reppa et al., 1998; Mavroudis et al., 1998; Taylor, 1995; Martinez-Monzo et al., 1998). The degree of water loss and solid gain in the process are related to the material (sample) behavior. The changes of different biomaterial physical properties are functions of the moisture content. Therefore, during soaking in concentrated solution three mass transfer flows are taking place. First is water outflow from the tissue to the surrounding solution, the second is solute movement from the medium to the bioproduct and the third mass transfer flow is the leaching of food solutes to the medium.

The aim of this study was to collect more information about apricot behavior during osmotic dehydration. The hypothesis, which had to be proved, was that solution temperature and concentration have an affect on moisture content decrease. If that was true, the next step would be to find the quality connection between apricot moisture content changes, temperature and concentration of the osmotic solution. An empirical equation would be established using statistical analyses.

Materials and methods

The study of solution's temperature and concentrate influence on the migration of water molecules from apricot samples was organized under laboratory conditions. The plan of tests was determined according to chosen influential factors of osmotic dehydration (Babic et al., 2002; 2003; 2004; 2005).

The first factor was apricot variety, therefore "Ambrozija", "Novosadska rodna" and "Keckemetska ruza" were selected because of abundance in fruit growing production. Three big producers in Vojvodina region delivered fresh fruit to Department laboratory.

The procedure was as follows (Figure 1). The fresh fruit was washed by hand under water stream and spread in single layer on towel, for drying. Too ripe or immature ones were eliminated from further processing.

All apricots were halved by hand with a knife along the suture. The kernel was removed; the halves were carefully placed in a plastic woven container. When the container was filled with five kilograms of apricots, it was laid down into the chamber to treat with sulphur. Four grams of sulphur was burned out per one kilogram of fresh fruit (Taylor, 1995; Sardi Horticulture, 2001). The chamber was closed airtight. The duration of sulphuring was four hours, and after that the batch was unloaded from the chamber.

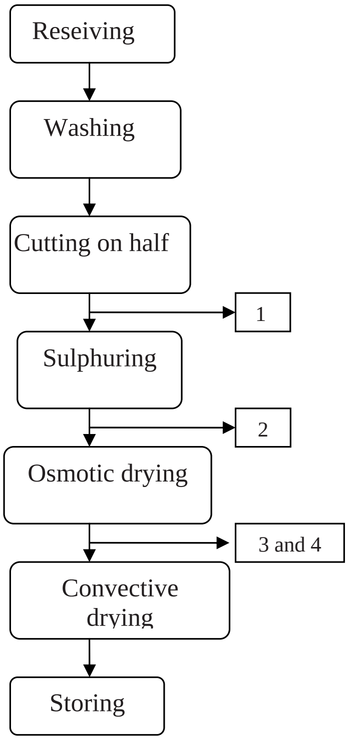

Figure 1. Flow chart of apricot drying with four critical control points (CCP)

Figure 2. Osmotic and batch convective pilot dryer

Table 1. The plan of tests

Apricot Variety	Tests			
	t=45°C		t=55°C	
	c=0.7	c=0.85	c=0.7	c=0.85
Ambrozija	2	4	3	5
Novosadska rodna	10.13	7.12	11	9
Kečkemetska ruža	15	17	14	18

All apricot halves were manually removed and placed in single layer in order to collect surface moisture by tissue. The sample was later put into osmotic dryer basket, where it was processed for 120 minutes. At the end of osmotic treatment, halves were removed from solution and gently blotted with tissue paper. The solution to fruit ratio was 14:1. To prevent evaporation, the apricot halves and osmotic solution were hermetically sealed.

The solute was sucrose. Two levels of it's concentration in distilled water were tested, 70% and 85% of saturated values at the chosen temperatures. The solution temperatures were 45°C and 55°C. Experimental set was carried out at two levels of solution's temperature and concentration and three levels of apricot varieties. Osmotic dehydration was performed with device shown in Figure 2, followed by convective drying.

A certain amount of apricot halves was immersed in a prepared solution according to testing plan (Table 1), which provided three or four repetitions for each influential factors. The samples were removed from the solution every 15 minutes for moisture content measurement. This procedure was repeated prior, during and at the end of all tests. Filter paper was used for samples drainage before moisture content was determined by laboratory oven at 70°C, until constant mass changes in two probes occurred.

