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OSMOTIC DEHYDRATION OF WHITE CABBAGE IN DIFFERENT HYPERTONIC SOLUTIONS-MASS TRANSFER KINETICS AND IMPROVEMENT OF NUTRITIONAL VALUE OF THE DEVELOPED PRODUCT

OSMOTSKA DEHIDRATACIJA BELOG KUPUSA U RAZLIČITIM HIPERTONIČNIM RASTVORIMA-PRENOS MASE I POBOLJŠANJE NUTRITIVNE VREDNOSTI PROIZVODA

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ABSTRACT

The presented paper describes an investigation of osmotic dehydration of white cabbage (Brasicca oleracea var. capitata), domestic cultivar Futoški and ways of improving nutritional value of the final product. Osmotic dehydration was carried out in three different osmotic solutions and on three temperatures. First osmotic solution was mixture of NaCl, KCl and sucrose in water (Solution I). Solution I was used in three concentrations 40, 50 and 60%. Second solution was mixture of solution I and sugar beet molasses in ratio 1:1 (solution II), concentrations 50, 60 and 70% and third solution was pure sugar beet molasses (solution III), in concentrations of 40, 60 and 80% dry matter. The most important kinetic parameters of the dehydration process: Water losses (WL), solid gain (SG), water loss/solid gain ratio were determined after 1, 3 and 5 hours of dehydration. Mineral content in the fresh cabbage and osmotically dehydrated cabbage was determined.

Key words: *cabbage, osmotic dehydration, minerals, sugar beet molasses.*

REZIME

Rad opisuje ispitivanje osmotske dehidratacije belog kupusa (Brasicca oleracea var . Capitata), domaće sorte Futoški i načine poboljšanja nutritivne vrednosti finalnog proizvoda. Osmotska dehidratacija je izvršena u tri različita osmotska rastvora i na tri temperature. Prvo osmotski rastvor bio je mešavina NaCl, KCl i saharoze u vodi (rastvor I). Rastvor I je korišćen u tri koncentracije 40, 50 i 60%. Drugi rastvor je mešavina rastvora I i melase šećerne repe u odnosu 1:1 (rastvor II), koncentracija 50, 60 i 70% i treći je čista melasa šećerne repe (rastvor III) u koncentracijama od 40, 60 i 80% suve materije. Najvažniji kinetički parametri procesa dehidratacije: gubitak vode (WL), povećanje suve materije (SG), gubitak vode/povećanje suve materije odnos je određeni su nakon 1, 3 i 5 sati dehidracije. Sadržaj minerala u svežem i osmotski dehidriranom kupusu je određen.

Ključne reči: *kupus, osmotski dehidracija, minerali, melasa šećerne repe.*

INTRODUCTION

It is known that fresh fruit and vegetables constitute an important source of valuable and essential nutrient substances such as vitamins, minerals, cellulose and others. One group of vegetables that has been widely regarded for their antioxidant and anticarcinogenic properties are Brassica vegetables, including all cabbage-like vegetables (*Singh et al., 2006*). Cabbage (Brassica oleracea L. var. capitata) is one of the most important vegetables grown worldwide. In our country Futog is well known region of its tradition in the cultivation of cabbage, where white cabbage, cultivar Futoški is indigenous population (*Cvetković et al., 2011*). Unfortunately, cabbage and other fresh fruit and vegetables can not be stored for a long time. High moisture content (for fruit and vegetables often higher than 80%) and water activity are conducive to developing of germs and putrefactive bacteria, which are responsible for decaying processes. For this reason fruit and vegetables are processed to extend their shelf life (*Kowalski and Mierzwa, 2011*).Drying, especially hot air drying, is one of the most often applied industrial methods of preserving post harvested fruit and vegetables. This process stabilizes and prolongs the shelf life of fruit and vegetables and enables their longer storage and further utilization. High temperature and long time drying often change the shape, color, taste, aroma and nutrient properties of fruit and vegetables (Mujumdar and Law, 2010). Besides, drying is also one of the most energy-intensive unit operations in food processing industry. It was stated that drying easily accounts for up to 15 % of all industrial energy usage (*Chua et al., 2001; Kudra, 2004*). Osmotic dehydration is an alternative method for reducing postharvest quality losses of vegetables, and a common process for producing dried vegetables which can be directly consumed or used as an ingredient in bread, cakes, pastries and many products of other food industries. Osmotic dehydration is the process by which water is partially removed from the cellular materials when these are placed in a concentrated solution of soluble solumate. Osmotic dehydration, which is effective even at ambient temperature and saves the color, flavor and texture of food from heat, is used as a pretreatment to improve the nutritional, sensorial and functional properties of food (*Singh et al., 2007*). Osmotic dehydration is way for improving cabbage nutritive value and to prolong its shelf-life. Response surface methodology (RSM) is an effective tool for optimizing a variety of food processes including osmotic dehydration (*Azoubel et al., 2003; Ozdemir, 2008; Singh et al., 2010; Mišljenović et al., 2012*). The main advantage of RSM is reduced number of experimental runs that provide sufficient information for statistically valid results. The RSM equations describe effects of the test variables on the observed responses, determine test variables interrelationships, and represent the combined effect of all test variables in the observed responses, enabling the experimenter to make efficient exploration of the process. The objectives of here presented article were to investigate the effects of temperature, processing time, and concentration on the mass transfer phenomena during osmotic dehydration of cabbage leaves in sugar beet molasses and sucrose and NaCl solutions to model water loss (WL), solid gain (SG), and Osmotic dehydration efficiency index DEI (WL/ SG) as a function of the process variables and to find the optimum osmotic dehydration conditions. The influence of osmotic dehydration on cabbage mineral content also has been measured. Potassium, sodium, iron, copper, magnesium and calcium were analyzed in cabbage dehydrated in three hypertonic solutions with maximum dry matter on temperature of 20^oC.

