Biblid: 1821-4487 (2018) 21; 4; p 153-156
UDK: 634.13:631.563

Original Scientific Paper
Originalni naučni rad

CONVECTIVE DRYING OF ORGANIC PEAR PULP IN A THIN STAGNANT LAYER

KONVEKTIVNO SUŠENJE KAŠE OD ORGANSKE KRUŠKE U TANKOM NEPOKRENOM SLOJU

Zoran STAMENKOVIĆ, Ana DOLOVAC, Ivan PAVKOV, Vojislava BURSIĆ, Milivoj RADOJČIN, Mirko BABIĆ, Krstan KEŠELJ
University of Novi Sad, Faculty of Agriculture, Trg Dositeja Obradovića 8, 21000 Novi Sad, Serbia
e-mail: zoran.stamenkovic@polj.uns.ac.rs

ABSTRACT

The aim of this paper is to present the influence of convective drying of organic pear pulp and adding ascorbic acid on changes in color, the difference in vitamin C content and also show the kinetics of convective drying.

It was a two-factor experiment. The first factor was the air temperature needed for drying, between 45 °C and 65 °C, with a constant speed of drying air of 1.5 m/s; the second factor of the experiment was the adding of ascorbic acid to the pear pulp in the amount of 1 % and 2 % of the full mass of the prepared pulp.

The lowest change in color was achieved by adding ascorbic acid in the amount of 2 % of the full mass of the pulp and drying air temperature of 45°C (ΔE= 23.981). The highest change was accomplished at the air temperature of 65 °C and by adding ascorbic acid in the amount of 1% (ΔE= 30.039).

With samples where ascorbic acid was added reduction of vitamin C was over 99 % with all samples.

By examining the kinetics of convective drying based on statistical indicators R, X2, RMSE, models Page and Logarithmic are the best in representing convective drying of pear pulp at air temperatures of od 65 °C and 45 °C respectively.

***Key words:** organic pear, convective drying kinetic, mathematical modeling, vitamin C, color change, fruit leather-rolls.*

REZIME

U centrima za sušenje često se prebiranjem javlja određeni udeo voća koje je "prezrelo" za ovakav vid prerade. Jedan od novijih metoda prerade prezrelih voćnih plodova jeste proizvodnja rolnica od sušene voćne kaše.

U radu je predstavljen uticaj konvektivnog sušenja kaše od kruške proizvedene po organskim principima sorte "Kiferov sejanac". Ekperiment je izveden kao dvofaktorski sa dva nivoa faktora. Prvi faktor je temperatura vazduha za sušenje od 45°C i 65°C, pri brzini vazduha za sušenje od 1,5 m/s, a drugi faktor ekperimenta je dodatak askorbinske kiseline u kaši od kruške u količini od 1% i 2%, od mase pripremljene kaše.

Cilj rada je da se ispita uticaj konvektivnog sušenja, na promenu boje, sadržaj vitamina C i da se definišu matematički modeli kinetike konvektivnog sušenja kaše od kruške.

Najniža promena boje ostvarena je kod kaše sa dodatkom askorbinske kiseline u vrednosti 2% od mase kaše i temperaturi vazduha za sušenje od 45°C (ΔE= 23,981). Najviša promena boje ostvarena je pri temperaturi vazduha za sušenje od 65°C i dodatkom askorbinske kiseline u vrednosti od 1% (ΔE= 30,039).

Zabeležena je razgradnja vitamina C u svim uzorcima. Kod kontrolnih uzoraka razgradnja vitamina C je ≈ 77-80%. Kod uzoraka sa dodatkom askorbinske kiseline razgradnja vitamina C prelazi preko 99%, kod svih uzoraka.

Page model najbolje prikazuje konvektivno sušenje kaše od kruške pri temperaturi vazduha od 65°C. Koeficijent korelacije izonosi R= 0,998, vrednost of the reduced X^2= 0,000262 i RMSE= 0,02.

Konvektivno sušenje kaše od kruške, vazduhom temperature 45°C, najbolje prikazuje Logarithmic model. Koeficijent korelacije iznosi R= 0,999660, vrednost of the reduced is X^2= 0,000066 i RMSE= 0,01.

***Ključne reči:** organska kruška, kinetika konvektivnog sušenja, matematički modeli, sadržaj vitamina C, promena boje, voćne rolnice.*

INTRODUCTION

Fruit produced by organic principles and production of products based on the principles of organic production comprises a set of advantages, particularly in health, ecological and economic terms.