The samples were collected at four points, before sulphuring (point 1), before osmotic dehydration (point 2), after first hour of osmotic drying (point 3) and at the end of drying (point 4). All samples were delivered to laboratory in Animal Science Department for chemical analysis. The laboratory was equipped with tools for measurement of: moisture content, protein, fat, cellulose, ash, N free extract, total sugar, phosphorus, calcium and vitamin C. All measurements were done according to Službeni list SFRJ, No 15/1987 regulations: methods 6, 7, 12, 16, 18, 20, 22 and 29; INS (02)-DM03-107 and INS (02)-DM03-101 successive.

A certain amount of apricots was dried only convectively, with an acidification as pre treatment, and those were used for referential procedure. All sulphuring and osmotic treatment samples were dried in convective dryer. The air temperature, as well as air velocity had the same values during convective drying tests. After measuring of weight, the samples were put in the chamber as elementary layer. The dryer was placed on a scale; the change of mass was recorded every 15 minutes. The end of process was predicted according to initial moisture content and mass of apricots in the dryer.

Results and discussion

The values of apricot halves moisture content in each 15 minutes periods during osmotic tests were presented as table and graphic data for three varieties. In order to prove the hypothesis that concentration and temperature of solution have an influence on apricot moisture change during osmotic dehydration, statistical analysis was employed. The first step was to study the affect of solution concentration (70% and 85%) at constant solution temperature of 55°C. The results of test No 3 is presented in Table 2. Those results are: w (%) - moisture content of samples on wet basis which were measured every τ - 15 minutes and Δw/Δτ (%/min) – the change of moisture contents in two measurements within 15 minutes.

Table 2. Test No 3 («Ambrozija», t=55°C, c=0.70)

	Time τ (min)	Moisture content w (%)	Moisture changesΔw/Δτ (%/min)
1	0	85.54	0.000
2	15	83.11	0.162
3	30	80.90	0.147
4	45	78.15	0.183
5	60	77.60	0.037
6	75	76.79	0.054
7	90	74.81	0.132
8	105	73.33	0.099
9	120	72.57	0.050

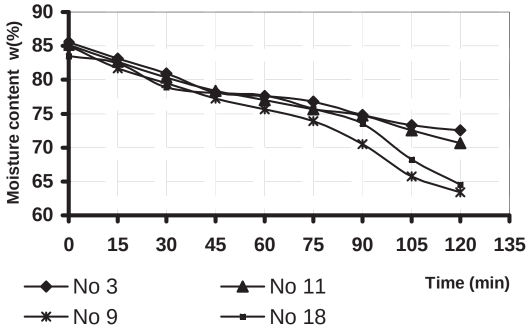

Figure 3. Mean values of apricot moisture content during osmotic dehydration for solution concentrations of 0.70 and 0.85 and temperature of 55°C

Tests No 11, 9 and 18 were also used for analysis. The graphic data of these four tests are presented on Figure 3. Four curves show apricot moisture contents change during osmotic time with the temperature of solution being constant, t = 55°C, and the concentrations of solution being

Table 3. ANOVA statistical analyse

SUMMARY						
Groups	Count	Sum	Average	Variance		
Column 1	16	1.828568	0.114286	0.002117		
Column 2	16	2.707988	0.169249	0.008425		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.024168	1	0.024168	4.585222	0.040491	4.170886
Within Groups	0.158126	30	0.005271			
Total	0.182294	31				

$c_1 = 0.7$ (test No 3 and 11) and $c_2 = 0.85$ (tests No 9 and 18). The trends of the curves are almost the same during first hour of dehydration, but during second hour there are differences in moisture content decrease. It is obvious that the water molecules migration from fruit to solution was more intensive (curves 9 and 18) in solution with the sugar concentration of saturation of 0.85 rather than 0.70 (curves 3 and 11) at the temperature of 55°C. ANOVA statistical analyse was employed for data calculation, and the results are presented in Table 3.

The calculated F criteria was F = 4.585222 and that value was higher then $F_{crit} = 4.170886$ within 95% of probability. The hypothesis was proven. That means that solution concentration has an influence on water molecules migration from fruit to sugar solution during soaking. Similar procedure was done for evaluation of the influence of solution temperature. The results were similar, therefore they confirmed an initial assumption.

