Mustafa Kemal Üniversitesi Tarım Bilimleri Dergisi 24 (Özel Sayı):71-77, 2019
(*Mustafa Kemal University Journal of Agricultural Sciences* 24 (Special Issue):71-77, 2019)
e-ISSN: 2667-7733
http://dergipark.org.tr/mkutbd

1st International Congress on Biosystems Engineering 2019 **ARAŞTIRMA MAKALESİ/RESEARCH ARTICLE**

Effects of different drying conditions on physical changes of apple (*Malus communis* L.)

Elmaların (*Malus communis* L.) bazı fiziksel değişimlerine farklı kurutma koşullarının etkisi

Necati ÇETİN [1], Cevdet SAĞLAM[1], Bünyamin DEMİR[2]
[1]*Erciyes University, Department of Biosystems Engineering, Faculty of Agriculture, 38039, Kayseri, TURKEY.*
[2]*Mersin University, Department of Mechanical and Metal Technologies, Vocational School of Technical Sciences, 33343, Mersin, TURKEY.*

MAKALE BİLGİSİ / ARTICLE INFO

***Makale tarihçesi / Article history*:**
Geliş tarihi /Received:09.10.2019
Kabul tarihi/Accepted:16.12.2019

***Keywords*:**
Apple, cabin type dryer, size, color.

Corresponding author: Necati ÇETİN
✉: necaticetin@erciyes.edu.tr

Ö Z E T / A B S T R A C T

Aims: The aim of this study was to investigate some physical changes of apple dried in cabin type dryer and to determine optimum drying conditions.

Methods and Results: The volume, diameter, area, width, and thickness properties of fresh fruits and dried fruits were measured using a digital caliper as three replications. Color of products was measured according to CIE-L^*, a^*, and b^* color space, and was calculated color index (CI), hue angle (h^*), and chroma (C^*) values. According to the findings, optimum drying condition was achieved in cabinet type dryer with the drying parameters of 7 mm 10 hours 50°C and 7 mm 10 hours 60°C. In addition, the highest chroma values after drying were obtained with the drying parameters of 5 mm 9 hours 50°C.

Conclusions: In the study, a positive correlation (p=0.99) was found between initial L^* and initial area, initial chroma and initial b^*, final a^* and final b^*.

Significance and Impact of the Study: Drying is the mass transfer process consisting of the removal of water from the product in order to extend the storage period of the agricultural product and to create a new product market. Drying stages of agricultural products consist of a warming phase, drying stage with constant speed and drying stage with decreasing speed. Due to the loss of moisture during the drying process, some physical changes occur in the products. The optimum drying duration, drying temperature and product thickness should be determined in order to achieve the desired moisture level of the dried product in different drying conditions.

Atıf / Citation: Çetin N, Sağlam C, Demir B (2019) Effects of Different Drying Conditions on Physical Changes of Apple (*Malus communis* L.). *MKU. Tar. Bil. Derg.* 24 (Özel Sayı) :71-77

INTRODUCTION

Apple with an old and deep-rooted is the second most widely cultivated fruit after banana. With an adaptation capacity to various ecologies, apple is grown over large geographical areas (Baytekin and Akca, 2011). World annual production has about 76.5 million tons of apple. Turkey with an annual production of 2.9 million tons has third place in world apple production after China and the USA (FAO 2012).

Drying is the process of decreasing the moisture in its structure in order to extend the storage periods of agricultural products (Aktas et al., 2013). In terms of the nutritional value of the product as well as energy saving of drying method, different types of drying methods are investigated (Gungor and Ozbalta, 1997; Kartal Kangaloglu, 2011).

Convective drying is one of the most commonly used methods. Circulating the air over the product by heating the removal of water. In this way, the drying time is shortened compared to the open sun drying process, the product is better in terms of quality and hygiene. In addition, process control is easy and investment and operating costs are low (Mundada et al., 2010; Leonid et al., 2006; Bondaruk et al., 2007; Orikasa et al., 2008; Hiranvarachat et al., 2011).

Due to the loss of moisture during the drying, some physical changes occur in the products. Optimization of drying duration and temperature contributes to improving product quality. In this study, some physical changes of dried apple and optimum drying conditions were determined in cabin type dryer.