Fruit needs to be processed, stored in cold storage, frozen and dried right after harvest. Convective drying of fruit, as the most common method of drying, effects the chemical-physical changes that occur during the process of drying, changes in the color, deconstruction of vitamin C, etc. *(Lutovska et al., 2015; Vakula 2015;Tepić, 2012; Radojčin, 2010; Ratti 2011).*

One of the newer products that can be found on the market is fruit leather rolls. Order of processing is that fruit is first blended into a pulp and set on drying trays in fixed thin-layers, 4-5 mm thick. After the drying process, it is cut in ribbons that are then used to form rolls. The downside of these products is a high level of oxidation and darkening during the preparation of the fruit pulp and during the process of convective drying. In addition, there is a loss in the content of vitamin C, which is especially noted with fruit that is susceptible to these changes.

Silvana M. Demarchi (2012), examines, in her paper, the effect of air temperature on convective drying, on antioxidant capacity in apple leather. Apple pulp, with the addition of potassium metabisulfite as antioxidant, was dried convectively at air temperatures of 50, 60 and 70 °C. The result of their research confirms that air temperature has a significant effect on antioxidant capacity during convective drying, where with an increase in temperature there is a decrease in antioxidant capacity in apple leather products.

The color of such products is seen as one of the important factors that influence customers to buy the product. Air temperature for convective drying and the length of drying reciprocally influence the darkening of fruit tissue. Tontul et. al (2017) have examined the effect of different drying techniques on the physical-chemical changes during the production of pomegranate leather. Convective drying was done at temperatures of 50, 60 and 70 °C, with the speed of drying air at

1.5 m/s. In their research, there was a marked increase in changes of color when the air temperature was increased. As for vitamin C, there was a greater reduction of vitamin C in cases when the air temperature was higher.

The aim of the paper is to examine the influence of air temperature used for convective drying and addition of ascorbic acid on the changes in color and the content of vitamin C, in the end product, pear leather rolls. In addition, kinetics of convective drying will be researched and mathematical models of convective drying of pear pulp in a thin, static layer defined.

The mathematical models developed in the literature are used for designing new drying systems as well as selection of optimum drying conditions and for accurate prediction of simultaneous heat and mass transfer phenomena during the drying process. The selection of the best model is a very important procedure describing the behavior of the thin-layer drying process *(Kucuk et. al 2014).*

MATERIAL AND METHOD

Materials

A pear of the sort "Kieffer Seedling" (Kiferov sejanac), was purchased at a local producer. The pear was picked while fully ripe and mature after which it was cold stored in a cooling chamber at a temperature of 3-4 °C. The moisture of the fresh pear was 4,88 g/g_{dm}. Before commencing with the experiment the pear was kept for a certain time at room temperature with the aim of balancing the temperature of the fruit and the environment. After that, the scarfskin was peeled off from the fruit, the seeds and the pedicle were removed, and the pear was blended in a laboratory blender.

Methods

It was a two-factor experiment. The first factor was the air temperature needed for drying, between 45 °C and 65 °C. The second factor of the experiment was the adding of ascorbic acid to the pear pulp, prior to the drying process, in the amount of 1 % and 2 % of the full mass of the prepared fruit pulp. The fruit pulp was dried at a constant air speed of 1.5 m/s and with absolute air humidity of cca. 0.0106 kg_w/kg_{dair}. With every experiment, cca. 1500 g of prepared pulp was set in a layer 5mm thick, on baking sheet paper with the desired effect of avoiding it to stick to the surface. The baking sheet paper with the fruit pulp was put on the tray in the laboratory convective dryer.

The experiment was done as a full factorial experiment with three repetitions. Besides this, there was another control experimental unit done, without the addition of the ascorbic acid.

Tissue color of the pear was measured immediately after the removal of the scarfskin and after the drying process with the use of a colorimeter Konika Minolta CR-400. The color of all the samples was measured at 10 different measurable surfaces.

The color was representedin a CIE L^*(whiteness/brightness), a^* (redness/greenness) and b^* (yellowness/blueness), color scheme. The total color difference (ΔE), hue angle for dried material, (h^o), hue angle for fresh material (h_{fresh}), and chromaticity (C^*) were expressed in Eqs. 1, 2, 3 and 4.

$$\Delta E = \sqrt{(L^* - L_0)^2 + (a^* - a_0)^2 + (b^* - b_0)^2} \quad (1)$$

$$h^o = \arctan\left(\frac{b^*}{a^*}\right) \quad (2)$$

$$h_{fresh} = 180 + \arctan\left(\frac{b_0}{a_0}\right) \quad (3)$$

$$C^* = \left(\sqrt{(a^{*2} + b^{*2})}\right) \quad (4)$$

where,L_0, a_0, b_0 are the color values before drying, while L^*,a^*, b^* are the color values after drying.

