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**SHELF LIFE STABILITY OF OSMODEHYDRATED**

**WHITE CABBAGE – PCA ANALYSIS**

**ROK UPOTREBE OSMOTSKI SUŠENOG**

**KUPUSA – PCA ANALIZA**

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***ABSTRACT***

*The aim of the present work is to determine the shelf life of osmodehydrated white cabbage in three different osmotic solutions. During 90 days of storage, chemical and color parameters were analysed together with the sensory acceptance and microbiological profile of the osmotic treated (OT) cabbage. Hybrid “Bravo“ was considered within this research because of its high yield and wide cultivation in the Province of Vojvodina. Solutions of sucrose and chloride were applied so as sugar beet molasses in OT. OT cabbage was packed in MAP with variation in a gas mixture of 40:60/ CO2:N2 (atmosphere 1) and 80:20/CO2:N2 (atmosphere 2). The shelf-life evaluation had shown good sensorial acceptance and satisfying microbiological quality. The obtained principal component analysis (PCA) was able to present the experimental results. The PCA analysis is easy to implement and could be effectively used for predictive optimization of the osmotic treatment.*

***Keywords:*** *Cabbage, Osmotic treatment, Shelf-life, PCA, MAP.*

***REZIME***

*Cilj ovog rada je da se analizira održivost osmotski dehidriranog belog kupusa. Hibrid “Bravo” je analiziran i podvrgnut osmotskom tretmanu u tri različita osmotska rastvora. Rastvor S1 je zasićen rastvor sharoze i natrijum hlorida u vodi, rastvor S2 je mešavina rastvora S1 i melase šećerne repe u odnosu 1:1 i rastvor S3 je čista melasa sa sadržajem suve materije od 84,05 %. Nakon osmotskog tretmana kupus je pakovan u poliamid/polietilen kese na laboratorijskoj pakerici sa vakuum zaptivanjem uz prethodno uvođenje modifikovane atmosfere u mešavini gasova od 40:60/ CO2:N2 (atmosfera 1) i 80:20/CO2:N2 (atmosfera 2). Tokom 90 dana skladištenja praćeni su mikrobiološki i hemijski parametri, instrumentalno merenje boje i senzorska svojstva. Kod kupusa dehidriranog u sva tri rastvora zabeležen je pad sadržaja ukupnih kiselina i posledično rast pH vrednosti tokom skladištnja, naročito kod rastvora S3. Pakovanje u MAP bez prisutva vazduha dovelo je do pada ukupnog broja mikroorganizama dok je rast kvasaca i plesni u potpunosti inhibiran. Tokom skladištenja dolazi do sukcesivnog smanjenja sadržaja L-askorbinske kiseline u kupusu i retencija je najveća nakon osmotskog rastvora S2 i iznosi 15,25 % nakon skladištenja od 90 dana. Senzorska analiza je pokazala zadovoljavajući kvalitet osmotski dehidriranog kupusa nakon 90 dana skladištenja. PCA analiza je uspešno opisala eksperimentalne rezultate. PCA analiza se može primenjivati u procesu optimizacije osmotskog tretmana u cilju dobijanja željenog kvaliteta finalnog proizvoda i efikasno koristiti u prediktivne svrhe.*