The relationship between samples moisture content changes and solution temperature and concentration was determined by the means of regression analyse. According to previous studies analyses (Stefanovic and Urosevic, 1995; Kowalska and Lenart, 2001) power function and exponential equation were tested:

$Y = Ax^n$ and $Y = Ae^{xn}$

Appropriate regression expressions are:

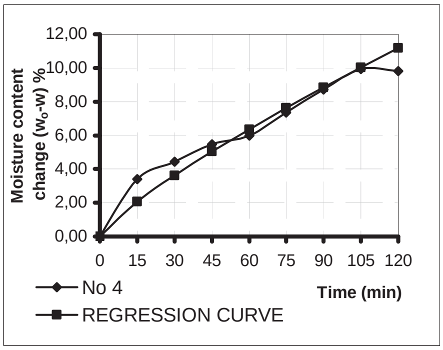

Figure 4. An empirical regression curve and measured values for test No 4

$\Delta w = w_o\text{-}w = A\tau^n$ or $\Delta w = w_o\text{-}w = Ae^{\tau n}$

where: w_o – initial sample moisture content (% wet basis), w – currant moisture content (% wet basis), τ – time (min). After incorporating the influential factors, they could be written as:

$$\Delta w = w_o - w = A\tau^{n1}(t/t_o)^{n2}(c/c_o)^{n3} \text{ or}$$
$$w = w_o - [A\tau^{n1}(t/t_o)^{n2}(c/c_o)^{n3}] \quad (1)$$

$$\Delta w = w_o - w = Ae^{\tau n1}(t/t_o)^{n2}(c/c_o)^{n3} \text{ or}$$
$$w = w_o - [Ae^{\tau n1}(t/t_o)^{n2}(c/c_o)^{n3}] \quad (2)$$

where: t_o – referential temperature assumed as 20°C, t – solution temperature (°C), c_o – saturated solution

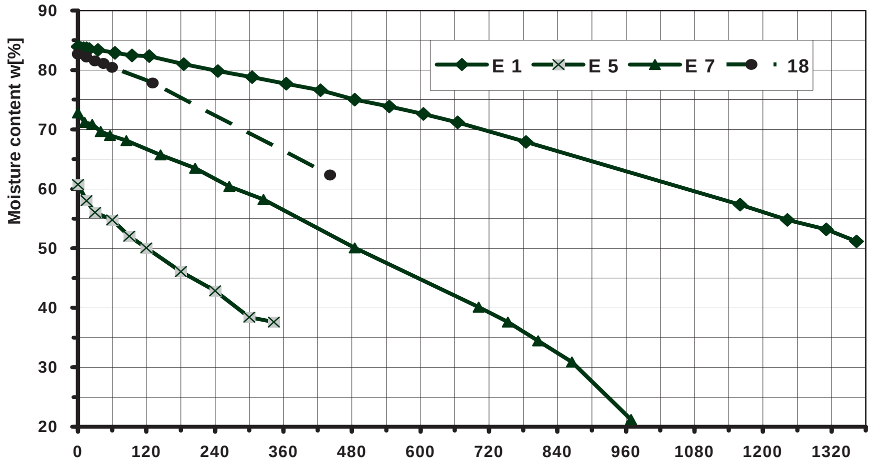

Figure 5. Osmotic kinetic drying curve (18) and convective kinetic drying curves of samples exposed to pretreatment:E1-acidification; E5, E7-sulfuring and osmotic dehydration

concentration at chosen temperature (or %), c – solution concentration (or %), A – coefficient dependent on test conduction, n_1, n_2, n_3 – exponents. By using PC software parameters were determined and results showed that expression [1] has better values of correlation coefficient. Regression summary for this equation is:

$A = e^{-2.53526} = 0.079241$; $n_1 = 0.881154$; $n_2 = 1.374136$; $n_3 = 0.312012$; $R = 0.96726394$ and standard error of 0.218. The final empirical expression is in the form:

$$w = w_o - [0.0792\ \tau^{0.88115}\ (t/t_o)^{1.3741}\ (c/c_o)^{0.3120}] \quad (3)$$

which describes apricot halves moisture content changes during osmotic drying valid for: solution temperature ranges 45-55ºC and solution concentration of 0.70 and 0.85 of saturated values at chosen temperatures.

An empirical equation was compared to data of moisture content changes during test No 4 (t = 45ºC, c = 0.85), presented in Figure 4. It is obvious that empirical equation fits well the experimental curve during most of the drying period except in the initial forty minutes.