A standard volumetric method was used to determine the content of vitamin C in fresh samples and the samples collected after the drying process.

The kinetics of convective drying was measured with the use of a laboratory convective dryer "IVA-2", which has the ability to continuously measure mass of the sample during the process of drying *(Pavkov 2012)*. The changes in mass of the fruit pulp during the process of drying and the changes in air temperature were recorded onto a computer in 5min intervals, with the use of the laboratory acquisition National Instrument. Every experiment lasted until there was the moisture of the pulp reached $\omega_{tdb} \approx 0,111$ g/g_{dm}.

The drying data from air drying test were then expressed as moisture radio (MR), calculated according to the following equation:

$$MR = \frac{X_t - X_{eq}}{X_0 - X_{eq}} \quad (5)$$

where X_t, X_0, X_{eq}, aremoisture content at time t (kg/kg $_{d.b.}$); initial moisture content ($kg/kg_{d.b.}$) and equilibrium moisture content (kg/kg $_{d.b.}$), respectively.

The drying curves (MR) were fitted by means of four different moisture ration models that are widely used in most food and biological materials (Table 1.)

The correlation coefficient (R), reduced chi – square (X^2) and root mean square error (RMSE) were used as the primary criterion to select the best equation to account for variation in the drying curves of the dried samples. Reduced X^2 is used to determine the accuracy of the fit. The lower the values of the reduced X^2, the better accuracy of the fit. The RMSE gives the deviation between the predicted and experimental values and it is required to reach zero *(Serdar and Bese, 2016, Zhengfu et al., 2007, Ertekin and Megnes, 2006)*.

RESULTS AND DISCUSSION

The "Kieffer Seedling" (Kiferov sejanac) pear is characterized by an expressed oxidation of the fruit tissue and scarfskin, which is noticeable during the drying process. During the preparation of the control sample, without the ascorbic acid, after the blending, there was an instant visible darkening of the sample. There was a lesser extent of darkening of the sample before the drying process when the ascorbic acid, in the amount equal to 1 % of the mass of the sample, was added; and even to a lesser extent with the 2 %. The measured values in the CIE color system L^*, a^* and b^*, after the drying process, with a total color difference (ΔE), hue angle (h^o) and chromaticity (C^*) were shown in table 2. The analysis of the measured values established that the lowest change in color was accomplished by adding ascorbic acid in the amount of 2 % of the pulp mass and by using the drying temperature of 45 °C, that resulted in the total change of color ΔE= 23.981.

The highest change in color was accomplished at the drying air temperature of 65 °C and by adding ascorbic acid in the amount of 1% and it equals ΔE= 30.039. The change of color in the control sample, with no ascorbic acid added, equals ΔE=40.536, at the temperature of 45 °C while the total change in color is ΔE=36.054 at the temperature of drying air of 65 °C. The results of the statistical importance of the influence of the factor as well as the interaction of influence of the factor were shown in table 3.Based on the analysis of the variance, the content of ascorbic acid has a statistically important influence on the conservation of color in the sample during convective drying.

However, there is no statistically important influence of the drying air temperature on the sample. Based on visual control, there is no significant difference in conservation of color between samples where 1 % of ascorbic acid was added and those with 2 %.

Table 1. Mathematical models applied to the drying curves

No.	Model	Name of model	References
1.	$MR = \exp(-kt)$	Newton	*Bon et al., 2007*
2.	$MR = \exp(-kt^n)$	Page	*Hassan-Beygi et al 2009*
3.	$MR = a\exp(-k_0t)$	Hend. and Pabis	*Hend. and Pabis, 1961*
4.	$MR = a\exp(-kt) + c$	Logarithmic	*Bon et al., 2007*