***Ključne reči:*** *Kupus, Osmotski tretman, Održivost, PCA, MAP.*

**INTRODUCTION**

Agricultural crops such as fruits, spices, vegetables are thermo-sensitive products with high nutritional and phytochemical properties (antioxidant, bioactive compounds, etc.) Fruits and vegetables contain high moisture content (80–95 %) which makes them very susceptible to microbial damage leading to shorter shelf-lives and high postharvest losses (*Osae et al., 2020*). Food technologists are still looking for methods of processing raw fruits and vegetables which will allow obtaining attractive foods fortified with components that are often lost during thermal and mechanical processing (*Ciurzyńska et al., 2016; Kowalska, 2005*). Non-thermal pretreatment techniques, such as osmotic treatment (OT), have been considered to be one of the most significant pretreatment technologies available for the preservation of fruits and vegetables (*Osae et al., 2019*). During OT browning reactions are minimized (*Bozkir et al., 2019*), while nutritional improvement and new sensorial characteristics have been previously reported (*Cvetković et al., 2019; Siriamornpun et al., 2015; Tolera and Abera, 2017*). The most frequently used osmotic solutions are sucrose and sodium chloride (*Lech et al., 2018*). Some investigations were conducted using sugar beet molasses as the osmotic solution for dehydration of plant origin food (*Knežević et al., 2019; Koprivica et al., 2014; Nićetin et al., 2017*) and animal origin food (*Ćurčić et al., 2015; Šuput et al., 2019*). The cabbage (*Brassica oleracea var. acephala*) is considered a “superfood” due to the rich content of calcium, folate, riboflavin, vitamins C, K and A (*Brito et al., 2020*). Consumption of cabbage in the Republic of Serbia is 20 kilograms per capita, which is significantly higher than the world average (*Vlahović, 2015*). Hybrid Bravo is widely harvested due to its high yield and uniform quality. Previous works reported that MAP significantly reduced the levels of total mesophilic microorganisms on cabbage (*Barbosa et al., 2016; Hyun et al., 2015*). Within this work white cabbage hybrid, Bravo was osmotically treated, packed in MAP and evaluated during 90 days of storage period.

**MATERIALS AND METHODS**

 Cabbage heads, hybrid “Bravo”, late fall variety, were harvested in northern Serbia (Province of Vojvodina) in the village Futog. Sugar beet molasses was obtained from the sugar factory Pećinci, Serbia. Overall dry matter content in sugar beet molasses was 85.04 %. Cabbage leaves were cut into square shapes with dimensions of approximately 1×1 cm. Solution S1 was a mixture of sucrose and NaCl in the relation of 1.200/350 g/l of distilled water. The second osmotic solution (S2) was a mixture of S1 and molasses in the same quantities with 70 % dry matter. Sugar beet molasses was used as a third osmotic solution (S3). The cabbage leaves were put in a glass jar with osmotic solutions with a material/solution ratio of 1:5 (w/w). The experiments were conducted at the temperature of 20 °C, under atmospheric pressure, for 5h. After OT in three different solutions, washing and draining, 50 g cabbage samples were packed using laboratory vacuum sealer (Audion Elektro, Swissvac) with teflonized heating areas in polyamide/polyethylene (PA/PE) bags of 14 × 20 cm size (0.08 cm thickness, <20 g/m2 (24h, 1 ATM) water vapour permeability, and <20 cm3/m2 (24h, 1 ATM) oxygen permeability). After vacuuming the content, the chosen gas mixture was inserted before bag heat sealing. The content of the gas mixture was 40:60/ CO2:N2 (atmosphere 1) and 80:20/CO2:N2 (atmosphere 2). Storage of packed samples was conducted in a refrigerator at 4-8 °C for 90 days for all samples. Colour was determined by a chromameter (Minolta Co., Type CR 400, Osaka, Japan) on the top surface of the samples. Because of the particle dispersion, colour quantifications were measured at five sections of the samples (at the centre and four corners) with a minimum of ten readings per sample, and the results were averaged. Colour characteristics were presented in the CIE L\*a\*b\* system.

The microbiological profile of osmodehydrated cabbage was examined by determining a total number of microorganisms (TN) (*ISO 4833, 1991*), yeasts and molds (*ISO 21527, 2008*). The pH of the cabbage was determined by a mobile pH meter (ExStickTM, Extech Instruments, USA). Acidity was determined by the standard method (*SRPS ISO 750, 2003*). The methodology of the sensory analysis was carried out in accordance with the Guidelines for the Assessment of Food Products by Methods of Scale (*ISO 4121, 2003*). For L-ascorbic acid (AA) HPLC determination was used as previously reported (*Cvetković et al., 2019*). The principal component analysis (PCA) has been applied effectively to classify and segregate the different samples. The statistical calculation was performed using StatSoft Statistical software v.10 (Stat soft Inc., Tulsa, OK, USA)

