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The possibility to increase antioxidant activity of celery root during osmotic treatment

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Abstract: Osmotic treatment of celery root was studied in two osmotic solutions (sugar beet molasses and ternary solution of water, sucrose and salt), at three temperatures (20, 35 and 50°C), and three different immersion periods (1, 3 and 5 h), at atmospheric pressure. The aim was to examine the influence of type of used hypertonic agent, temperature and immersion time on the water loss, solid gain, water activity, dry matter content, antioxidant activity (expressed by DPPH) and color attributes (described by CIEL Lab coordinates L^*, a^* and b^*). During the experiments antioxidant activity of celery root was increased in sugar beet molasses, while DPPH value tended to decrease in ternary solution. For PCA modelling, experimental data of osmotic dehydration have been used. The standard scores analysis revealed that optimum process parameters were gained for the immersion time of 5 h and temperature of 35°C.

Keywords: antioxidant capacity; celery root; osmotic treatment; sugar beet molasses; optimization.

INTRODUCTION

From old times, celery (*Apium graveolens L.*) has been known as a special medicinal herb or spice, due to the presence of many healthful and aromatic substances [1,2]. Celery is a source of digestible carbohydrates, proteins, and high amount of dietary fibers, proven rich in bioactive compounds such as vitamins, free amino acids, minerals [3,4]. The main bioactive components in celery, responsible for its healing properties are flavonoids (mostly apiin and apigenin),

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essential oils (α-limonene and selinene, butylphalide, celerin, apiol, myristicin), organic acids (chlorogenic acid, caffeic acid), bergapten, niacin, inositol, etc.[5].

Presently, there is an increasing interest in phenolic compounds derived from celery, mainly phenolic acids and flavonoids, because of their strong antioxidant properties[6]. Phenolic substances have been shown to be the most responsible for the antioxidant activity of celery plants, thereby for their physiological functionalities, such as lowering cholesterol levels, anti-inflammatory, antimicrobial and anticancer activity[7]. Current studies have confirmed that celery can lower blood pressure, regulate heart function, as well as the blood glucose level by stimulating the pancreas to insulin secretion, so that it can be used to reduce complications caused by diabetes[8]. Antioxidants in celery, also possess the potential to retard lipid oxidation, which is one of the major causes of chemical spoilage of foods and inhibit various types of oxidizing enzymes. Therefore, celery can be added to foods as a preservative, to improve nutritional quality and food safety, then to reduce the need for synthetic food antioxidants [9,10].

Since celery is highly perishable, with high moisture content, several drying treatments can be used to extend its shelf life. For certain fruit and vegetable products, traditional drying process may not be satisfactory, due to texture degradation, color alteration and nutritional loss[11,12]. The application of osmotic treatment (OT) at a mild temperature in food preservation has been widely applied, for it represents many advantages as compared to the traditional drying treatments [13]. Foodstuff is not exposed to high temperatures, the changes in the initial sensory characteristic is minimal, while the nutritional value and the functional properties of the product are kept on the same level or even improved. Furthermore, OT is environmentally acceptable and energy efficient process due to the low temperature and energy requirements and lower waste material [14,15]. OT involves soaking a food, mostly fruit and vegetable, in hypertonic solution to reduce the moisture content of food, in minimal processing under ambient or modified environment conditions. The driving force for water removal is the concentration gradient between the surrounding hypertonic solution and the immersed plant material [16,17]. The complex cellular structure of plant tissue acts as a semi-permeable membrane, which allows two main counter-current flows: water outflow from the plant tissue into the osmotic solution and the simultaneous migration of solids from solution to the tissue [18]. Leaching out of the tissue`s own solutes takes place in lesser extent, but it can affect on the quality of the final product [19].

The hypertonic solution choice depends on the expected water loss (WL) and solid gain (SG), and the sensory properties of the final food product [20]. Concentrated sucrose solution, sodium chloride solutions and their combinations are usually used as hypertonic solutions [21, 22] .

