The influence of packaging materials protective properties and applying modified atmosphere on packed dried apricot quality changes

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Abstract
The influence of protective properties of packaging materials and modified atmosphere on quality changes of dried apricot is shown in this paper. In our investigation, we used four different characteristic combinations of packaging materials with different barrier properties for packaging of dried apricot: polyester-polyethylene (PET/PE), paper/polyethylene (PAP/PE), paper/aluminum/polyethylene (PAP/Al/PE), polyester/aluminum/polyethylene (PET/Al/PE) and two different atmospheric conditions: normal and modified. Modified atmosphere was made under laboratory conditions: CO_2, about 30%, N_2, about 60%, and the rest is O_2. Over the 12-months storage period, the changes in the water content, water activity (a_w) and overall polyphenol content were monitored in the packed product.

Keywords: packaging, modified atmosphere, dried apricot.

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The packaging of dehydrated processed food products represents a very specific problem in terms of product protection. Due to its significant active surface, dried fruit and vegetables are a substrate sensitive to humidity and oxidation during the storage period. That is why it is necessary to choose the right packaging, capable to protect the product in the best way and to enable the longest possible quality of content after conservation.

When it comes to the packaging of dried products, there are special requirements which depend on the sensitivity of the packed dehydrated product. When their water content is reduced, fruit and vegetable products become very hydroscopic, sensitive to humidity, oxidation and light. Depending on the production, packaging and storage conditions, some physicochemical processes occur in this sensitive substrate, which further cause changes in the quality of the packaged product.

In order to prevent these changes, the packaging of this kind of products is carried out in an oxygen-free atmosphere. The best results are obtained by implementing inert gases in which case the air in the packaged product is being extracted or replaced. As a protective gas during packaging, usually nitrogen, carbon dioxide or their suitable combination is used. The dosing is performed after the air has been extracted from the packaging unit.

The packaging of food in modified atmosphere (MAP) is a special way of treating already prepared food which protects the food from oxidation, keeps it fresh and extends product shelf life without any change in its color [1–4].

The storing of food in a modified gas atmosphere can preserve quality and extend product shelf life, slowing down the chemical and bio-chemical spoilage processes and also slow down (and in some cases even prevent) the growth of microorganisms [5].

The properties of packaging material, such as mechanical and barrier, are very important when it comes to decision about which materials are to be used in packaging of different types of products. Exposure to various conditions during processing can lead to a number of physical/chemical changes.

Flexible and semi-hard/hard plastic materials and laminates are the materials most frequently used in modified atmosphere food packaging. Plastic materials constitute approximately one third of the material required for packaging in food industry and it is estimated that its use is going to increase even more in future [5].

Some of the properties that make plastic materials suitable for food packaging are: they are rather easy to mold, light, pretty translucent, solid and they are also heat insulators. The usual polyolefin films, such as PE and PP, are excellent moisture barriers [6].

If a polymer material does not satisfy all strict quality requirements for packaging and preservation of a product until it is used, then it is combined with other polymer materials in which case double-layer (duplex) or multi-layer polymer materials are obtained [7,8]. These materials possess better physical and mechanical properties, and especially better barrier properties

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than the mono-materials. This is due to the fact that by combining them, all the positive properties of mono-materials are gathered up. In this way, the area of the application of these materials is significantly extended [8,9].

Combined materials are consisted of a polymer and some other material (paper, cardboard, aluminum foil,…), for example, PE/PAP/PE, PET/A1/PE, metPET//PE, PE/PAP/PE/A1/PE,… Each material brings in its good properties and in this way it contributes to the optimal properties of the produced multi-layer or combined material [10].

In order to obtain optimal protective properties as a barrier against electromagnetic radiation, permeability of gas molecules and vapor, metal foil is also used, mostly aluminum foil cassated on polymer film. The thickness of the metal layer is 7 μm or more. The combined packaging material obtained in this way is light proof and very little gas molecule and vapor proof [11].

With the aim of improving barrier properties, a thin layer of aluminum (or other materials) can be applied on polymer films using metallization process. In this way, the metalized films barrier properties regarding electromagnetic radiation are improved (over 90%), as well as regarding gas molecules and vapor. Barrier properties improvement rate is conditioned by the mass (layer thickness) of the applied metal, as well as by the application on the surface of the polymer film [4,11,12].

The right choice of the packaging material for dried apricot is very important for keeping the quality of the dried fruit during storage due to its chemical structure and the changes that occur during the drying process.