** k - drying constant, n - model exponent, a, b, c - model coefficients and t - drying time*

Table 2. Color change results

Experiment factors		Measured values					
Drying air temperature [°C]	Amount of ascorbic acid [%]	*L**	*a**	*b**	**Δ*E***	*h*°	*C**
45	1	58.293	9.389	41.729	29.169	77.319	42.77
	2	65.154	5.364	40.338	**23.981**	82.425	40.69
	Control sample	35.101	15.110	18.432	40.536	50.656	23.83
65	1	55.263	14.011	37.607	**30.039**	69.566	40.13
	2	65.005	6.872	40.148	27.014	80.286	40.73
	Control sample	42.062	16. 474	26.929	36.054	58.543	31.56
Color of the fresh pear		L_o	a_o	b_o	-	h_{fesh}	C^*_{fresh}
		71.676	-2.262	18.712		96.893	18.84

Table 4. shows the values of vitamin C content measured in pear samples after the drying process, together with the content of vitamin C in the pulp prepared for the drying (with the addition of the ascorbic acid). The C vitamin content measured in the fresh pear (without adding ascorbic acid) amounted to cca. 24 mg/100g_{db}. Similar results, when it comes to the content of vitamin C in a pear, were measured by the group of authors *Guo, et al., 2003; Chen, et al., 2007 and Sanchez, et al., 2003.*

Table 3. Statistical results of the influence of the factor on color change

Effect	SS	DF	MS	**F**	**p**
Intercept	**77540.46**	**1**	**77540.46**	**2589,279**	**0.00000**
Air temp.	0.74	1	0.74	0.025	0.87521
Ascorbic acid cont.	**2277.10**	**2**	**1138.55**	**38.019**	**0.00000**
Air temp. * Asc. acid cont.	**199.53**	**2**	**99.77**	**3.331**	**0.04052**
Error	2515.53	84	29.95		

The content of vitamin C in samples after adding ascorbic acid amounts to between 5000 and 5500 mg/100g_{db}, with 1 % of ascorbic acid, or 10000-11000 mg/100g_{db} with 2 % of ascorbic acid. After convective drying, there was a marked reduction in vitamin C, in all samples. In samples where ascorbic acid was added, the largest reduction of vitamin C was noted at the drying air temperature of 45 °C. This occurrence can be explained by the increase in time of the drying process when 45 °C is compared to the air temperature of 65 °C. In control samples, the content of vitamin C amounted to cca. 4-5 mg/100g_{db}, at both drying air temperatures. In other words, there was a marked reduction of vitamin C equal to cca. 77-80 %. In samples where ascorbic acid was added the reduction of vitamin C is over 99 %, in all samples. However, it is important to note that by adding ascorbic acid the sample was significantly enriched with vitamin C before the drying process, therefore the remaining vitamin C, after the drying process, is higher than the content of vitamin C measured in fresh pear samples.

Table 4. Vitamin C content

Experiment factors		Content of vitamin C in samples prepared for the drying process [mg/100g db]	Vitamin C in samples after the drying process [mg/100g]	Level of vitamin C reduction [%]
Drying air temperature [°C]	Amount of ascorbic acid [%]			
45	1	5332.02	28.55	99.46
	2	10640.16	81.83	99.23
	Cont. Samp.	23.88	5.48	77.04
65	1	5630.92	41.08	99.27
	2	11236.61	118.60	98.94
	Cont. Samp.	25.22	4.79	80.97
Fresh sample		24.53		

Drying kinetics

Statistical parameters for four mathematical models of convective drying of pear pulp R, X^2, RMSE, are shown in table 5. The Page model best shows the convective drying of pear pulp in a thin layer at air temperatures of 65 °C. The correlation coefficient for the Page model is R=0.998. Furthermore, this model has the lowest value of the reduced X^2= 0.000262 and the lowest value of *RMSE*= 0.02.Convective drying of pear pulp, at air temperature of 45 °C is best shown by the Logarithmic model. The correlation coefficient is R=0.999660, value of the reduced is X^2= 0.000066 and *RMSE*= 0.01. The whole drying process of the pear pulp at temperature of 65 °C took around 350 min, and during that the moisture of the pulp was reduced from the starting $\omega_{0db} \approx 4.88$ g/g_{dm} (cca. 83 % moisture relative to the moisture bas) to $\omega_{t\ db} \approx 0.111$ g/g_{dm} (cca. 10 % moisture relative to the moisture base). The experimental results of the kinetics of drying and the results predicted by the Page model of convective drying of the pear pulp are shown in figure 1. The drying process of the pear pulp at temperatures of 45 °C, lasted longer than in the previous case and amounts to 480 min. The experimental results of the kinetics of drying and the results predicted by the Logarithmic model for convective drying of pear pulp are shown in picture 2. Table 6. Shows the constants and the coefficients of the mathematical models Page and Logarithmic, for the kinetics of convective drying of the pear pulp at temperatures of 65 °C and 46 °C.