In recent research was shown that sugar beet molasses is a highly effective osmotic medium for treatment of fruits, vegetables and meat. High dry matter content and a high water loss, a specific nutrient composition and nutritive quality of osmodehydrated product, low costs and energy requirements are a few of the main reasons why sugar beet molasses is a useful osmotic solution.[17, 23].

Molasses, the thick, dark syrup obtained as a byproduct from the processing of sugar beet into sucrose, consists of fermentable carbohydrates (sucrose, glucose, fructose) and several non-sugar organic materials (betaine and other amino acids; minerals, mainly potassium; vitamins, especially of the B-group, etc.) [24, 25]. Various studies evidenced that molasses is a rich source of phenolic compounds having possible roles in the prevention of several chronic diseases involving oxidative stress. Maillard browning carbohydrate–amino acid condensation products, formed during sugar processing, are also in very high concentration in molasses in a range from low organic compounds to complex aromatic polymers, and they have been reported to have antioxidant activities. Therefore, molasses has health benefits in the human diet, beyond its special taste and flavor, due to it being rich in minerals and antioxidants [26, 27].

The color of any food product, depending upon the nature and content of pigment and colored substances present in food material, may be represented in terms of the CIELAB coordinates L^*, a*, b* system. The L*, a* and b* values explain a three-dimensional color space. The L* value is the vertical axis and defines the lightness, and a* and b* values are perpendicular horizontal axes and define red-to-green and blue-to-yellow, respectively [18, 28].

The objective of presented work was to investigate the effects of osmotic solution type, processing time and temperature, on the mass transfer phenomena during osmotic treatment of celery root in sugar beet molasses and aqueous ternary solution. The aim was to determine: water loss (WL), solid gain (SG), water activity (a_w), dry matter (DM), antioxidant activity (expressed by DPPH) and color attributes (described by CIELAB coordinates L^*, a^* and b^*) as a function of the process variables and to find the optimum osmotic treatment conditions.

EXPERIMENTAL

Osmotic treatment

Sugar beet molasses, obtained from the sugar factory Crvenka, Serbia with initial dry matter content of 85.04 %, was diluted to concentrations of 80 % (this solution was marked as S_1). The aqueous ternary osmotic solution was made from sucrose in the quantity of 1.200 g/kg water, NaCl, in the quantity of 350 g/kg water and distilled water. This solution (S_2) was diluted with distilled water to concentrations of 60 %.

Celery root (*Apium graveolens L.* var. *rapaceum*, Alabaster variety) was purchased on a local market in Novi Sad, Serbia, shortly prior to the experiment. Prior the acquisition, the samples were stored in the sales gondola at room temperature. Celery root samples were cut into cubes (1x1x1 cm) using kitchen knife. After preparation samples were measured and

immersed in hypertonic solutions. Sample to solution ratio was 1:5 which can be considered high enough to neglect the influence of solution concentration changes during the process.

After each sampling time (1, 3 and 5 hours) celery root samples were taken out from solutions (S_1 and S_2), lightly washed with distilled water, gently blotted with paper to remove excessive water from the surface and weighted. The dry matter content of the fresh and treated samples was determined by drying the material at 105 °C for 24 hours in a heat chamber (Instrumentaria Sutjeska, Croatia). The a_w value of the osmotically treated samples was measured using a water activity measurement device (TESTO 650, Testo SE & Co. KGaA, Lenzkirch, Germany) with an accuracy of ±0.001 at 25ºC.

Preparation of celery root extracts

To prepare the extracts for antioxidant analysis, fresh and osmotically dehydrated celery root samples dried at 50ºC in a heat chamber (Instrumentaria Sutjeska, Croatia) until constant weight. Dried samples were finally grounded into a powder, using Universal laboratory mill type WZ-1 (Spolem, ZBPP, Bydgoszcz, Poland). 2g of powder for each sample, were extracted with 200 ml of boiled water. After extraction, at room temperature for 10 min, obtained aqueous extracts were filtered using Whatmann No. 1 filter paper. The extracts were stored in a refrigerator (4 ºC) until further use.