From a nutritional point of view, apricot pericarp contains saccharides, organic acids and mineral elements (iron, boron and potassium), vitamins such as provitamin A, vitamins B and C and polyphenols. It was found that apricots are rich in phenolic substances, in addition to the aforementioned compounds. Phenolic compounds, such as catechin, epicatechin, *p*-coumaric acid, caffeic acid, ferulic acid and their esters have been identified in the fruits [13].

During the drying process, in the presence of carbon hydrates and proteins, that are the products of their decomposition, like peptides and amino acids, poly hydroxyl phenol transformation reactions in non-enzymatic oxidative browning reactions can be isolated by means of reducing water [14].

The moisture content is one of the most important factors in preserving the quality of dried products. During the storage period of dried fruit (with low moisture content and low water activity) moisture content and water activity increase, followed by the increase in activation energy of the reactions that are responsible for quality changes of packaged content. This leads to the production of HMF (hydroxymethylfurfural) and to the changes in colour compounds in the reactions of auto oxidative changes and nonenzymatic browning [14].

Water-soluble color compounds and brown pigments, which are the indicators of undesirable browning that occurs during the production and storage period, are polyphenols and HMF. During the storage period their content increases [15].

During the storage period of dried carrot and dried apple, the transformation of polyphenols occurs as the result of oxidative reactions of non-enzymatic browning [16,17]. During the first six months, the decreasing of the polyphenol content is almost linear. After six months storage period the polyphenol content rapidly increases in both cases.

After further water reduction, auto oxidation reactions become very pronounced. These reactions will reach their maximum peak at certain water content in the packed product. In addition, each food group has its own optimal moisture balance area in which the sum of all the changes is minimal, in which case, the food has extended shelf life period [12,18].

EXPERIMENTAL

Chemicals

Folin–Ciocalteu reagent, sodium carbonate and gallic acid were purchased from Merck® (KGaA, Darmstadt, Germany).

A sample

Dried apricot was packed under normal atmospheric pressure and in the modified atmosphere. The air was taken out from the sample and the gas mixture injected into the achieved vacuum. The sample was hermetically closed. A 100 g of dried apricot was packed into formed packaging material units. Dried apricot was packaged in four characteristic combinations of packaging materials with different barrier properties: polyester/polyethylene (PET/PE), paper//polyethylene (PAP/PE), paper/aluminum/polyethylene (PAP/Al/PE) and polyester/aluminum/polyethylene (PET/Al/PE). A 12 μm packaging material in the case of PET/PE i PAP/PE and 15 μm material for PAP/Al/PE and PET/Al/PE was used. Packed samples were kept at room temperatures (17 to 22 °C) and were exposed to the influence of light for 12 months.

Packaging materials barrier properties testing

Modified atmosphere sustainability was monitored by OXY-BABY device (Witt Gasetechik, Germany).

Dried packed apricot analyses

Moisture content was determined after drying of samples at 103±2 °C to constant mass (Laboratory dryer, Termodry, Raypa, Spain).

Water activity

Water activity is determined by avemeter (Termo-constater - Novasina , tip TN 2(RTD), Switzerland).

Total polyphenols are determined by the Folin–Ciocalteu method

The Folin-Ciocalteu method, based on the reduction of a phosphotungsten-phosphomolybdatecomplex by phenolics to blue reaction products, was used to determine the phenolic compounds. Sample (0.5 mL) was pipetted into cuvette and diluted with deionized water (1.5 mL). Subsequently, Folin–Ciocalteu reagent (0.05 mL) was added and the solution was incubated at 22 °C for 2 h. The absorbance readings were taken at 760 nm. Gallic acid was used as a reference standard, and the results were expressed as milligram gallic acid equivalent (mg GAE)/100 g [19].

Instruments

UV/Vis spectrophotometer T80 (PG Instrument, England) was used for all measurements.

RESULTS AND DISCUSSION

Modified atmosphere was made in laboratory conditions. Initial values for all gas components of modified atmosphere in the moment of closing of packaging materials are shown in Table 1.

The measurement results are given in Figures 1–3. The most significant changes were observed after the first month in PAP/PE. In this package, the percentage of O_2 has been increased from the initial 1.43 to 17.53%, the percentage of CO_2 changed from the initial 31.53 to 1.53%, while the percentage of N_2 starting from 67.03 reached 80.93%. The PET/Al/PE showed the smallest change in CO_2 concentration, where the concentration of this gas was 28.84% at the beginning, 27.94% at the end of the first month, and 27.48% after 12 months. These further support good barrier characteristics of this packaging material.