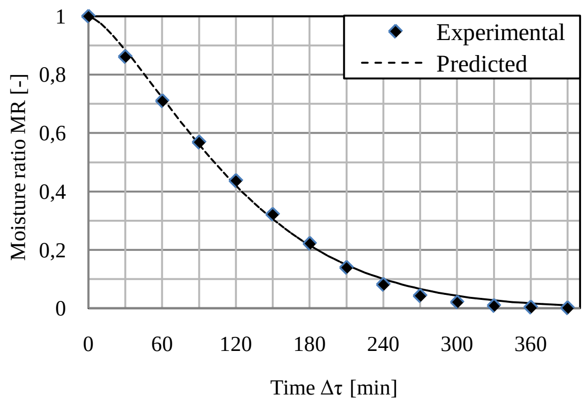

Fig. 1. Experimental and predicted moisture ratio for convective drying of organic pear pulp at 65 °C air temperature

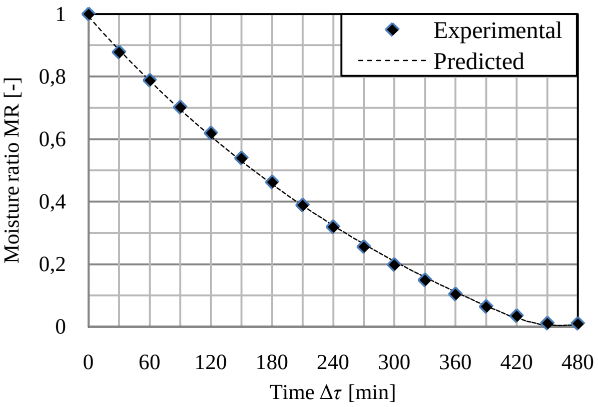

Fig. 2. Experimental and predicted moisture ratio for convective drying of organic pear pulp at 45 °C air temperature

Table 5. Statistical results of four mathematical models for pear pulp convective drying

Name of model	Air temperature	Statistical coefficients		
		R	X^2	*RMSE*
Newton	45°C	0.981812	0.003078	0.06
	65°C	0.981130	0.003731	0.06
Page	45°C	0.995280	0.000804	0.03
	65°C	**0.998685**	**0.000262**	**0.02**
Henderson and Pabis	45°C	0.985197	0.002509	0.05
	65°C	0.988210	0.002340	0.05
Logarithmic	45°C	**0.999660**	**0.000066**	**0.01**
	65°C	0.997710	0.000455	0.02

Table 6. Constants and coefficient for Page and Logarithmic mathematical model of organic pear pulp convective drying

Name of model	Air temp.	*k*	*n*	*a*	*c*
Page	65 °C	0.00106	1.40103	-	-
Logarithmic	45 °C	0.00244	-	1.50465	-0.51307

CONCLUSION

This paper shows the influence of convective drying of the pear pulp produced in accordance with the organic principles of the "Kieffer Seedling" (Kiferov sejanac) with the aim of producing pear leather-rolls.

It has been established that the least amount of color change occurs during drying with the addition of ascorbic acid in the amount of 2 %, relative to the mass of the pulp, and the highest change was noted on the control sample, without ascorbic acid. With the use of dispersive analysis, it has been established that the amount of ascorbic acid within the sample significantly affects the conservation of color in the sample, while the air temperature used for the drying process does not have a statistical influence, based on the range of 45-65 ℃, in given experimental conditions. By the use of analysis of the total color difference ΔE, it has been established that there is no significant difference in conservation of color when adding 1 % in comparison to the addition of 2 % of ascorbic acid relevant to the mass of the sample.

In samples with the addition of ascorbic acid, the largest reduction of vitamin C was achieved at drying air temperatures of 45 °C. This occurrence can be explained by the longer time needed for the drying process than with the temperatures of 65 °C. In samples where ascorbic acid was added, the reduction of vitamin C amounts to approximately 99 %, in all drying regiments. However, the ascorbic acid, as an antioxidant supplement, considerably raises the total content of vitamin C in the end product. The process of drying pear pulp at air temperatures of 65 °C, lasted for around 350 min, while the drying process at the temperature of 45 °C took around 480 min and resulted in the decrease of the moisture of the pulp from the starting value from $\omega_{t\ db} \approx 4.88$ g/g_{dm} (cca. 83% moisture relative to the moist base), to $\omega_{t\ db} \approx 0.111$ g/g_{dm} (cca. 10% moisture relative to the moist base).By examining the four, most frequently used models for convective drying based on the statistical indicators R, X^2, RMS, it has been determined that the Page and Logarithmic models best show the convective drying of pear pulp in a thin layer at temperatures of 65 °C and 45 °C respectively.

