GIDA
THE JOURNAL OF FOOD
E-ISSN 1309-6273, ISSN 1300-3070

Research / Araştırma
GIDA (2020) 45(4)699-709
doi: 10.15237/gida.GD19158

THE EFFECT OF PRETREATMENTS AND VACUUM DRYING ON DRYING CHARACTERISTICS, TOTAL PHENOLIC CONTENT AND ANTIOXIDANT CAPACITY OF ARTICHOKE (*CYNARA CARDUNCULUS* VAR. *SCOLYMUS* L.) SLICES

Kubra Gizem SAHIN, Gulsah OZCAN-SINIR,
Feride DURMUS, Omer Utku COPUR[*]
Uludag University, Faculty of Agriculture, Department of Food Engineering, Bursa/ Turkey

Received /Geliş: 04.12.2019; *Accepted* / Kabul: 08.06.2020; *Published online* / Online baskı: 23.07.2020

Sahin, K.G., Ozcan-Sinir, G., Durmus, F., Copur, O.U. (2020). The effect of pretreatments and vacuum drying on drying characteristics, total phenolic content and antioxidant capacity of artichoke (Cynara cardunculus var. *Scolymus L.) slices. GIDA (2020) 45(4)699-709 doi: 10.15237/gida.GD19158*

Sahin, K.G., Ozcan-Sinir, G., Durmus, F., Copur, O.U. (2020). Önişlemlerin ve vakum kurutma yönteminin enginar (*Cynara cardunculus* var. *Scolymus* L.) dilimlerinde kurutma karakteristikleri, toplam fenolik madde içeriği ve antioksidan kapasite üzerine etkisi. *GIDA* (2020) 45(4)699-709 doi: 10.15237/gida.GD19158

ABSTRACT

In this study, boiling and steaming pretreatments applied on artichoke slices and then dried by using vacuum-assisted dryer (70°C with 10, 15 and 25 kPa) to determine the drying characteristics, color analysis, total phenolic content and antioxidant capacity. Color values showed differences according to pretreatments and drying conditions. In comparison to the fresh sample, the dried samples showed an important decrease in both antioxidant capacity and total phenolic content. The highest total phenolic content of vacuum dried artichoke slices (160.24±0.16 mg GA/100 g dw) was determined at 70°C-15 kPa with boiling water-treated samples. According to the drying characteristics, Page and Modified Page models were the best fitted drying models with the highest value of R^2 (for both 0.9989) and the lowest values of RMSE (0.0023 for both) and χ^2 (0.000067).

Keywords: Antioxidant capacity, artichoke (*Cynara cardunculus* L. var. *Scolymus*), mathematical modeling, vacuum drying.

---

[*] Corresponding author / *Yazışmalardan sorumlu yazar*
✉ ucopur@uludag.edu.tr, ✆ (+90) 224 294 1494 🖷 (+90) 224 294 1402

Kübra Gizem Şahin; ORCID no: 0000-0003-0298-0615
Gülşah Özcan-Sinir; ORCID no: 0000-0003-3954-0058
Feride Durmuş; ORCID no: 0000-0002-6431-1428
Ömer Utku Çopur; ORCID no: 0000-0002-1951-7937

ÖNIŞLEMLERIN VE VAKUM KURUTMA YÖNTEMININ ENGINAR (*CYNARA CARDUNCULUS* VAR. *SCOLYMUS* L.) DILIMLERINDE KURUTMA KARAKTERISTIKLERI, TOPLAM FENOLIK MADDE IÇERIĞI VE ANTIOKSIDAN KAPASITE ÜZERINE ETKISI

ÖZ

Bu çalışmada, farklı ön işlemler (suda haşlama ve buharla muamele) uygulanarak, vakumlu kurutucuda kurutulan (70°C'de 10, 15 ve 25 kPa) enginar dilimlerinin renk analizi, toplam fenolik madde içeriği, antioksidan kapasiteleri ve kurutma karakteristikleri incelenmiştir. Uygulanan ön işlemler ve kurutma parametreleri renk değerleri üzerinde farklılık oluşturmuştur. Kurutulmuş enginar dilimlerinde toplam fenolik madde içeriği ve antioksidan kapasite değerleri taze enginara kıyasla önemli oranda azalma göstermiştir. Vakum kurutma yapılan enginar dilimlerinde en yüksek toplam fenolik madde içeriği (160.24±0.16 mg GA/100 g dw) 15 kPa vakumda suda haşlama ön işlemine tabi tutulan enginar örneklerinde tespit edilmiştir. Enginar dilimlerinin kurutma karakteristikleri incelendiğinde uygulanan matematiksel modelleme sonucunda elde edilen verilere göre, en yüksek R^2 değeri (0.9989), en düşük χ^2 (0.000067) ve RMSE (0.0023) değerleri Page ve Modifiye Page modellere ait olduğu belirlenmiştir.