Other combinations showed more significant changes in CO_2 concentration after the first month.

The smallest changes in nitrogen concentration were measured in PET/Al/PE, whereas other combinations showed insignificant increase.

Moisture content change

The dried product had 31.2% of moisture at the beginning. Following the humidity values during the storage of the samples packed under the atmospheric pressure in combination with PET/PE, PAP/PE, PAP/Al/

Table 1. Initial values of modified atmosphere

Packaging material	CO_2 Content, %	N_2 Content, %	O_2 Content, %
PAP/PE	31.53	67.03	1.43
PAP/AL/PE	30.17	68.76	1.07
PET/PE	32.60	66.43	0.97
PET/AL/PE	28.48	69.93	1.23

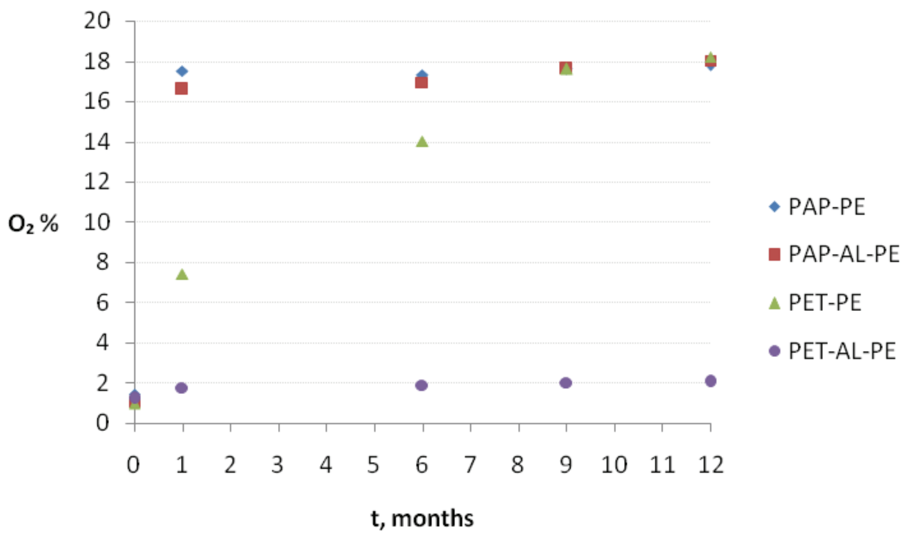

Figure 1. Changing the concentration of oxygen in modified atmospheric conditions.

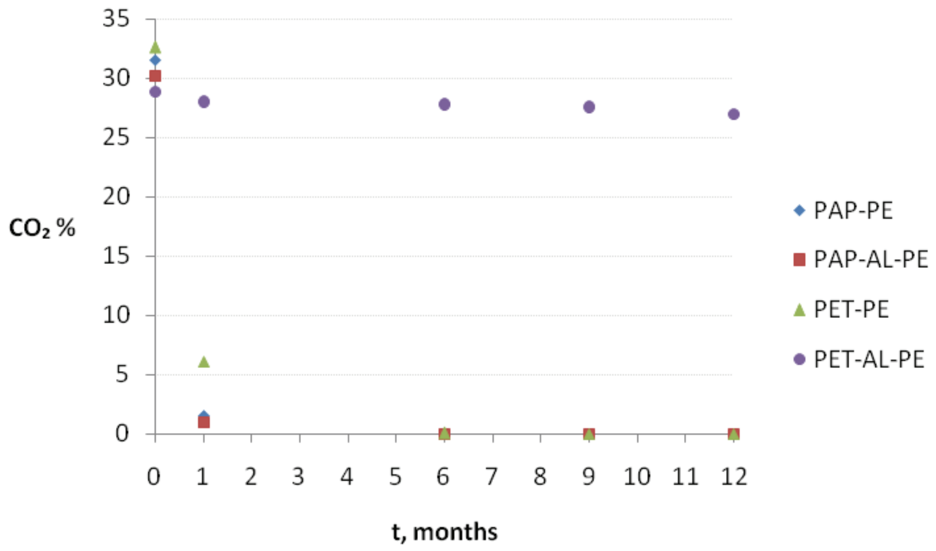

Figure 2. Changing the concentration of carbon dioxide in modified atmospheric conditions.