MATERIAL and METHODS

''Red Chief'' apple variety constituted the plant material of this study. Apples were obtained from an apple orchard in Kayseri province of Turkey. Dimensions were measured with a digital caliper (±0.01 mm) and 30 fruits were used for each dimensional measurement. The mass of each fruit was measured using a digital balance (±0.001 g). Apples were cut cylindrical in different sizes with product slicer machine. Periodically the volume, area, diameter, width, and thickness properties were measured. The tests were conducted with 3 replications in complete factorial experimental design.

Color measurements were performed with a chromameter (CR-400; Konica Minolta, Japan). Drying was carried out in a single unit drying cabinet (ETHK-20M drying cabinet) with a capacity of 1500 kg. The moisture content (wet basis) obtained from the drying experiments was calculated by the following equation. (Yagcıoglu, 1999).

$$MR(w.b.,\%) = \frac{W_w - W_d}{W_w} \times 100 \qquad Eq.(1)$$

where;

MR: moisture ratio (w.b.%),
W_w: Wet mass of product (g),
W_d: dry mass of product (g).

Color measured CIE-L^*, a^*, and b^* values were used to calculate color index (CI), hue angle (h^*), and chroma (C^*) values (McGuire, 1992):

$$c^* = \sqrt{(a^*)^2 + (b^*)^2} \qquad Eq.(2)$$

$$h^* = \tan^{-1}(b^*/a^*), \qquad (\text{if } a^* > 0 \text{ and } b^* \geq 0) \qquad Eq.(3)$$

$$h^* = 180 + \tan^{-1}(b^*/a^*), \qquad (\text{if } a^* < 0 \text{ and } b^* \geq 0) \qquad Eq.(4)$$

$$h^* = 180 + \tan^{-1}(b^*/a^*), \qquad (\text{if } a^* < 0 \text{ and } b^* < 0) \qquad Eq.(5)$$

$$h^* = 360 + \tan^{-1}(b^*/a^*), \qquad (\text{if } a^* > 0 \text{ and } b^* < 0) \qquad Eq.(6)$$

$$CI = \frac{1000\, a^*}{L^*\, b^*} \qquad Eq.(7)$$

The drying process was carried out at two different product thicknesses (5 and 7 mm), two different durations (9 and 10 hours) and two different temperatures (50 and 60°C) with combinations. Area and volume of the product were calculated by the following equations:

$$Area = 2\pi r(r + h) \qquad Eq.(8)$$

$$Volume = \pi r^2 h \qquad Eq.(9)$$

where;
r: radius of the sample (mm),
h: thickness of the sample (mm).

Principal components analysis (PCA) was performed using PAST version 3.20 software (Hammer et al., 2001). Correlations among physical data were determined using Pearson correlations with SPSS version 19.0 software (IBM SPSS® Statistics, 2010).

RESULTS and DISCUSSION

Some drying parameters and physical properties of the product are given in Table 1 and Table 2. The moisture (% w.b.) values were found to be very close to each other. The highest is at 5 mm 9 hours 50°C and the lowest is at 7 mm 10 hours 50°C. The highest outer diameter difference was determined at 7 mm 10 hours 60°C. It was observed that the inner diameter values increased slightly. The most obvious thickness changes occurred at 5 mm 9 hours 50°C and 7 mm 10 hours 50°C. The area and volume values are given in Table 3. The highest volume differences were found at 7 mm 10 hours 50°C. The highest area difference was determined at 7 mm 10 hours 60°C.

Table 1. Some physical parameters before drying

Parameters	Initial Mass (g)	Outer Diameter (mm)	Inner Diameter (mm)	Moisture (% w.b.)
5 mm 9 hours 50°C	10.83	59.68	22.19	88.92
7 mm 10 hours 50°C	19.32	70.85	24.18	84.73
5 mm 9 hours 60°C	12.05	64.95	20.26	85.83
7 mm 10 hours 60°C	14.58	62.69	20.17	86.17

Table 2. Some physical parameters after drying

Parameters	Final Mass (g)	Outer Diameter (mm)	Inner Diameter (mm)	Final Thickness (mm)
5 mm 9 hours 50°C	1.20	51.86	22.80	2.32
7 mm 10 hours 50°C	2.95	61.79	24.73	2.58
5 mm 9 hours 60°C	1.67	55.75	20.50	2.80
7 mm 10 hours 60°C	2.07	52.89	21.25	3.59