Anahtar kelimeler: Antioksidan kapasite, enginar (*Cynara cardunculus* L. var. *Scolymus*), matematiksel modelleme, vakum kurutma.

INTRODUCTION

Globe artichoke (*Cynara cardunculus* L. var. *Scolymus*) belonging to the Asteraceae family is a perennial herbaceous plant, which has been known since the 4th century BC. This plant has been used for its nutritional and therapeutic effects since ancient Egypt, Greek and Roman Empires (Lattanzio et al., 2009). Globe artichoke is an important crop especially, around the Mediterranean region. It is widely produced in Italy, Egypt, Spain, China and France as well as in the Near East countries like Turkey and Iran, in the Northern Africa (Morocco, Algeria, and Tunisia) and South America (Lombardo et al., 2012).

In recent years with the increasing interest in functional foods, globe artichoke had a high demand in consumer choices. Previous in vitro and in vivo studies proved its antioxidant, anticarcinogenic, antigenotoxic, reducing cholesterol, hepatoprotective, diuretic and anti-inflammatory effects, as well as antifungal, anti-HIV and antibacterial properties of globe artichoke extracts (Pandino et al., 2013; Eljounaidi et al., 2015). Although there were plenty of researches done about the chemical composition of artichoke leaves, however studies on the edible parts of the globe artichoke heart was not sufficient (Abu-Reidah et al., 2013).

Drying process have become important in the 20th century, because it is not just a preservation method, it also provides great convenience for storage, packaging and transportation of food products (Sagar and Suresh, 2010). The main purpose of the drying process is to provide the inhibition of microorganisms and prevent the spoilage of food products by reducing the moisture content and water activity (Vega-Galvez et al., 2009). Also, enzymatic and non-enzymatic browning reactions can be avoided with the decrease in moisture content and water activity in food products (Krokida et al., 2001). Blanching and steaming were the most widely used pretreatments in the dehydration of fruits and vegetables (McBean and others 1964).

The current study focused on the antioxidant activity and physicochemical changes in dried artichoke heart, which was dried by using a vacuum-assisted dryer with and without pretreatments and under different vacuum conditions (10, 15 and 25 kPa). Also, mathematical modelling of drying artichoke heart was carried out by using Lewis, Page, Modified Page, Henderson & Pabis and Logarithmic methods.

MATERIAL AND METHODS

Material

Artichoke hearts, Bayrampaşa variety, were supplied as fresh, peeled, and vacuum-packed during the harvesting period from Bursa Hasanağa province, and stored at +4°C until the vacuum drying process.

Preparation of Fresh Artichoke

Fresh artichoke hearts were cut into 2 mm thickness and 1x2 cm slices then the sliced artichokes were kept in 0.2% citric acid solution in order to prevent the polyphenoloxidase enzyme activity until next step. The samples were washed with tap water and drained on filter paper before pretreatments or drying process.

Pretreatments

Before drying, (1) no pretreatment and two types of pretreatments; (2) pretreated in boiling water for 1 min and steaming for 1 min, were applied to artichoke samples. The ratio between water and solid was 1 L / 50 g for boiling water pretreatment. In steaming, artichoke samples were homogenously and separately placed on the stainless steel blanching net and the net was located in the cooker without any contact with the boiling water. The lid of the cooker kept close for 1 min to avoid steam loss during steam pretreatment.

Drying Process

After pretreatments, samples were drained on filter paper and then equally distributed to aluminum trays without overlapping and then dried. Sliced artichokes were dried by using a vacuum-assisted dryer. 200 g samples were weighted, homogeneously distributed and dried in eight batches in aluminum tray. Vacuum drying (Memmert VO400, Germany, 49 L volume) was carried out at 70°C and under 10, 15 and 25 kPa pressures. The initial moisture content of artichokes were measured as 6.7, 9.0, and 10.5 g water/ g dry matter without pretreatment, boiling pretreatment, and blanching pretreatment, respectively. The moisture loss of samples during drying was recorded at 30 min. intervals periodically until the moisture content reaches to 0.06 g water/g DM (Özkan-Karabacak, 2019), which is a calculated limit to prevent the growth and reproduction of microorganisms in dried food. Every weighing process was carried out in maximum 15 s during drying treatment.

Drying is one of the most common preservation methods for extending the shelf life of fruits and vegetables by reducing the water content to a level so as to prevent the growth and reproduction of microorganisms and to inactivate many of the moisture-mediated deteriorative reactions (Mujumdar, 2014; Omolola et al., 2017).