MATERIAL AND METHOD

Raw cabbage heads, Futoški and was harvested on parcels of farmers from Futog, Serbia and stored at 4^oC before use. Sugar beet molasses was obtained from the sugar factory Pećinci, Serbia. The initial dry matter content in sugar beet molasses was 85.04%.

Cabbage was dehydrated after removing 3-4 outer leaves. Cabbage leaves were cut into cubes dimension of approximately 1 cm×1 cm×1 cm. An aqueous osmotic solution (AOS) (*solution I*) was made from commercial sucrose, NaCl and KCl in the quantities of 40, 50 and 60 % dry matter, respectively. Second osmotic solution was mixture of AOS and molasses in ratio 1:1 (*solution II*) in concentrations of 50, 60 and 70 % dry matter. Sugar beet molasses in different concentrations (40, 60 and 80% dry matter) were used as osmotic *solution III*. The experiments were conducted under the temperatures of 20, 35 and 50^oC, during 5 h (Table 1). The cabbage leaves were put in a glass jars with 1000 g of molasses and others solutions with a material/solution ratio of 1:5 (w/w). The jars were placed in the heat chamber and process was performed without agitation. After each sampling time (1, 3, and 5 hours), which is determined according to the experimental design (tab. 1), after the process of OD, the cabbage samples were washed with sterilized water and gently blotted to remove excessive water. The cabbage samples were weighed and part of the samples were kept in an oven (Instrumentaria Sutjeska, Croatia) at 105 °C until constant weight was attained, and dry matter content calculated from the samples weights before and after drying. Values of dry matter content (DMC), water loss (WL), and solid gain (SG) were calculated as described by Mišljenović *et al.* [10]. Moisture content of the samples was determined by the oven drying method according to AOAC (AOAC, 2000). Minerals content were determined by AAS.

The RSM method was selected to determinate the main effect of the process variables on the osmotic dehydration of cabbage. The accepted experimental design was taken from Box et al, 1960 . The independent variables were temperature (X1) of 20, 35 and 50^oC, osmotic time (X2) of 1, 3, and 5 hours, solution concentration (X3) of 40, 50, 60%, 50, 60, 70%, 40, 60 and 80 % (by weight) for solution I, solution II and solution III respectively, and the dependent variables observed were the response: WL(Y1), SG (Y2) and DEI (Y3) (Table 1.). The design included 27x3 experiments with 3 replications of the center point (Table 2). A model was fitted to the response surface generated by the experiment. RSM method was performed by Stat Soft Statistica, for Windows, ver. 10 program. The model was obtained for each dependent variable (or response) where factors were rejected when their significance level was less than 95%.

The second order polynomial (SOP) model was applied to the data:

$$y = b_0 + \sum_{i=1}^{k} b_i x_i + \sum b_{ii} x_i^2 + \sum_{i=1}^{k} \sum_{j=i+1}^{k} b_{ij} x_i x_j \quad (1)$$

where b are regression coefficients, y is dependent variable, and x_i, i=1, 2..k are factors of experiment. Model includes analysis of the main factors, their quadrants and relation between every two factors.