Table 3. Area and volume values

Parameters	Initial Area (mm^2)	Final Area (mm^2)	Initial Volume (mm^3)	Final Volume (mm^3)
5 mm 9 hours 50°C	2703.36	1391.21	12045.47	4184.06
7 mm 10 hours 50°C	3994.42	2767.67	24370.60	6494.82
5 mm 9 hours 60°C	3484.39	2265.01	20946.05	5908.11
7 mm 10 hours 60°C	3099.37	1406.17	13828.06	6611.78

Color properties at $L^*a^*b^*$ color space are given in Table 4 and 5. In the study, it was determined that all color values increased except for 7 mm 10 hours 50°C. While L^* and b^* values decreased and a^* value increased at 7 mm 10 hours 50°C. The highest and lowest L^* values after drying were obtained at 7 mm 10 hours 60°C and 7 mm 10 hours 50°C respectively.

Table 4. Color properties before drying

Parameters	L^*	a^*	b^*
5 mm 9 hours 50°C	45.21	-2.63	17.13
7 mm 10 hours 50°C	75.96	-6.76	27.67
5 mm 9 hours 60°C	63.38	-1.60	21.19
7 mm 10 hours 60°C	53.26	-2.37	21.16

Table 5. Color properties after drying

Parameters	L^*	a^*	b^*
5 mm 9 hours 50°C	67,35	0,33	32,54
7 mm 10 hours 50°C	64,32	-0,65	24,05
5 mm 9 hours 60°C	70,87	0,08	30,50
7 mm 10 hours 60°C	72,76	0,28	31,82

Chroma, hue angle and color index values are given in Table 6 and Table 7. Similar to L^*, a^* and b^* values, chroma and hue angle are increased at all drying parameters except for 7 mm 10 hours 50°C. Color index increased in all drying parameters. The highest chroma values after drying were obtained at 5 mm 9 hours 50°C.

Table 6. Chroma, Hue angle and Color index before drying

Parameters	Chroma	Hue Angle	Color Index
5 mm 9 hours 50°C	17.33	178.58	-3.39
7 mm 10 hours 50°C	28.49	178.67	-3.22
5 mm 9 hours 60°C	21.29	178.54	-2.10
7 mm 10 hours 60°C	21.25	178.50	-1.19

Table 7. Chroma, Hue angle and Color index after drying

Parameters	Chroma	Hue Angle	Color Index
5 mm 9 hours 50°C	32.54	181.56	0.15
7 mm 10 hours 50°C	24.06	178.46	-0.42
5 mm 9 hours 60°C	31.82	181.56	-0.51
7 mm 10 hours 60°C	30.50	181.57	0.04

The statistical correlation between physical properties are given in Table 8. The correlations are marked in bold. A positive correlation (p=0.99) was found between initial L^* and initial area, initial chroma, and initial b^*, final a^* and b^*. However, a negative correlation (p=-0.99) was found between the final chroma and the final diameter. The physical properties centroid coordinates shown is in Figure 1. The scatter plot showed the physical properties centroids with related to their canonical discriminant functions. Final thickness, final volume, and initial diameter have been observed to have a significant effect. In addition, initial L^*, initial b^* and initial chroma parameters are closely related. Initial color index and final L^* were also found to have a significant effect.