The results of convective drying under controlled conditions were presented. The changes of sample's mass were measured in time and calculated in order to draw drying curves. Figure 5 shows these curves, where E1 is a kinetic drying curve of sample which was treated with acidifying agent only, E5 and E7 are curves where sulphuring and osmotic drying were applied, and curve 18 represents kinetic curve of osmotic dehydration only. The temperatures of air for convective drying were 50ºC (E1 and E7) and 60ºC (E5), while the air velocity had the same value during all the tests. It is obvious that drying air temperature had an influence on moisture migration (E5 and E7) but this factor was limited because of the final product quality.

It is well known that rapid absorption of sulphur dioxide into intercellular spaces of fruit occurs while the samples are exposed to gas. Once present in intercellular spaces, osmotic migration of sulphur dioxide through the tissue takes place. Over time, sulphur dioxide combines with soluble solids, sugars, pectin and aldehydes. These chemical reactions may explain how the sulphur dioxide causes the breakdown of cell walls and rupture of the fruit. The paths for moisture migration are available during further convective drying (curves E5 and E7). During osmotic dehydration the moisture migration is in form of liquid, through micro and macro capillaries in the body (Babic et al., 2004; Stefanovic and Urošević, 1995). There is no boundary force between vapor-liquid, so there is low deformation – contraction of solids. The structure and configuration of capillaries are not ruined. That is the reason why duration of further convective drying is two or three times shorter, compared to acidification sample.

The results of three apricot varieties chemical analysis are presented on Figure 6. The quantities of ingredients (N

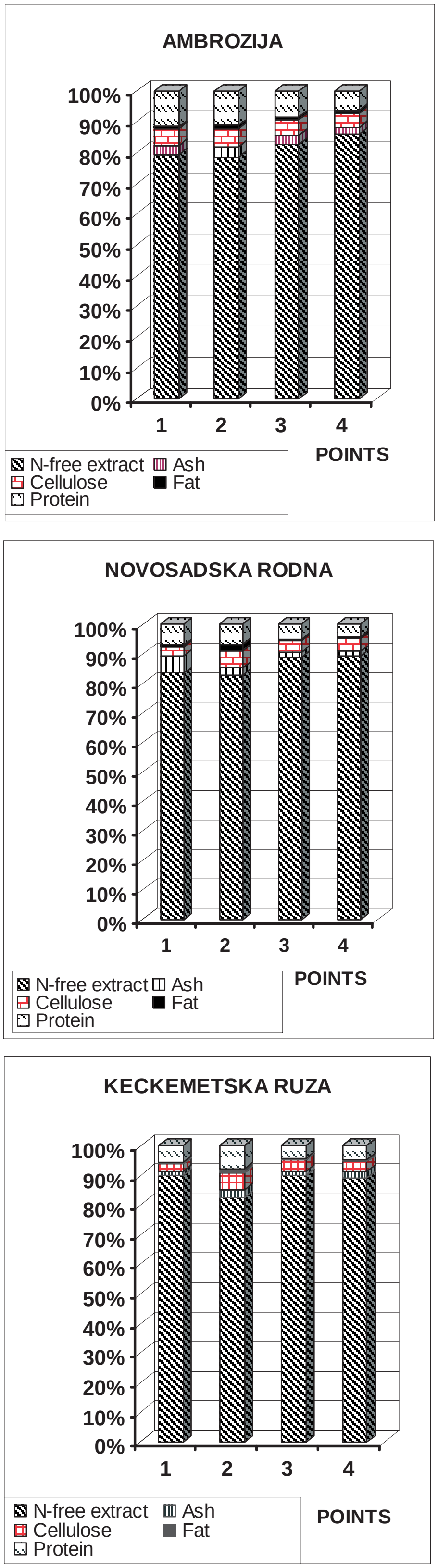

Figure 6. Ingredients of "Ambrozija", "Novosadska rodna" and "Kečkemetska ruža" apricot varieties at control points