Determination of free radical scavenging ability by the use of DPPH radical

The antioxidant capacity of celery root, during osmotic treatment, was determined using the DPPH radical scavenging assay[29], with some modifications. Briefly, 100 µL of the extract was added to 1.9 mL of 0.094 mM 2.2-diphenyl-1-picrylhydrazyl (DPPH) in methanol up to completing 2 mL, which is afterward vortexed vigorously. The free radical scavenging capacity of the sample was evaluated by measuring the absorbance after 30 min at 517 nm, using UV/VIS Evolution 300 (Thermo Fisher Scientific, Waltham, MA, USA). Antioxidant capacity was expressed as mmol/L Trolox equivalents, using the calibration curve of Trolox (0–1000 µM), a water soluble vitamin E analogue. All determinations were performed in triplicate.

Investigation of color attributes

Color images of experimental results were captured by a Canon PowerShot A550 (Canon Europe Ltd, Uxbridge, Middlesex, United Kingdom), which is a common digital camera for home use. All the acquired images were 24 bit RGB (16.8 millions of colors) with a 1024 x 768 spatial resolution. The macro function of the digital camera has been used, to cover a scenic area of approximately Ø60 mm. Samples were placed on a white paper napkin set on a flat white painted surface, inside the closed chamber, 15 cm below the digital camera. Paper napkins were used in order to avoid undesired reflection effects from chamber's walls. With this setup, it was possible to capture images with negligible shadows and without specular reflections. The acquired images were transferred to a personal computer in the form of jpeg compressed image files. The images were imported to an originally developed computer program used for this investigation, and each image color data were transformed to the three-dimensional array of the R (red), G (green) and B (blue) values, ranging from 0-255. The frequency of color indexes was recorded, and the maximum values were observed. Afterwards, these data were transformed to CIELAB color coordinates, using a Java algorithm for RGB to XYZ and XYZ to Lab color coordinates[30].

Statistical analysis

The experimental results were expressed by means and standard deviation (SD) for each treatment. Collected data were subjected to ANOVA to explore the effects of process variables. Furthermore, pattern recognition techniques, including PCA and CA were applied successfully to classify and discriminate the different samples. The evaluation of RSM, ANOVA, PCA and CA of the obtained results was performed using Statistica software version 12 (StatSoft Inc. 2012, USA)®,[31].

The experimental data used for the analysis were derived using the Box and Behnken's fractional factorial (3 level-2 parameter) design, 2 blocks, according to RSM. Independent experimental factors for each of the five mixtures are shown in Table 1.

TABLE I. Independent experimental factors and their levels

Experimental factor	Symbol	Coded factor's level		
		-1 (low)	0 (center)	+1 (high)
Time, h	X_1	1	3	5
Temperature, °C	X_2	20	35	50

The RSM equations describe the effects of the test variables on the observed responses, determine test variable interrelationships and represent the combined effect of all test variables in the observed responses.

The following second order polynomial (SOP) model was fitted to the experimental data. Eight models of the following form were developed to relate eight responses (Y) and two process variables (X), for each of the different osmotic treatments:

$$Y_k^l = \beta_{k0}^l + \sum_{i=1}^{2} \beta_{ki}^l X_i + \sum_{i=1}^{2} \beta_{kii}^l X_i^2 + \beta_{k12}^l X_1 X_2 \quad k=1\text{-}8,\ l=1\text{-}2 \tag{1}$$

where: β_{k0}^l, β_{ki}^l, β_{kii}^l, β_{k12}^l are constant regression coefficients; Y_k^l, either: WL, SG, a_w, DM, DPPH, L^*, a^* and b^*, while X_1 is time, and X_2 is temperature. A model describing osmotic treatment in S_1 solution is marked with l=1, while treatment in S_2 is marked with l=2.

Determination of normalized standard scores

In order to get a more complex observation of the ranking of osmotic treated celery root quality, standard scores (SS) are evaluated using a chemometric approach by integrating the measured values generated from different measuring methods.