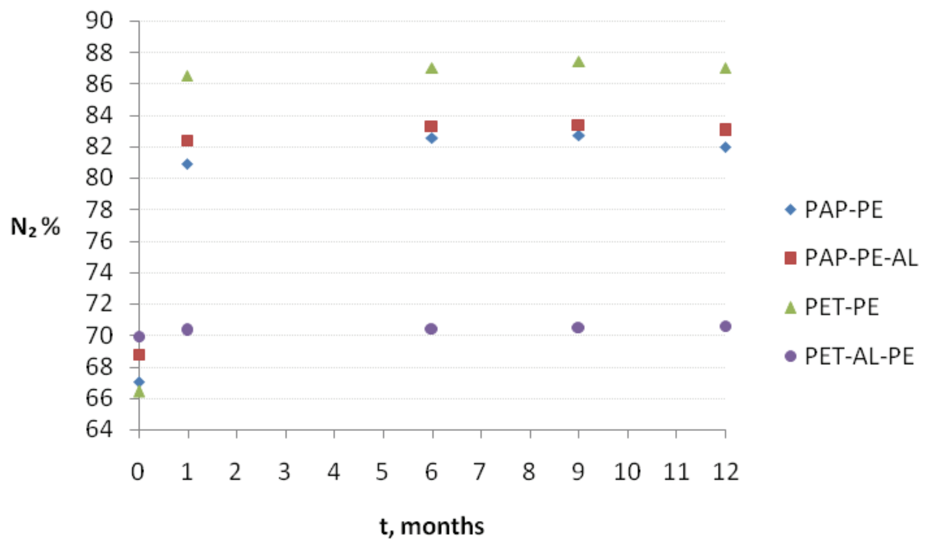

Figure 3. Changing the concentration of nitrogen in modified atmospheric conditions.

/PE, PET/Al/PE materials and according to Table 2, we can conclude that more changes occurred after 12 months, especially with samples packed in PAP/PE where the humidity concentration increased from 31.2 to 39.6%. PET/Al/PE showed the best moisture protection. In this package, the humidity concentration after 12 months reached 32.5%, which is 1.3% more than the initial value.

Modified atmosphere packaging showed the same tendencies as the corresponding packaging in atmospheric conditions (Table 3). The PET/Al/PE material combination sample showed the best protection from humidity in modified atmospheric conditions. In this package, the humidity concentration increased by 0.8%.

The water activity changes in the packed dried apricot during the storing are given in Tables 4 and 5.

Table 2. Changes of the moisture content (%) of packed dried apricots during storage under the normal atmospheric conditions

Time, months	Package			
	PAP/PE	PAP/Al/PE	PET/PE	PET/AL/PE
0	31.2	31.2	31.2	31.2
1	35.4	33.8	33.1	31.3
9	39.6	36.8	35.4	32.5
12	39.6	36.8	35.4	32.5

Table 3. Changes of the moisture content (%) of packed dried apricots during storage under the modified atmospheric conditions

Time, months	Package			
	PAP/PE	PAP/Al/PE	PET/PE	PET/AL/PE
0	31.2	31.2	31.2	31.2
1	34.5	33.0	32.0	31.3
9	38.0	35.0	34.0	32.0
12	38.0	35.0	34.0	32.0

Table 4. Changes of the water activity of packed dried apricots during storage under the normal atmospheric conditions

Time, months	Package			
	PAP/PE	PAP/Al/PE	PET/PE	PET/AL/PE
0	0.645	0.645	0.645	0.645
1	0.713	0.709	0.72	0.671
6	0.766	0.72	0.752	0.691
9	0.782	0.753	0.778	0.701
12	0.955	0.851	0.792	0.715

Table 5. Changes of the water activity of packed dried apricots during storage under the modified atmospheric conditions

Time, months	Package			
	PAP/PE	PAP/Al/PE	PET/PE	PET/AL/PE
0	0.645	0.645	0.645	0.645
1	0.704	0.711	0.718	0.66
6	0.75	0.732	0.737	0.689
9	0.772	0.761	0.763	0.693
12	0.912	0.831	0.81	0.698

Water activity changes start after the first month of the sample being stored. The biggest changes were noticed in samples packed under normal atmospheric pressure. According to Table 3 we can conclude that after 12 months the biggest changes were observed in PAP/PE samples, where the water activity value increased from 0.645 to 0.955. The smallest changes of water activity values were observed in samples packed into PET/Al/PE packaging material under the modified atmospheric conditions, where the value at the beginning was 0.645, after 9 months it was 0.693, while after 12 months it was 0.698 (Table 4). The increase of water activity is correlated with the increase of moisture content, and it depends on the packaging material and atmosphere conditions applied [14].