Table 8. Correlation matrix for physical properties

Parameters	Initial Mass	Initial Outer Diameter	Initial Inner Diameter	Moisture	Final Mass	Final Outer Diameter	Final Inner Diameter	Final Thickness	Initial Area	Final Area	Initial Volume	Final Volume	Initial L*	Initial a*	Initial b*	Final L*	Final a*	Final b*	Initial Chroma	Initial Hue Angle	Initial Color Index	Final Chroma	Final Hue Angle	Final Color Index
Initial Mass	1																							
Initial Outer Diameter	.88	1																						
Initial Inner Diameter	.63	.58	1																					
Moisture	-.79	-.90	-.17	1																				
Final Mass	.99**	.91	.55	-.87	1																			
Final Outer Diameter	.85	.99**	.69	-.81	.87	1																		
Final Inner Diameter	.98*	.93	.72	-.77	.97*	.92	1																	
Final Thickness	.13	-.07	-.64	-.35	.19	-.23	-.03	1																
Initial Area	.82	.99**	.47	-.93	.87	.96*	.86	-.03	1															
Final Area	.68	.94	.55	-.78	.72	.96*	.77	-.31	.95*	1														
Initial Volume	.68	.94	.45	-.85	.73	.94	.75	-.19	.97*	.99**	1													
Final Volume	.72	.68	-.07	-.92	.79	.55	.64	.69	.70	.47	.56	1												
Initial L*	.81	.99**	.50	-.91	.86	.97*	.86	-.08	.99**	.97*	.98*	.67	1											
Initial a*	-.89	-.79	-.92	.51	-.84	-.84	-.93	.31	-.70	-.67	-.61	-.33	-.71	1										
Initial b*	.95*	.98*	.57	-.91	.98*	.95*	.97*	.06	.95*	.85	.87	.75	.95*	-.83	1									
Final L*	-.50	-.52	-.98*	.09	-.42	-.65	-.61	.78	-.43	-.57	-.46	.21	-.47	.83	-.48	1								
Final a*	-.88	-.96*	-.77	.75	-.88	-.99**	-.95*	.28	-.92	-.92	-.89	-.49	-.93	.91	-.94	.73	1							
Final b*	-.90	-.97*	-.77	.76	-.90	-.99**	-.96*	.24	-.92	-.90	-.88	-.52	-.93	.92	-.95*	.72	.99**	1						
Initial Chroma	.96*	.98*	.60	-.89	.97*	.96*	.98*	.03	.95*	.86	.86	.73	.95*	-.85	.99**	-.51	-.95*	-.96*	1					
Initial Hue Angle	.63	.68	.97*	-.28	.57	.79	.74	-.69	.60	.71	.62	-.03	.63	-.90	.63	-.98*	-.85	-.84	.67	1				
Initial Color Index	-.09	-.17	-.82	-.29	-.01	-.34	-.23	.96*	-.09	-.32	-.20	.59	-.14	.53	-.09	.91	.41	.39	-.13	-.82	1			
Final Chroma	-.98*	-.91	-.77	.73	-.96*	-.91	-.99**	.08	-.84	-.76	-.74	-.59	-.84	.96*	-.95*	.66	.95*	.96*	-.96*	-.78	.29	1		
Final Hue Angle	-.91	-.89	-.87	.63	-.88	-.93	-.96*	.30	-.82	-.80	-.75	-.41	-.83	.98*	-.90	.80	.97*	.98*	-.92	-.90	.48	.98*	1	
Final Color Index	-.42	-.79	-.16	.78	-.50	-.77	-.49	.13	-.86	-.91	-.94	-.51	-.87	.30	-.67	.21	.67	.65	-.66	-.37	.04	.46	.48	1