*Table 1. Experimental data for the shelf-life study of OT cabbage packaged in different MAP.*

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **No.** | **CO2****content****(%)** | **Days** | **Solution S1** |  | **Solution S2** |  | **Solution S3** |  |
| **Sample** | **AA** | **pH** | **AC** | **TN** | **YM** | **AA** | **pH** | **AC** | **TN** | **YM** | **AA** | **pH** | **AC** | **TN** | **YM** |
| 1 | / | 0 | 7.23 | 5.49 | 0.50 | 1800 | nd | 7.25 | 6.26 | 0.38 | 6400 | 300 | 7.65 | 6.80 | 0.40 | 2100 | 400 |
| 2 | 40 | 20 | 5.85 | 5.37 | 0.50 | 6000 | nd | 4.97 | 6.23 | 0.39 | 5800 | 100 | 6.04 | 6.42 | 0.50 | 600 | 100 |
| 3 | 40 | 40 | 4.46 | 5.45 | 0.48 | 200 | nd | 4.67 | 6.14 | 0.41 | 650 | nd | 4.89 | 6.53 | 0.43 | 750 | nd |
| 4 | 40 | 70 | 2.29 | 5.21 | 0.51 | 180 | nd | 2.88 | 6.0 | 0.41 | 680 | nd | 3.01 | 6.16 | 0.47 | 1100 | nd |
| 5 | 40 | 90 | nd | 5.51 | 0.43 | 460 | nd | 1.30 | 6.36 | 0.37 | 1500 | nd | 1.48 | 6.59 | 0.41 | 2100 | nd |
| 6 | 80 | 20 | 5.72 | 5.66 | 0.45 | 5600 | 100 | 5.68 | 6.31 | 0.34 | 7500 | 100 | 6.01 | 6.42 | 0.43 | 5600 | nd |
| 7 | 80 | 40 | 4.32 | 5.28 | 0.48 | 350 | nd | 4.29 | 6.20 | 0.36 | 650 | nd | 4.78 | 6.53 | 0.39 | 300 | nd |
| 8 | 80 | 70 | 2.93 | 5.28 | 0.46 | 400 | nd | 2.87 | 5.97 | 0.42 | 1000 | nd | 2.91 | 6.15 | 0.38 | 800 | nd |
| 9 | 80 | 90 | nd. | 5.57 | 0.41 | 500 | nd | 1.41 | 6.31 | 0.38 | 1000 | nd | 1.09 | 6.61 | 0.33 | 1200 | nd |

*AA- ascorbic acid (mg/100 g); AC-acidity (%); TN-total number of microorganisms (cfu/g); YM-yeasts and molds (cfu/g);*

*nd – not detected*

**RESULTS AND DISCUSSION**

Table 1 displays the studied quality attributes of OT cabbage dehydrated in three solutions packed in different MAP during 90 days of storage. In all measured samples, a slight decrease in total acidity content was detected during the storage. The lowest acidity content was observed in cabbage Bravo dehydrated in solution S2 after 90 days of storage. MAP slightly restrained the decrease in titratable acidity (TA) values compared to standard cold storage (*Sabır et al., 2011*). A detected decline in the acidity level can influence consumer’s acceptability and it is associated with quality loss during postharvest storage (*Guillén et al.,2006; Zapata et al., 2008***).**