REFERENCES

Bon, J., Rossello, C., Femenia, A., Eim, V., Simal, S. (2007). Mathematical modeling of drying kinetics for apricots. Influence of the external resistance to mass transfer. Drying Technology, 25, 1829–1835.

Chen, J., Wang, Z., Wu, J., Wang, Q., Hu, X., (2007). Chemical compositional characterization of eight pear cultivars grown in China. Food Chemistry, 104, 268-275.

Demarchi, M. S., Quintero, Ruiza, A. N., Concellóna, A., Ginera, A. S. (2013). Effect of temperature on hot-air drying rate and on retention of antioxidant capacity in apple leathers. Food and Bioproducts Processing, 91, 310-318.

Ertekin, C., Menges, O., H. (2006). Mathematical modeling of thin layer drying of Golden apples. Journal of Food Engineering, 77, 119-125.

Guo,C., Yang, J., Wei, J., Li, Y., Xu, J., Jiang, Y. (2003). Antioxidant activities of peel, pulp and seed fractions of common fruits as determined by FRAP assay. Nutrition Research, 23, 1719-1726.

Hassan-Beygi, S.R., Aghbashlo, M., Kianmehr, M.H., Massah, J. (2009). Drying characteristics of walnut (Juglans regiaL.) during convection drying. International Agrophysics, 23, 29–135.

Henderson, S.M., Pabis, S. (1961). Grain drying theory. I.Temperature effect on drying coefficient. Journal of Agricultural Engineering Research, 6 (3), 169–174.

Kucuk, H., Midilli, A., Kilic, A., Dincer, I., (2014). A Review on Thin-Layer Drying-Curve Equations. Drying Technology: An International Journal, 32 (7), 757-773.

Lutovska, Monika, Mitrevski, V., Pavkov, I., Babić, M., Geramitcioski, T., Mijakovski, V., Bundalevski, S.(2015). Modeling of thin-layer drying of quince. Journal on Processing and Energy in Agriculture, 19 (1), 12-16.

Pavkov, I. (2012). Kombinovana tehnologija sušenja voćnog tkiva. Doktorska disertacija. Poljoprivredni fakultet, Novi Sad.

Radojčin, M., Babić, M., Pavkov, I., Stamenković, Z. (2010). Color parameters change of quince during combined drying. Journal on Processing and Energy in Agriculture, 14 (2), 81-84.

Ratti, C., (2001). Hot air and freeze-drying of high-value foods: a review. Journal of Food Engineering, 49, 311–319.

Sanchez, C.G. Andrea, Gil-Izquierdo, Gil, I. Marıa, (2003). Comparative study of six pear cultivars in terms of their phenolic and vitamin C contents and antioxidant capacity.Journal oftheScienceofFoodandAgriculture, 83, 995-1003.

Serdar, A., Bese, A., V. (2016). Convective drying of hawthorn fruit (Crataegus spp.): Effect of experimental parameters on drying kinetics, color, shrinkage and rehydration capacity. Food Chemistry, 210, 577-584.

Tepć, Aleksandra (2012). Bojene materije voća i povrća. Monografija nacionalnog značaja i pomoćni udžbenički matrerijal. Tehnološki fakultet, Novi Sad.

Tontul I., Topuz A. (2017). different drying methods on the physicochemical properties of pomegranate leather (pestil). LWT - Food Science and Technology. 80, 294-303.

Vakula, Anita, Radojčin, M., Pavkov, I., Stamenković, Z., Tepić Horecki, Aleksandra, Šumić, Z., Pavlić, B.(2015). The impact of different drying methods on quality indicators of red currants (ribesrubrum l.). Journal on Processing and Energy in Agriculture, 19 (5), 249-254.

Wang, C.Y., Singh, R.P. 1978. A single layer drying equation for rough rice. ASAE Paper No: 3052 ASAE, St Joshep, MI

Zhengfu, W., Junhong, S., Xiaojun, L., Fang, C., Guanghua, Z., Jihong W., Xiaosong H. (2007). Mathematical modeling on hot air drying of thin layer apple pomace. Food research International, 40, 39-46.

Received: 15. 11. 2018. Accepted: 28. 11. 2018.