Min-max normalization is one of the most widely used technique to compare various characteristics of complex samples determined using multiple measurements, where samples are ranked based on the ratio of raw data and extreme values of the measurement used [27]. The evaluation is performed, according to following equations:

$$\bar{x}_i = 1 - \frac{\max\limits_i x_i - x_i}{\max\limits_i x_i - \min\limits_i x_i}, \quad \forall i \text{ in case of the higher, the better" criteria, or}$$

$$\bar{x}_i = \frac{\max\limits_i x_i - x_i}{\max\limits_i x_i - \min\limits_i x_i}, \quad \forall i \text{ , in case of "the lower, the better" criteria.}$$

where x_i represents the raw data.

Normalized scores of the most of properties are evaluated using above written equations, except for L^*, a^* and b^* parameters, which are evaluated according to initial values, as follows: $\bar{x}_i = \min_i (x_i - x_0), \quad \forall i$.

The sum of normalized scores of a sample of different measurements when averaged give a single unitless value termed as SS_i, which is a specific combination of data from different measuring methods with no unit limitation. This approach also enables the ease of employing some other sets of osmotically treated celery root samples to this elaboration in the future comparisons. Standard scores are calculated and the results have been written to Table II.

TABLE II. Experimental design for kinetics investigation, antioxidant activity and color attributes during osmotic treatment of celery root and standard score analysis

Solution	Sugar beet molasses solution									Ternary solution								
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Time	1	1	1	3	3	3	5	5	5	1	1	1	3	3	3	5	5	5
Temp.	20	35	50	20	35	50	20	35	50	20	35	50	20	35	50	20	35	50
SS	0.61	0.65	0.60	0.53	0.57	0.56	0.64	0.77	0.74	0.42	0.51	0.49	0.42	0.41	0.40	0.45	0.47	0.45

RESULTS AND DISCUSSION

All analytical measurements were carried out in accordance with AOAC[32]. All experiments were repeated three times, according to experimental plan described in Table 2. The obtained results are presented in Fig. 1. According to the results presented in Fig. 1, better solution for OT, with respect to obtaining higher values of WL and DM, and lower values of SG and a_w, was sugar beet molasses.

Maximum values of WL (0.78 g/g i.s.) and DM (63.02%) were achieved after an immersion time of 5 h and temperature of 50°C. Also, superiority of sugar beet molasses as an osmotic solution was confirmed from the aspect of retaining and even increasing antioxidant activity in treated celery. OT in molasses has provoked increase in DPPH values in all samples of celery root from initially 0.41 to 0.45 mM TE/L. DPPH values for all samples treated in ternary solution were decreased proportional to the increase of temperature and immersion time (from initial 0.41 to 0.26 mM TE/L). In comparison with molasses, use of the ternary solution in the OT of celery root, can be considered less convenient, if comparison is based on antioxidant activity, as a general indicator of potential health effect. Enhancement in DPPH values in celery root treated in molasses confirms the fact that molasses is a rich source of antioxidants. Probably, during OT has occurred penetration of some phenolic compounds from molasses into the tissue of celery. Also, the results showed reduction in L^* values and increase in a^* values for samples treated in molasses which indicate a darkening, because of the diffusion of colored substances from molasses into dehydrated samples during the process. The penetration of color

substances from molasses was in proportion to the temperature increasing. It was found that the color CIELAB parameters significantly correlated with DPPH values. It seems that there is a relationship between the increase of color parameters and antioxidant activity in samples treated in molasses, and this is probably due to the fact that some of the pigments in molasses are known for their antioxidant properties.

Fig. 1. Experimental results of kinetics parameters, antioxidant activity and color attributes during osmotic treatment of celery root; WL - water loss, SG - solid gain, a_w - water activity, DM - dry matter content, L*, a*, b* - colour cordinates. [a-q] Different letters written in superscript within the same column in the table show significantly different means of observed data (at $p<0.05$ level). n=3.

Principal component analysis (PCA)

Principal component analysis (PCA) is a mathematical procedure used as a central tool in exploratory data analysis[33]. It is a multivariate technique in which the data are transformed into orthogonal components that are linear combinations of the original variables. PCA is done by Eigenvalue decomposition of a data correlation matrix[34]. This transformation is defined in such a way that the first component has the largest possible variance. This analysis is used to achieve maximum separation among clusters of parameters[27]. This approach, evidencing spatial relationship between processing parameters, enabled a differentiation between the different samples in both solutions (S_1 and S_2).