**Correlation is significant at the 0.01 level
*Correlation is significant at the 0.05 level

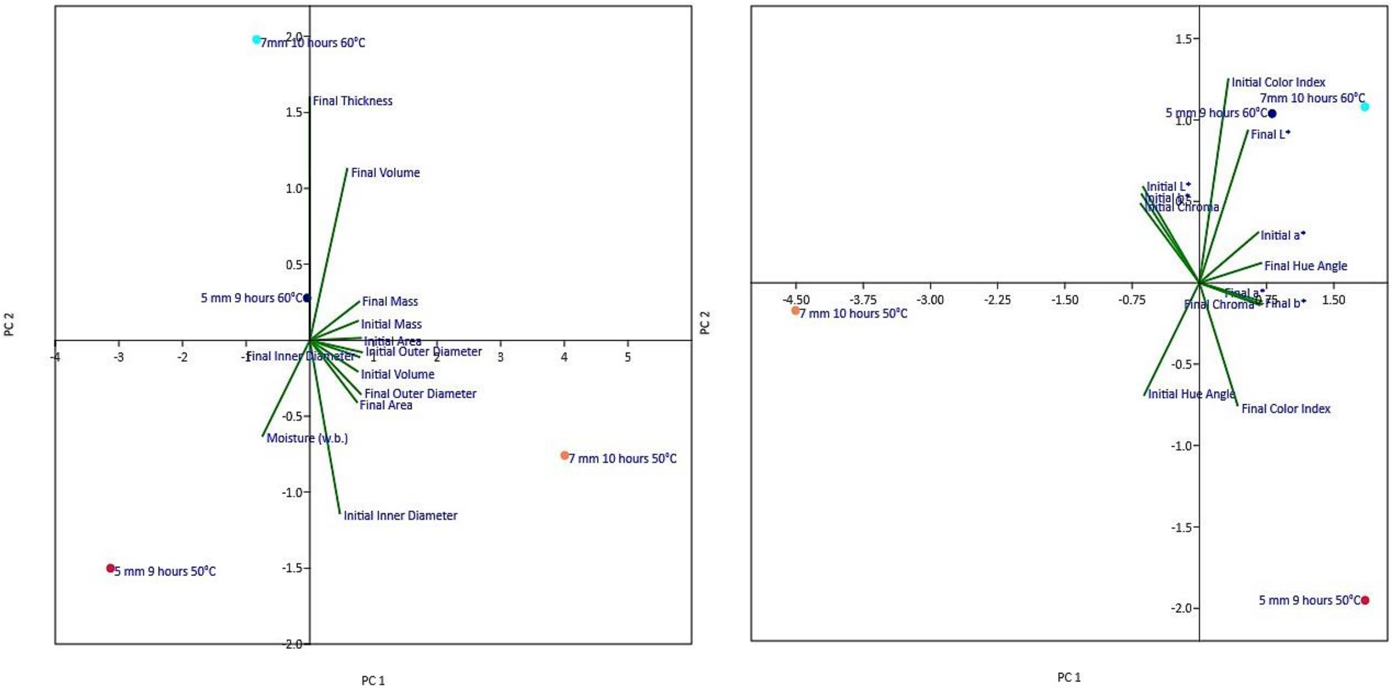

Figure 1. Principal components (PCs) analysis of physical properties

Physical and color properties and the identification key of single components are reported in Tables 9 and Table 10, respectively. A summary of the information contained in the physical and color properties was obtained by principal component analysis. PC1 had high loadings to almost physical and color properties. The loadings of the first two PCs functions explained 92.7% of the total variance in physical properties. Variance explained by PCs is 94.08% of the sum of the loadings of the first two components in color properties.

Table 9. Identification key of some physical properties and loadings of individual components to the first three factors (PCs) extracted by means of principal component analysis

Parameters	PC 1	PC 2	PC 3
Initial Mass	0.92	0.08	0.39
Initial Outer Diameter	0.99	-0.05	-0.07
Initial Inner Diameter	0.58	-0.70	0.42
Moisture	-0.90	-0.39	0.18
Final Mass	0.95	0.16	0.28
Final Outer Diameter	0.97	-0.22	-0.06
Final Inner Diameter	0.95	-0.07	0.31
Final Thickness	-0.01	0.98	0.15
Initial Area	0.98	0.01	-0.21
Final Area	0.90	-0.25	-0.35
Initial Volume	0.91	-0.13	-0.39
Final Volume	0.72	0.70	0.15
Variance explained by PCs (%)	73.74	18.96	7.30

Table 10. Identification key of color properties and loadings of individual components to the first three factors (PCs) extracted by means of principal component analysis

Parameters	PC 1	PC 2	PC 3
Initial L*	-0.90	0.39	-0.19
Initial a*	0.94	0.21	-0.27
Initial b*	-0.92	0.36	0.12
Final L*	0.77	0.63	0.09
Final a*	0.99	-0.08	0.04
Final b*	0.99	-0.09	0.01
Initial Chroma	-0.93	0.32	0.12
Initial Hue Angle	-0.88	-0.46	-0.10
Initial CI	0.46	0.83	0.29
Final Chroma	0.96	-0.09	-0.27
Final Hue Angle	0.99	0.08	-0.14
Final CI	0.61	0.51	0.61
Variance explained by PCs (%)	77.18	16.90	5.93

CONCLUSIONS

The physical properties of apple samples in different drying conditions were carried out in the cabinet type dryer. The thickness of the sample, drying period and temperature directly affected the drying characteristics. According to the physical properties, the optimum drying condition was determined as 7 mm 10 hours 50°C and 7 mm 10 hours 60°C. Determining the optimum drying parameters is important in terms of the quality and storage time of the dried product. In addition, the biochemical properties of the products must be known for precision drying. Since some measurements such as physical and biochemical are time-consuming, for future studies, the use of new technologies will be of great importance. The results obtained by the principal components analysis, which allow comparative evaluation of the multiple parameters examined in the study, are important for the optimization of drying processes. Determining and correlating some physical properties and optimizing the drying process in this way will make current contributions to the literature.

ÖZET

Amaç: Bu çalışmanın amacı, kabin tipi kurutucuda kurutulan elmaların bazı fiziksel değişikliklerini belirlemek ve optimum kurutma koşullarını tespit etmektir.