Observed polyphenol changes (Tables 6 and 7) point to the occurrence of change in cyclicities depending on packing material and storage time.

During the nine-month period, the total polyphenol content decrease occurs followed by an increase of water activity and moisture content. The biggest change occurs during the first month. The least amount of these changes was observed in the specimens packed into the PET/AL/PE combination. These results show that the reactions of nonenzymatic browning changed the polyphenol content, over the storage period.

After nine months, the total polyphenol content continues to increase, except in the PET/AL/PE combination, where the total polyphenol content decreased.

Table 6. Changes of the total polyphenol content (mg/100 g) of packed dried apricots during storage under the normal atmospheric conditions

Time, months	Package			
	PAP/PE	PAP/Al/PE	PET/PE	PET/AL/PE
0	0.137	0.137	0.137	0.137
1	0.063	0.038	0.105	0.053
6	0.063	0.016	0.038	0.053
9	0.018	0.015	0.038	0.040
12	0.078	0.070	0.050	0.037

Table 6. Changes of the total polyphenol content (mg/100 g) of packed dried apricots during storage under the normal atmospheric conditions

Time, months	Package			
	PAP/PE	PAP/Al/PE	PET/PE	PET/AL/PE
0	0.137	0.137	0.137	0.137
1	0.067	0.074	0.080	0.053
6	0.058	0.069	0.064	0.049
9	0.017	0.035	0.064	0.047
12	0.054	0.050	0.075	0.037

The smallest changes are ascertained in the specimens packed in modified atmospheric conditions, which points to the oxidation nature of the change and the influence of the applied packing materials barrier properties. The modified atmosphere conditions didn't affect the total polyphenol content in PET/AL/PE combination.

CONCLUSION

Moisture content, water activity and total polyphenol content changes are conditioned by the type, combination, barrier properties of the used materials and the packaging conditions applied.

According to the tests, it can be concluded that adequately applied modified atmosphere combination, choice of packaging materials, their combinations and barrier characteristics all bare great significance and influence the sustainability of packed dried apricot. PET/Al/PE combination provides the best protection to packed dried apricot.

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REFERENCES

[1] A. Exama,J. Arul, Suitability of plastic films for modified atmosphere packaging of fruit and vegetables, J.Food Sci. **58** (1993) 1365–1370.

[2] J.D. Mannapperuma, R.F. Singh, Modelling of gas exchange in polymeric packages of fresh fruits and vegetables, in: CRC Press, Boca Raton, FL, 1994, pp. 437–458.

[3] J. Gvozdenovic, V. Lazic, G. Svrzic, Influence of monomaterials characteristics and combined packaging materials on dried fruits packed, J. Process. Energy Agric. (former PTEP) **10** (2006) 32–36.

[4] M. Achour, A new method to assess the quality degradation of food products during storage, J. Food Eng. **64** (2005) 125–127.

[5] R. Coles, D. McDowell, M.J. Kirwan, Food Packaging Technology, Blackwell Publishing Ltd., Oxford, 2003, pp. 303–319.

[6] B.F. Ozen, J.D. Floros, Effects of emerging food processing techniques on the packaging materials, Trends Food Sci. Tech. **12** (2001) 60–67.

[7] I. Vujković, Polimerna i kombinovana ambalaža, Poli, Novi Sad, 1997 (in Serbian).

[8] R.R. Goddarg, Flexible Plastics Packaging, Developments in Food Packaging 1, Applied Science Publishers Ltd., London, 1999.

[9] V. Crnčević, Ambalaža za životne namirnice, Privredni pregled, Beograd, 1980, pp. 109–111 (in Serbian).

[10] J. Gvozdenović, M. Curaković, V. Lazić, Dehydrated fruit packaging and packing conditions, Časopis za procesnu tehniku i energetiku u poljoprivredi (PTEP) **6** (2002) 34––38.

[11] J. Gvozdenović, M. Curaković, Ambalaža i njen uticaj na održivost voća i povrća, Tehnološki fakultet, Novi Sad, 1993 (in Serbian).