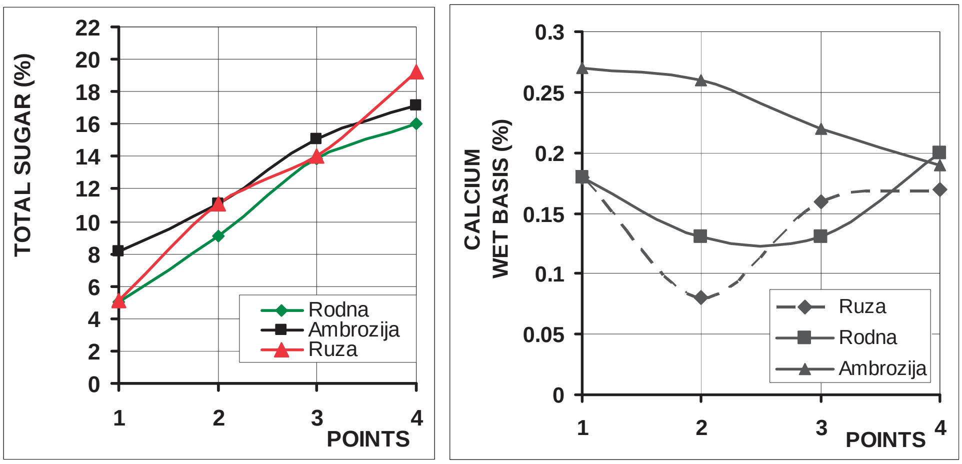

Figure 7.
Total sugar and calcium changes at control points

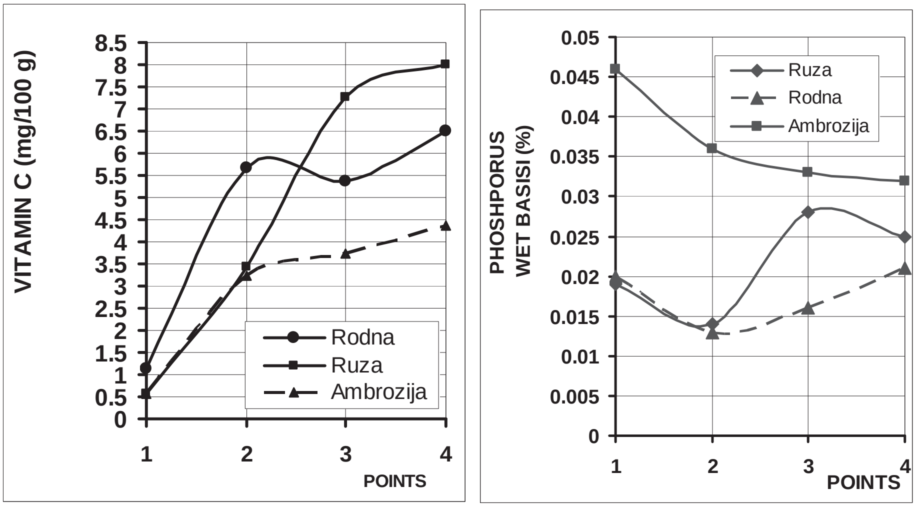

Figure 8.
Vitamin C and phosphorus contents during processing

free extract, cellulose, protein, ash and fat) were measured in the fruit samples. The samples were collected at: control point 1 (after cutting on halves), control point 2 (after sulphuring), control point 3 (after first hour of osmosis) and control point 4 (after second hour of osmosis). It can be emphasized that there were no significant distinctions between fresh fruit sample composition and sample after two hours of osmosis. There were distinctions between some components in sample after sulphuring. It can be explained by the fact that chemisorption of SO_2 takes place on the surface of apricot halves. Halves are large and therefore two hours of exposition to sulphur dioxide is a short period, especially when recommended amount of sulphur is burning per kilo of fresh fruit. Chemisorption didn't take place inside the halves and original structure of chemical composition was preserved. That is the reason why it is environmentally friendly procedure.

On the other hand, the content of total sugar in samples changed during soaking in solution as a result of solids gain of apricot halves (Figure 7). This higher content of sugar has an effect on the equilibrium moisture content. On average, values of outcome moisture content of halves were 32-35%, much higher compared to traditional convective drying. It seems that sugar gain acts as conservation means within apricot tissues. The significant changes in phosphorous and calcium were not observed (Figure 8).

Conclusion

The results of chemical analysis showed that new technology strongly supports the demands for environmentally friendly procedure in food processing. The aim of this study was to collect more information about behavior of apricot halves during combined osmotic and convective drying. The full attention was paid to apricot osmotic dehydration. When the hypothesis about temperature and concentration of solution influence on moisture content decrease was proven, an empirical equation was obtain, which describe the effect of influential factors on moisture content reduction:

$$w = w_o - [0.0792\ \tau^{0.88115}\ (t/t_o)^{1.3741}\ (c/c_o)^{0.3120}]$$

is valid for: solution temperature ranges 45-55ºC and solution concentration of 0.70 and 0.85 of saturated values at chosen temperatures. The conclusion is that en empirical equation fits well the experimental curve during most of the drying period except in the initial forty minutes. The calculated data will be used for semi industrial plant design, and main target will be production of dried fruits by energy rational processes.

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