The PCA, applied to the given data set, Fig. 1, has shown a differentiation between the samples according to the observed process parameters and is used as a tool in exploratory data analysis to characterize and differentiate neural network input parameters. As can be seen, there is a neat separation of the observed samples, according to used assays. Quality results show that the first two principal components, accounting for 83.14% of the total variability for solution S_1 and S_2, can be considered sufficient for data representation. Considering the map of the PCA performed on the data, SG (which contributed 20.4% of total variance, based on correlations), DM (12.1%) and L^* (8.8%) exhibited positive scores according to first principal component, whereas a_w (16.6%) and a^* (11.8%) showed a negative score values according to first principal component (Figure 3). WL (which contributed 23.5% of total variance, based on correlations) and DM (16.7%) showed the positive influence towards the second principal component, while negative impact was observed by color coordinates L^* (23.1%) and b^* (18.7%).

PCA graphics showed quite good discrimination between solutions S_1 and S_2 solutions. The influence of processing parameters can be observed in Fig. 2, with samples processed with lower immersing time and temperature parameters located at the bottom left side of the graphic. Samples treated in sugar beet molasses solution are located at the upper left side of the graphic, showing increased DPPH and a^* values, while samples treated with ternary solution showed increased color attributes L^* and b^*. Also, it is evident that SG is augmented for samples treated in ternary solution, especially for samples with increased immersing time and temperature.

Cluster analysis (CA)

Fig. 3 show dendrogram of CA for the osmotic treatment of celery root in sugar beet molasses solution and ternary solution. The complete linkage algorithm and City block (Manhattan) distances were used as the measure of proximity among the samples. City block distances (shown on ordinate axis) are measured as the average difference across the dimensions of the observed

samples. This distance measure yields results similar to the Euclidean distance, but in this measuring technique, the effect of single large differences (outliers) is dampened (since they are not squared). The dendrogram presented in Fig. 3 is based on experimental data. The resulting dendrogram showed three main clusters; the first cluster contained samples 3, 5, 6, 8 and 9 (samples treated with S_1 solution, with increased DM), the second cluster included 1, 2, 4 and 7, while the third cluster contained samples treated with S_2 solution. The linkage distance (shown on the ordinate axis) between the main clusters was nearly 120.

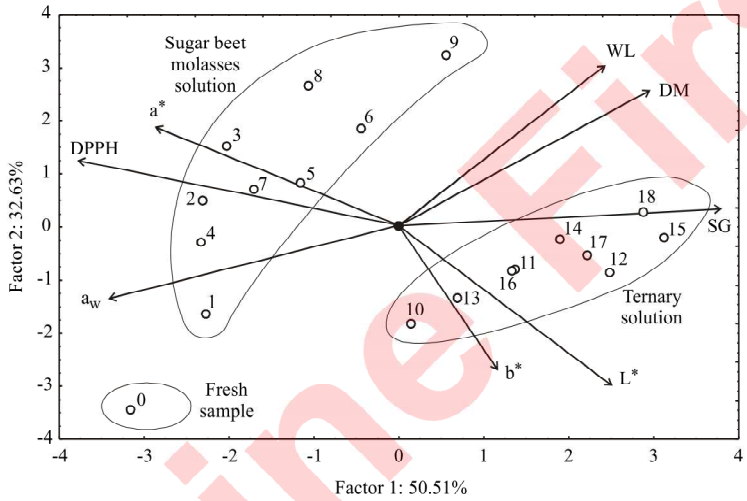

Fig. 2. Biplot graphic of celery root osmotic treatment in sugar beet molasses solution and ternary solution.

Response surface methodology (RSM)

The ANOVA calculation showed the effects of the independent variables on the responses (Table III). The SOP models for all variables were found to be statistically significant and the response surfaces were fitted to these models.