Raw hybrid Bravo contains 8,89 mg/100g of L-ascorbic acid (AA). The results showed a significant decrease of L-ascorbic acid content during the storage (Table 1). In cabbage osmodehydrated in S1 L-ascorbic acid wasn’t determined after 90 days. In cabbage dehydrated in solution S2 and S3 AA retention at the end of the period was 15.45 % and 14.25 %, respectively. One of the possible reasons for L-ascorbic acid decrease is chemical degradation by oxidative reactions by enzyme activity (*Martínez-Romero et al., 2003; Patras et al., 2009; Phisut et al., 2013*). Another cause for poor L-ascorbic acid retention is the leaching of water-soluble compounds out from the cell tissues during cutting and osmotic dehydration (*Rincon and Kerr, 2010*). The microbiological profile of osmodehydrated cabbage samples is expressed by a total number of microorganisms and yeasts and molds as shown in Table 1. At the beginning of the storage period in the MAP, a total number (TN) of microorganisms decreased probably due to the inaccessibility of oxygen (*Noseda et al., 2012*). At the later storage period re-growth of microorganisms was observed, probably anaerobic microorganisms. The growth of yeasts and molds was inhibited. The PCA analysis was applied and the results are presented in Fig. 1 The first two PCs explained 59.68 % of the total variance in the experimental data. The projection of the factors indicated that L\* and h\* contributed positively to the first principal component PC1 (30.9 % and 32.6 %, respectively), while a\* negatively influenced the PC1 coordinate. The negative influence of b\* and C\* was observed on the second principal component PC2 (47.4 % and 48.4 %, respectively). The separation between samples could be observed from the PCA graph, in which most samples treated with solution 1 were placed at the right side of the graph, with higher L\* and h\* parameters, while samples treated with solution 3 were placed at the left of the graph, with the augment in a\* parameter. Samples located at the bottom side of the graph were characterized by lower processing time (most samples were processed for 20 days). The map of PCA analysis showed that the first principal component described the differentiation among the samples according to L\*, a\* and h\* coordinates, while the second principal component described the variations in b\* and C\* coordinates between samples.

In order to show the sensory analysis data which could be applied for a better understanding of the properties of OT cabbage samples during storage, PCA results were shown in Fig. 2. The first two PCs clarified 59.68 % of the total variance in the experimental data. The projection of the variables in the factor plane indicated that ACLY, ACYB, ACG, OM, OCR, TSS, TSA, TM, TCR, TP, TB and ATSS contributed mostly to the first principal component PC1 (8.2 %, 7.7 %, 5.4 %, 6.8 %, 5.9 %, 6.3 %, 8.6 %, 7.9 %, 6.0 %, 6.4 %, 5.1 % and 5.6 %, respectively), while ACB, TSW, TCB, TSR, TB and ATSB contributed more to the second principal component PC2 (8.8 %, 10.0 %, 22.2 %, 19.2 %, 5.7 % and 11.9 %, respectively).



*Fig. 1: The PCA biplot diagram, depicting the*

 *relationships among OT cabbage samples treated*

*with different osmotic solutions*

**CONCLUSIONS**

This paper presented the influence of osmotic dehydration process parameters and storage on ascorbic acid content, acidity, colour parameters and microbiological profile of the processed samples. The observed samples were characterized by chemical, microbiological, color and sensory analysis. During the 90 days storage of OT white cabbage hybrid, Bravo packaged in MAP, a slight decrease in acidity and pH increase was observed. During storage in a MAP total number of microorganisms decreased. The cabbage treated in molasses and chloride /sucrose solution and packed in MAP with 80 % CO2 gas mixture showed the highest retention of L-ascorbic acid during storage. Sensory analysis showed acceptable consumable characteristics of stored osmodehydrated cabbage. Solution type has a significant influence on pH and acidity, storage period on the total number of microorganisms and gas mixture content has no significant influence on analyzed parameters.