Yöntemler ve Bulgular: Kurutma öncesi ve sonrasında ürünlerin hacim, çap, alan, genişlik ve kalınlık özellikleri dijital bir kumpas kullanılarak üç tekerrürlü olarak ölçülmüştür. Ürünlerin rengi CIE-L*, a* ve b* renk uzayına göre ölçülmüş ve renk indeksi (CI), ton açısı (h*) ve kroma (C*) değerleri hesaplanmıştır. Bulgulara göre, kabin tipi kurutucuda optimum kurutma koşulları 7 mm 10 saat 50°C ve 7 mm 10 saat 60°C olarak saptanmıştır. Ayrıca, kurutma sonrası en yüksek kroma değerleri 5 mm 9 saat 50°C kurutma parametresine elde edilmiştir.

Genel Yorum: Bu çalışmada, ürünün kurutma öncesi L* değeri ile kurutma öncesi alanı, kurutma öncesi kroması ile kurutma öncesi b* değeri ve kurutma sonrası a* değeri ile kurutma sonrası b* değeri arasında pozitif bir ilişki bulunmuştur ($p = 0.99$).

Çalışmanın Önemi ve Etkisi: Kurutma, tarımsal ürünün depolama süresini uzatmak ve yeni bir ürün pazarı oluşturmak için suyun üründen uzaklaştırılmasını içeren kütle transfer işlemidir. Tarımsal ürünlerin kurutma aşamaları; ısınma aşaması, sabit hızda kuruma aşaması ve azalan hızda kuruma aşaması olarak karşımıza çıkmaktadır. Kurutma işlemi sırasında nem kaybına bağlı olarak ürünlerde bazı fiziksel değişiklikler meydana gelmektedir. Ürünün istenen nem düzeyine getirilmesi için farklı kurutma koşullarında optimum kurutma süresi, kurutma sıcaklığı ve ürün kalınlığı belirlenmelidir.

Anahtar Kelimeler: Elma, kabin tipi kurutucu, boyut, renk

DECLARATION OF CONFLICTING INTERESTS

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

REFERENCES

Aktas M, İlbas M, Yalcın A, Sahin M (2013). Experimental Investigation of Drying Behaviours in an Infrared Radiation Dryer. Journal of the Faculty of Engineering and Architecture of Gazi University, 28(4): 767-775.

Baytekin S, Akca Y (2011). Determination of Performance Different Apple Cultivars on M9 Apple Rootstock). J. Agric. Fac. Gaziosmanpasa Uni. (JAFAG). 28:45–51.

Bondaruk J, Markowski M, Blaszczak W (2007). Effect of drying conditions on the quality of vacuum-microwave dried potato cubes. J. Food Eng. 81: 306–312.

FAO (2012). Crop production statistics. www.fao.org Accessed 23.08.2019.

Gungor A, Ozbalta N (1997). Endüstriyel Kurutma Sistemleri (In Turkish). III.Ulusal Tesisat Mühendisliği Kongresi ve Sergisi, Bildiriler Kitabı, II. Cild, pp.737-747.

Hammer Ø, Harper DAT, Ryan PD (2001). PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1): 9pp.

Hiranvarachat B, Devahastin S, Chiewchan N (2011). Effects of acid pretreatments on some physicochemical properties of carrot undergoing hot air drying. Food Bioprod. Process. 89: 116-127.

IBM SPSS® Statistics (2010). IBM Company© Version 19. SSS Inc.

Kartal Kangaloglu, AS (2011). Research About Drying Time Efficiency of Microwave and Cabinet Dryer on (Fruity Product) Dried Fruit Pulp. Master Thesis. İstanbul Teknik University, İstanbul, p91.

Leonid AB, Vladimir PG, Andrew VB, Alexander ML, Valeriy L, Vladimir AK (2006). The investigation of low temperature vacuum drying processes of agricultural materials. Journal of Food Engineering, 74: 410-415.

McGuire RG (1992). Reporting of objective color measurements. HortScience 27: 1254-1255.

Mundada M, Hathan BS, Maske S (2010). Convective dehydration kinetics of osmotically pretreated pomegranate arils. Biosys. Eng. 107: 307-316.

Orikasa T, Wu L, Shiina T, Tagawa A (2008). Drying characteristics of kiwifruit during hot air drying. Journal of Food Engineering, 85: 303-308.

Yagcıoglu A (1999). Tarım Ürünleri Kurutma Tekniği (In Turkish). EÜZF Yayınları, İzmir, Türkiye, No: 536.