[12] R. Heiss, Verpackung von Lebensmitteln, Springer Verlag, Berlin, 1980.

[13] J. Sochor, O. Zitka, H. Skutkova, D. Pavlik, P. Babula, B. Krska, A. Horna, V. Adam, I. Provaznik, R. Kizek, Content of Phenolic Compounds and Antioxidant Capacity in Fruits of Apricot Genotypes, Molecules **15** (2010) 6285––6305.

[14] T.P. Labuza, M. Saltmarch, The nonenzymatic browning reaction as affected by water in foods, in properties of water related to food quality and stability, L.B. Rockland, G.V. Stewart, Eds., Academic Press, London, 1980, pp. 360–365.

[15] K. Eichner, M. Ciner-Doruk, Formation of browning intermediates and visible sugar-amino browning reactions, Properties of Water Related to Food Quality and Stability, L.B. Rockland, G.V. Stewart, Eds., Academic Press, London, 1980.

[16] J. Gvozdenović, M. Curaković, Uticaj višeslojne ambalaže na očuvanje kvaliteta sušenog povrća, Savetovanje o sušenom povrću, Janja, BiH, Zbornik radova, 1985, pp. 323–340 (in Serbian).

[17] J. Gvozdenović, A. Aljilji, V. Lazić, G. Svrzić, A. Tepić, Uticaj zaštitnih svojstava ambalažnih materijala na promene kvaliteta upakovane sušene jabuke, Časopis za

procesnu tehniku i energetiku u poljoprivredi (PTEP) **11** (2007) 112–115 (in Serbian).
[18] S.N. Dirim, O.H. Ozden, A. Bayindirli, A. Esin, Modification of water vapour transfer rate of low density polyethylene films for food packaging, J. Food Eng. **63** (2004) 9–13.
[19] V.L. Singleton, R. Orthofer, R.M. Lamuela-Raventos, Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin–Ciocalteu reagent, in: Oxidants and Antioxidants, Part A, H. Sies, Ed., Academic Press Inc., San Diego, CA, 1999; pp. 152–178.

IZVOD

UTICAJ ZAŠTITNIH SVOJSTAVA AMBALAŽNOG MATERIJALA I PRIMENE MODIFIKOVANE ATMOSFERE NA PROMENE KVALITETA UPAKOVANE SUŠENE KAJSIJE

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(Naučni rad)

U ovom radu prikazan je uticaj zaštitnih svojstava ambalažnog materijala i primene modifikovane atmosfere na promene kvaliteta upakovane osušene kajsije. U istraživanju su za pakovanje osušene kajsije korišćene četri kombinacije ambalaže sa različitim barijernim svojstvima: poliestar/polietilen (PET/PE), papir/ /polietilen (PAP/PE), papir/aluminijum/polietilen (PAP/Al/PE) i poliestar/ aluminijum/polietilen (PET/Al/PE), kao i dva različita uslova atmosfere. Parametri koji su praćeni u ovom istraživanju su sadržaj vlage, aktivitet vode i sadržaj polifenolnih materija. Najveća promena u sadržaju vlage u upakovanoj osušenoj kajsiji je utvrđen kod PAP/PE u uslovima normalne atmosfere (od 31,2 na 39,6% nakon 12 meseci skladištenja). Porast aktiviteta vode bio je u korelaciji sa porastom sadržaja vlage i zavisi od primenjenog ambalažnog materijala i uslova pakovanja. Praćenjem vrednosti polifenola tokom skladištenja konstatovano je opadanje vrednosti kod uzoraka upakovanih u PET/Al/PE. Kod ostalih uzoraka utvrđena je cikličnost promena tokom skladištenja. Nakon jačeg pada vrednosti u periodu do 9 meseci, najviše izraženog kod uzoraka pakovanih u kombinaciju PAP/Al/PE u uslovima normalne atmosfere (0,015 mg/100 g) imamo nagli porast vrednosti tako da nakon 12 meseci najveće vrednosti polifenola imamo kod uzoraka pakovanih u PAP/PE u uslovima normalne atmosfere (0,078 mg/100 g). Rezultati istraživanja ukazuju na to da optimalna kombinacija primenjene modifikovane atmosfere i barijernih svojstava ambalažnog materijala pruža dobru zaštitu i dugotrajniju održivost upakovane osušene kajsije u periodu sprovedenog istrazivanja u trajanju od 12 meseci.

Ključne reči: Pakovanje • Modifikovana atmosfera • Osušena kajsija