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*Fig. 2. The PCA biplot diagram, depicting the sensory analysis of OT cabbage samples treated with different osmotic solutions during storage; ACLY-appearance-colour- light yellow, ACLYG -appearance-colour- light yellow-green, ACLYBE-appearance colour light yellow-brown edges, ACYB-appearance colour yellow-brown, ACB-appearance colour brown, ACG-appearance colour grey, OM-odour molasses, OCR-odour caramel, OCB-odour cabbage, OODRS-off odour (rancid, sour), TSW-taste sweet, TSS-Taste sweet-salty, TSA-taste salty, TCB-taste raw cabbage, TM-taste molasses, TCR- taste caramel, TP-taste pungent, TSR-taste sour, TB- taste bitter ATTS- aftertaste sweet-salty, ATSB- aftertaste sweet-bitter, ATS- aftertaste salty, ATB-aftertaste bitter, ATSR-aftertaste sour, ATP- aftertaste pungent, TXCW-texture chewiness, TXTG-texture toughness, TXHD- texture hardness*

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**REFERENCES**

Barbosa, C., Alves, M. R., Rocha, S., and Oliveira, M. B. P. (2016). Modified atmosphere packaging of precooked vegetables: Effect on physicochemical properties and sensory quality. Food Chemistry 194, 391-398.

Bozkir, H., Ergün, A. R., Serdar, E., Metin, G., and Baysal, T. (2019). Influence of ultrasound and osmotic dehydration pretreatments on drying and quality properties of persimmon fruit. Ultrasonics sonochemistry 54, 135-141.

Brito, T., Pereira, A., Pastore, G., Moreira, R., Ferreira, M., and Fai, A. (2020). Chemical composition and physicochemical characterization for cabbage and pineapple by-products flour valorization. LWT 124, 109028.

Ciurzyńska, A., Kowalska, H., Czajkowska, K., and Lenart, A. (2016). Osmotic dehydration in production of sustainable and healthy food. Trends in Food Science & Technology 50, 186-192.

Ćurčić, B. L., Pezo, L., Filipović, V., Nićetin, M., and Knežević, V. (2015). Osmotic treatment of fish in two different solutions-artificial neural network model. Journal of Food Processing and Preservation 39, 671-680.

Cvetković, B. R., Pezo, L. L., Mišan, A., Mastilović, J., Kevrešan, Ž., Ilić, N., and Filipčev, B. (2019). The effects of osmotic dehydration of white cabbage on polyphenols and mineral content. LWT 110, 332-337.

Guillén, F., Castillo, S., Zapata, P., Martínez-Romero, D., Valero, D., and Serrano, M. (2006). Efficacy of 1-MCP treatment in tomato fruit: 2. Effect of cultivar and ripening stage at harvest. Postharvest Biology and Technology 42, 235-242.

Hyun, J.-E., Bae, Y.-M., Yoon, J.-H., and Lee, S.-Y. (2015). Preservative effectiveness of essential oils in vapor phase combined with modified atmosphere packaging against spoilage bacteria on fresh cabbage. Food Control 51, 307-313.

ISO, E., 1991: 4833 (1991) Methods for Microbiological Examination of Food and Animal Feeding Stuffs. Enumeration of Micro-organisms. Colony Count Technique at 30° C.

ISO, SPRPS, 2003: 750 (2003) Fruit and vegetable products -- Determination of titratable acidity

ISO, I., 2003: 4121 (2003) Sensory analysis — Guidelines for the use of quantitative response scales. International Organization for Standardization, Geneva.

ISO, I., 2008: 21527-2 (2008) Microbiology of Food and Animal Feeding Stuffs: Horizontal Method for the Enumeration of Yeasts and Moulds: Part 2: Colony Count Technique in Products with Water Activity Less Than Or Equal to 0, 95: ISO.

Knežević, V., Pezo, L. L., Lončar, B. L., Filipović, V. S., Nićetin, M. R., Gorjanović, S. Ž., and Šuput, D. (2019). Antioxidant capacity of nettle leaves during osmotic treatment. Periodica Polytechnica Chemical Engineering 63, 491-498.

Koprivica, G. B., Pezo, L. L., Ćurčić, B. L., Lević, L. B., and Šuput, D. Z. (2014). Optimization of osmotic dehydration of apples in sugar beet molasses. Journal of Food Processing and Preservation 38, 1705-1715.

Kowalska, H. (2005). The effect of C vitamin on the osmotic dehydration process in apples. Zywność. Nauka Technologia Jakość 4, 109-119.