Linear terms of immersion time and process temperature were the most influential variables for WL and SG calculation (statistically significant, at $p<0.01$ level). The linear term of solution type in the SOP model was the most influential factor for SG calculation, as well as for the color properties (L^*, a^* and b^*). The linear term of solution type was very important for a_w and DPPH calculation, while the linear term of process temperature in the SOP model for a_w exerted the highest impact.

The residual variance is shown in Table III, where the lack of fit represents other contributions of the higher order terms. A significant lack of fit generally shows that the model failed to represent the data in the experimental domain at which points were not included in the regression [35]. All SOP models had an

insignificant lack of fit tests, which means that all the models represented the data satisfactorily.

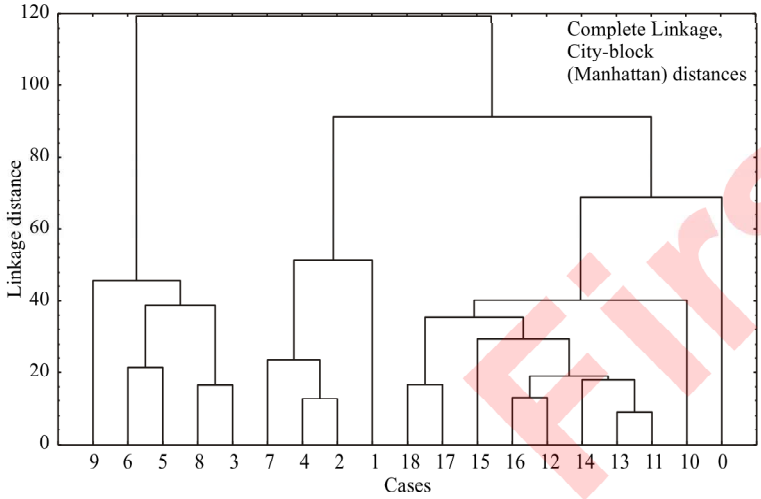

Fig. 3. Tree diagram for celery root osmotic treatment in sugar beet molasses solution and ternary solution.

TABLE III. The ANOVA calculation for celery root osmotic treatment in sugar beet molasses solution and ternary solution; $^{+}$significant at $p < 0.01$ level, *significant at $p < 0.05$ level, **significant at $p < 0.10$ level; unmarked terms were not statistically significant; df – degrees of freedom; i. s. – initial sample

Parameter	df	WL g/g i.s.	SG g/g i.s.	a_w	DM %	DPPH mM TE/L	L^*	a^*	b^*
Sol.	1	0.0004	0.0094^{+}	0.0054^{+}	100.3^{+}	0.0679^{+}	5061.7^{+}	1183.9^{+}	317.2^{+}
T	1	0.0894^{+}	0.0001	0.0008	985.8^{+}	0.0035^{+}	91.7^{**}	3.7	74.9^{**}
t^2	1	0.0004	0.0012^{+}	0.0008	15.8	0.0000	20.4	69.2^{**}	50.6
Temp	1	0.1069^{+}	0.0021^{+}	0.0086^{+}	800.4^{+}	0.0038^{+}	67.0	11.2	247.1^{+}
$Temp^2$	1	0.0048^{*}	0.0001	0.0005	1.1	0.0000	15.7	20.9	12.2
Sol. × t	1	0.0097^{+}	0.0000	0.0012^{**}	77.0^{*}	0.0022^{+}	4.5	60.4^{**}	56.7
Sol. × Temp	1	0.0020^{**}	0.0001	0.0000	7.7	0.0022^{*}	249.4^{+}	32.8	211.1^{*}
t × Temp	1	0.0012	0.0001	0.0000	50.3^{*}	0.0000	13.5	12.4	46.6
Error	9	0.0042	0.0007	0.0025	73.7	0.0002	189.8	150.2	181.5
r^2		0.981	0.953	0.843	0.965	0.998	0.967	0.903	0.848

The coefficient of determination, r^2, is defined as the ratio of the explained variation to the total variation and is explained by its magnitude. It is also the proportion of the variability in the response variable, which is accounted for by the regression analysis. A high r^2 is indicative that the variation was accounted and that the data fitted satisfactorily to the proposed model.