Table 1. Coded values of the treatment variables

	Treatment variables	Coded values		
		-1	0	+1
X_1	Temperature (°C)	20	35	50
X_2	Time (hour)	1	3	5
X_3	Solution I concentration (%)	40	50	60
	Solution II concentration (%)	50	60	70
	Solution III concentration (%)	40	60	80

Table 2. Experimental design and data for the response surface analysis

Run No.	Treatment variables			Solution I			Solution II			Solution III		
	X_1 (t) °C	X_2 (τ) hour	X_3(%)	Y_1 (WL)	Y_2 (SG)	Y_3 (DEI)	Y_1 (WL)	Y_2 (SG)	Y_3 (DEI)	Y_1 (WL)	Y_2 (SG)	Y_3 (DEI)
1	-1	-1	-1	0.214	0.049	4.367	0.213	0.033	6.389	0.204	0.021	9.716
2	-1	0	-1	0.335	0.093	3.602	0.336	0.049	6.854	0.245	0.025	9.803
3	-1	+1	-1	0.412	0.093	4.430	0.553	0.068	8.132	0.351	0.040	8.784
4	-1	-1	0	0.331	0.080	4.137	0.307	0.047	6.531	0.234	0.024	9.749
5	-1	0	0	0.406	0.113	3.593	0.470	0.065	7.238	0.280	0.029	9.657
6	-1	+1	0	0.498	0.108	4.611	0.676	0.074	9.131	0.397	0.041	9.683
7	-1	-1	+1	0.455	0.102	4.4661	0.519	0.072	7.213	0.313	0.032	9.784
8	-1	0	+1	0.490	0.092	5.326	0.689	0.075	9.185	0.451	0.044	10.252
9	-1	+1	+1	0.524	0.114	4.596	0.773	0.080	9.666	0.626	0.057	10.985
10	0	-1	-1	0.403	0.111	3.631	0.365	0.050	7.299	0.203	0.022	9.227
11	0	0	-1	0.443	0.097	4.567	0.461	0.066	6.987	0.281	0.030	9.367
12	0	+1	-1	0.601	0.100	6.010	0.555	0.074	7.501	0.398	0.039	10.215
13	0	-1	0	0.653	0.098	6.665	0.391	0.057	6.859	0.252	0.028	8.990
14	0	0	0	0.681	0.100	6.810	0.505	0.070	7.215	0.392	0.043	9.110
15	0	+1	0	1.098	0.134	8.191	0.633	0.079	8.009	0.415	0.045	9.213
16	0	-1	+1	0.903	0.124	7.286	0.529	0.073	7.252	0.313	0.032	9.780
17	0	0	+1	0.957	0.110	8.704	0.601	0.077	7.807	0.521	0.049	10.633
18	0	+1	+1	1.019	0.109	9.351	0.749	0.090	8.325	0.615	0.056	10.982
19	+1	-1	-1	0.978	0.099	9.875	0.378	0.060	6.306	0.291	0.030	9.707
20	+1	0	-1	1.005	0.099	10.151	0.461	0.066	6.982	0.394	0.039	10.101
21	+1	+1	-1	1.313	0.121	10.853	0.564	0.077	7.329	0.440	0.043	10.235
22	+1	-1	0	1.246	0.112	11.125	0.584	0.065	8.992	0.354	0.032	11.052
23	+1	0	0	1.310	0.119	11.005	0.717	0.077	9.318	0.632	0.054	11.712
24	+1	+1	0	1.639	0.144	11.382	0.787	0.085	9.258	0.760	0.059	12.884
25	+1	-1	+1	1.325	0.121	10.951	0.722	0.070	10.320	0.508	0.039	13.015
26	+1	0	+1	1.483	0.133	11.155	1.028	0.087	11.815	0.825	0.059	13.990
27	+1	+1	+1	1.852	0.153	12.106	1.201	0.100	12.010	0.924	0.065	14.212

RESULTS AND DISCUSSION

This study was conducted to optimize osmotic dehydration conditions for sliced cabbage leaves, and to investigate possibility of improving the nutritive profile of cabbage. Experimental design and data are shown in Table 2 Table 3 shows the regression coefficients for the response SOP models of WL (Y1), SG (Y2) and DEI (Y3) used by eq. (1). These regression coefficients can be used for predicting the values at optimum conditions.