Lech, K., Michalska, A., Wojdyło, A., Nowicka, P., and Figiel, A. (2018). The influence of physical properties of selected plant materials on the process of osmotic dehydration. LWT 91, 588-594.

Martínez-Romero, D., Guillén, F., Castillo, S., Valero, D., and Serrano, M. (2003). Modified atmosphere packaging maintains quality of table grapes. Journal of Food Science 68, 1838-1843.

Nićetin, M. R., Pezo, L. L., Lončar, B. L., Filipović, V., Šuput, D. Z., Knezević, V. M., and Filipović, J. S. (2017). The possibility of increasing the antioxidant activity of celery root during osmotic treatment. Journal of the Serbian Chemical Society 82, 253-265.

Noseda, B., Islam, M. T., Eriksson, M., Heyndrickx, M., De Reu, K., Van Langenhove, H. and Devlieghere, F. (2012). Microbiological spoilage of vacuum and modified atmosphere packaged Vietnamese Pangasius hypophthalmus fillets. Food Microbiology 30, 408-419.

Osae, R., Essilfie, G., Alolga, R. N., Akaba, S., Song, X., Owusu-Ansah, P., and Zhou, C. (2020). Application of non-thermal pretreatment techniques on agricultural products prior to drying: a review. Journal of the Science of Food and Agriculture 100, 2585-2599.

Osae, R., Zhou, C., Xu, B., Tchabo, W., Tahir, H. E., Mustapha, A. T., and Ma, H. (2019). Effects of ultrasound, osmotic dehydration, and osmosonication pretreatments on bioactive compounds, chemical characterization, enzyme inactivation, color, and antioxidant activity of dried ginger slices. Journal of food biochemistry 43, e12832.

Patras, A., Brunton, N. P., Da Pieve, S., and Butler, F. (2009). Impact of high pressure processing on total antioxidant activity, phenolic, ascorbic acid, anthocyanin content and colour of strawberry and blackberry purées. Innovative Food Science & Emerging Technologies 10, 308-313.

Phisut, N., Rattanawedee, M., and Aekkasak, K. (2013). Effect of osmotic dehydration process on the physical, chemical and sensory properties of osmo-dried cantaloupe. International Food Research Journal 20.

Rincon, A., and Kerr, W. L. (2010). Influence of osmotic dehydration, ripeness and frozen storage on physicochemical properties of mango. Journal of Food Processing and Preservation 34, 887-903.

Sabır, A., Sabır, F. K., and Kara, Z. (2011). Effects of modified atmosphere packing and honey dip treatments on quality maintenance of minimally processed grape cv. Razaki (V. vinifera L.) during cold storage. Journal of food science and technology 48, 312-318.

Siriamornpun, S., Ratseewo, J., Kaewseejan, N., and Meeso, N. (2015). Effect of osmotic treatments and drying methods on bioactive compounds in papaya and tomato. RSC advances 5, 18579-18587.

Šuput, D., Lazić, V., Pezo, L., Gubić, J., Šojić, B., Plavšić, D., Lončar, B., Nićetin, M., Filipović, V., and Knežević, V. (2019). Shelf life and quality of dehydrated meat packed in edible coating under modified atmosphere. Romanian Biotechnological Letters 24, 545-553.

Tolera, K. D., and Abera, S. (2017). Nutritional quality of Oyster Mushroom (Pleurotus Ostreatus) as affected by osmotic pretreatments and drying methods. Food science & nutrition 5, 989-996.

Vlahović, B. (2015). Tržište agroindustrijskih proizvoda, Poljoprivredni fakultet, Novi Sad, Republika Srbija

Zapata, P. J., Guillén, F., Martínez-Romero, D., Castillo, S., Valero, D., and Serrano, M. (2008). Use of alginateor zein as edible coatings to delay postharvest ripening process and to maintain tomato (Solanum lycopersicon Mill) quality. Journal of the Science of Food and Agriculture 88, 1287-1293.

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