Chemical Analysis

Total phenolic content and antioxidant capacity analysis

Extraction procedure of antioxidant and phenolic compounds was applied according to Vitali et al. (2009) by placing 2 g of grinded (Moulinex, China) fresh or dried samples and 20 mL extraction solution (HCl: methanol: water, 1: 80: 10) in a falcon tube and tubes were placed in a shaking water bath (Memmert WNB 22) at 20°C for 2h with 160 strokes per min. Total phenolic content and antioxidant capacity analyzes were done by using the supernatants of extracts after centrifugation (Beta et al., 2005; Vitali et al., 2009). Folin-Ciocalteu (FC) method was used for the determination of the total phenolic content. It was determined spectrophotometrically by using FC reagent at 725 nm and the results were expressed through the equation achieved from the gallic acid curve (R^2 =0.98) as "mg gallic acid equivalent (GAE)/ 100 g" (Zhang and Hamauzu, 2004). DPPH (2-diphenyl-1-picrylhydrazyl) (Katalinic et al., 2006), FRAP (Ferric Reducing Antioxidant Power) (Benzie and Strain, 1996), and CUPRAC (Copper (II) reducing antioxidant capacity) (Apak et al., 2005) methods were applied to determine antioxidant capacity. All of the results were expressed as μmol TE (trolox equivalent)/g in dried artichoke slices by using equation obtained from calibration curves. R^2 values of curves were determined as 0.99, 0.97 and 0.99 for DPPH, FRAP and CUPRAC methods, respectively.

Color analysis

Color analysis of the samples was measured by using the Konica Minolta CR-5 (Japan) color analyzer. Hunter *L, a, b, C,* and *h*° values were determined.

Mathematical modelling

Five different thin-layer drying models; Page (Sarsavadiva et al., 1999), Modified Page (Overhults et al., 1973), Henderson and Pabis (Westerman et al., 1973), Logarithmic (Yagcioglu, 1999) and Lewis (Doymaz, 2006) were used for the estimation of the best model, which reproduces the drying curve of artichoke slices (Table 1). The following equations were used to establish the moisture ratio (MR) and drying rate in artichoke slices during drying:

$$MR = \frac{M - M_e}{M_{i}\_M_e}$$

where MR is moisture ratio, M is the moisture content at a certain time (g water/g dry base), Mi is the primary moisture content (g water/g dry base) and M_e is the equilibrium moisture content (g water/g dry base) (Arslan and Ozcan, 2010).

Table 1: Mathematical models were used in the study

Model Name	Model	References
Page	MR = exp(-kt^n)	(Sarsavadiva et al., 1999)
Modified Page	MR = exp[(-kt)^n]	(Overhults et al., 1973)
Logarithmic	MR = a exp(-kt)+c	(Yagcioğlu, 1999)
Lewis	MR = exp(-kt)	(Doymaz, 2006)
Henderson and Pabis	MR = a exp(-kt)	(Westerman et al., 1973)

The root mean square error (RMSE) provides the deviation between the approximate and experimental values for the models. Higher correlation coefficients (R^2) and lower RMSE and Chi-square (χ^2) values were used to specify the perfection of the fit of the model to the vacuum drying curves of artichoke slices. These parameters were calculated using the following equations:

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}\left(MR_{exp,i} - MR_{pre,i}\right)^2\right]^{\frac{1}{2}}$$

$$x^2 = \frac{\sum_{i=1}^{N}\left(MR_{exp,i} - MR_{pre,i}\right)^2}{N - n}$$

where $MR_{exp,I}$ is the empirically dimensionless moisture ratio for test i, $M_{Rest,I}$ is the estimated dimensionless moisture ratio for test i, N is the number of observations and n is the number of constants in the model (Avhad and Marchetti, 2016).

Statistical analysis

The variant analysis was performed on the data achieved from analyzes for three times in accordance with “Randomized Block Design”. The difference between means was calculated by using the LSD test with the 5% probability and calculations were carried on “JMP 14” statistical software (JMP, 2018).

RESULTS AND DISCUSSION

Drying characteristics of artichoke slices

Time-dependent change of the moisture content of dried artichokes was given in Figure 1. When the figures were examined, a direct correlation was observed between absolute pressure and drying time. When the absolute pressure decreased drying time was also getting shorter. Differences in moisture content before the drying process could be explained by changes in texture due to the pretreatments. According to the applied pretreatments, artichoke slices subjected to boiling water were dried the latest, whereas the untreated artichoke slices were dried quickest. Özkan-Karabacak (2019) was also observed a decrement in drying time with the reduction in absolute pressure level in vacuum drying.