Table 3. Regression coefficients of the SOP model for the three responses

	Solution I			Solution II			Solution III		
	Y_1	Y_2	Y_3	Y_1	Y_2	Y_3	Y_1	Y_2	Y_3
b_0	-0.974089 ns	-0.125472 ns	-4.34904 ns	1.547235 ns	-0.016474*	19.1062 ns	0.782017*	0.014212*	20.24905*
b_1	-0.038943*	0.000881 ns	-0.09588 ns	-0.038647*	0.001631*	-0.53231*	-0.029470*	-0.000490*	-0.45102
b_2	-0.111528 ns	0.005222 ns	-0.25276 ns	0.022042 ns	0.011931*	0.17132 ns	-0.001722 ns	0.004653*	-0.44519 ns
b_3	0.058171 ns	0.006456 ns	0.26677 ns	-0.036854 ns	-0.000218*	-0.24122 ns	-0.010136 ns	-0.000001*	-0.16676*
b_{12}	0.000568*	-0.000005 ns	0.00378*	0.000346*	-0.000005*	0.00448*	0.000358*	0.000011*	0.00501*
b_{13}	0.017278 ns	0.000833 ns	0.05843 ns	-0.000514 ns	-0.000139*	-0.00389 ns	-0.006167 ns	-0.000542*	-0.01440 ns
b_{11}	-0.000562 ns	-0.000053 ns	-0.00201 ns	0.000309 ns	0.000016*	0.00126 ns	0.000065 ns	0.000002*	0.00093 ns
b_{22}	0.002281*	0.000006 ns	0.00479 ns	-0.000264 ns	-0.000008*	-0.01060 ns	0.000967 ns	0.000014*	0.00932 ns
b_{33}	0.000476*	0.000008 ns	0.00075 ns	0.000372*	-0.000013*	0.00491*	0.000151*	0.000001*	0.00235*
b_{23}	-0.000079 ns	-0.000108 ns	-0.00029 ns	0.000988 ns	-0.000088*	0.00937 ns	0.001125*	0.000054*	0.00628 ns

*Significant at 95% confidence level
nsNot significant

Figure 1 shows amounts of minerals in the raw cabbage and after the osmotic dehydration (OD) in three hypertonic solutions.

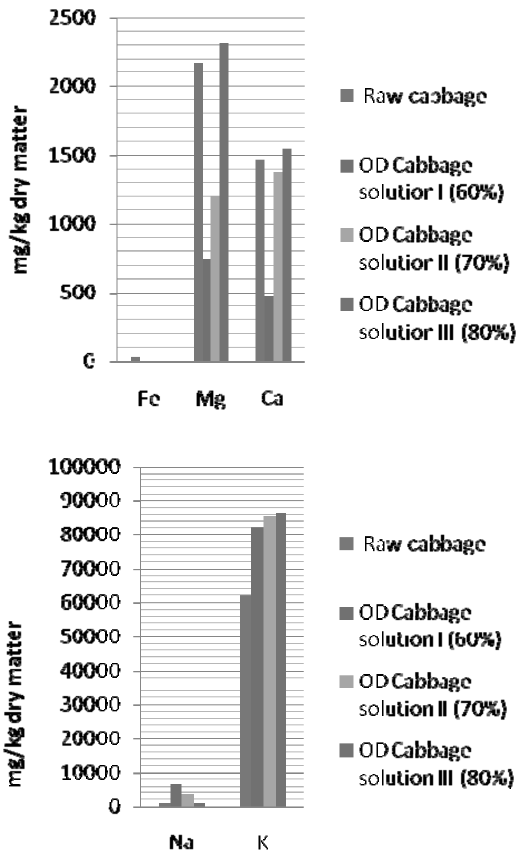

Fig. 1. Minerals content in raw and osmotically dehydrated cabbage in solution I, II and III with maximum concentration

Iron was detected only in raw cabbage in the small quantities, about 30 mg/kg dry matter. In cabbage osmotically dehydrated in Solution III (pure sugar beet molasses) content of magnesium and calcium was increased for about 6 % in comparison with raw cabbage. Sodium content of raw cabbage is not changed after osmotic dehydration in solution III. Sodium content was tripled increased in cabbage after OD in solution II and six fold increased after OD in solution I, as expected because of added amounts of NaCl in these hypertonic solutions. Potassium content in osmotically dehydrated cabbage in comparison with raw cabbage was increased for 32%, 38 and 40% after dehydration in solution I, II and III, respectively.

CONCLUSION

Cabbage is worldwide grown and used vegetable which has amounts of bioactive compounds, vitamins, and micro and macro elements. Osmotic dehydration is way to significantly improve nutritive profile and shelf-life of cabbage, especially dehydration with sugar beet molasses as hypertonic solution (Solution III). After cabbage dehydration in solutions I and II sodium content was multiple increased, and potassium contents in the cabbage were increased for 32%, 38% and 40 % after dehydration in solution I, II and III, respectively. Besides sodium and potassium, there was slightly increase in magnesium and calcium content in cabbage dehydrated in sugar beet molasses (solution III). Optimization of osmotic dehydration process was performed using RSM method, and regression factors which are determined can be used to setting the model to fit the experiment results of the process.

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