The r^2 values for WL (0.981), SG (0.953), a_w (0.843), DM (0.965), DPPH (0.998), L^* (0.967), a^* (0.903) and b^* (0.848) were very good and show the good fit of the model to experimental results.

Standard score analysis

SS as the mean value of standard score transformed from the initial data generated with different methods (assays) for each item has been calculated according the following equation:

$$SS = 0.2 \cdot \left(\overline{WL} + \overline{SG} + \overline{a_W} + \overline{DPPH} + \frac{\overline{L^*} + \overline{a^*} + \overline{b^*}}{3} \right) \quad (2)$$

The maximum of SS represents the optimal parameters for processing parameters, and also the optimum for response variables. The graphs of the dependent variables with significant parameters were obtained using an objective function to determine optimum production conditions, plotted on optimization graph. If the value of membership trapezoidal function is close to 1, it shows the tendency of tested processing parameters of being optimal.

In this article, standard scores are calculated for various properties and obtained data are presented in Table 2. SS above 0.60 stands for the high standard. Samples with a SS value below 0.60 are attributed with poorer characteristics. Using the standard score analysis and revealing the SS of different samples and different processing parameters can be referenced for developing strategies for improving final product characteristics.

Standard scores analysis showed that the optimum characteristics of osmotically dehydrated celery root has been experienced at a temperature of 35°C, during 5 hours of treatment, with sugar beet molasses as osmotic solution (0.77), while the SS score for osmotic treated celery root in ternary solution was quite lower (0.47). Generally, sugar beet molasses was a much better solution for osmotic treatment of celery root, according to SS results and DPPH value.

CONCLUSIONS

On the basis of presented results it can be concluded that both solutions are adequate for effective dehydration, considering the satisfying losses of water and decrease of a_w values during all experiments. Since the quality of osmotically treated celery root is influenced by many parameters which are altered as the technological treatments change, standard score analysis has been applied for evaluating the quality, in conjunction with PCA and CA. These analyses compiled various properties of the product. Similar results have been obtained with these analyses, pointing out that the osmodehydrated celery root samples treated in sugar beet molasses, processed at optimal processing parameters

(temperature 35°C, during 5 hours), gained the best score (0.77 of 1.00). Despite the fact that molasses proved to be superior as an osmotic solution, the most important finding in this study presents its effect on increasing initial antioxidant activity of celery root. This finding increases the possibility of embedding the molasses as a natural ingredient in various food formulations, in spite of its unpleasant sensory characteristics. In addition, the use of sugar beet molasses as osmotic agent is economy and environmentally reasonable, because it is a side product of the sugar industry. It can be concluded that celery root osmotically treated in molasses, with extended shelf-life and improved antioxidant properties is suitable as food additive or functional food ingredient. As an addition to soups, yogurt, mayonnaise, sauces and other complex systems of food, it has a potential to contribute to the overall improvement of their oxidative stability, nutritional value and taste. Likewise, its use as natural preservative can reduce the need for applying artificial preservatives, additives and antioxidants in food.

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ИЗВОД

МОГУЋНОСТ ДА СЕ ОСМОТСКИМ ТРЕТМАНОМ ПОВЕЋА АНТИОКСИДАТИВНА АКТИВНОСТ КОРЕНА ЦЕЛЕРА

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У овом раду је испитиван осмотски третман корена целера у два осмотска раствора (раствору меласе шећерне репе – S1 и тројном воденом раствору – S2), на три температуре (20, 35 и 50 °C) и три различита периода потапања (1, 3 и 5 h), при атмосферском притиску. Циљ рада је био да се покаже утицај врсте хипертоничног раствора, температуре и периода потапања на губитак воде, прираштај суве материје, активност воде (a_w), садржај суве материје, антиоксидативну активност (изражену преко DPPH) и боју корена целера (описану колорним координатама CIELAB, L^*, a^* и b^*). Током експеримента, антиоксидативна активност корена целера се повећавала у раствору S1, али је вредност DPPH имала тенденцију смањивања у раствору S2. Анализом стандардне оцене показано је да су оптимални параметри процеса постигнути при времену потапања од 5 h и температури од 35 °C.

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