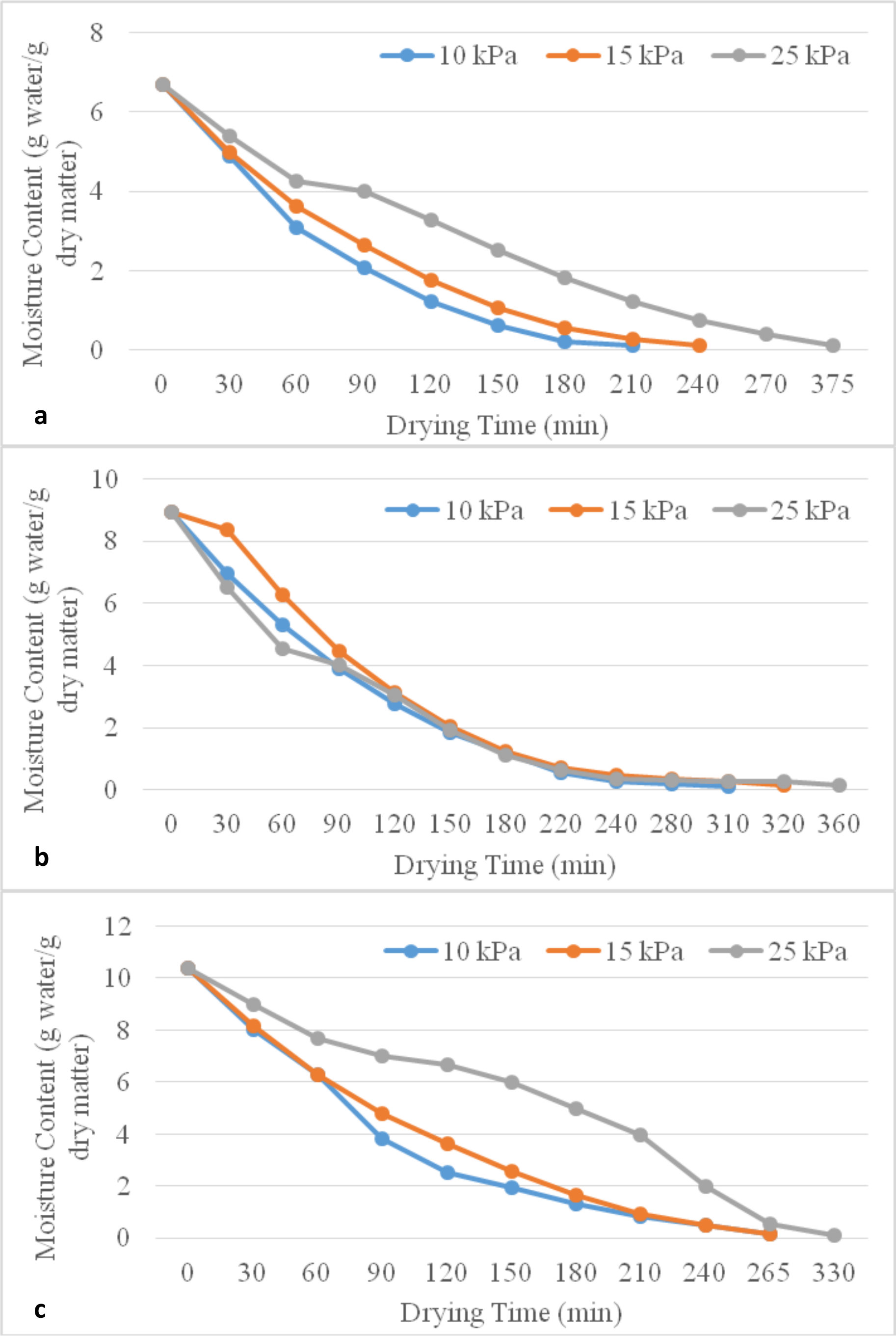

Figure 1: Drying curves of sliced artichokes without pretreatment (a), with boiling water pretreatment (b) and with steaming pretreatment (c)

Mathematical modeling was very important for engineering applications. They were mostly used in freezing, drying, heating and cooling processes. With the introduction of mathematical models in food engineering applications, time and material losses were minimized (Devres and Pala, 1993). Correlation factor (R^2) was the most important statistical value for the determination of the best mathematical model as well as χ^2 and RMSE values, which were calculated for each model used for the specification of the best model. As a result, the highest value of R^2 and the lowest χ^2 and RMSE values were expressed as the most appropriate mathematical model (Avhad and Marchetti, 2016).

According to the results of each mathematical model, Page and Modified Page models had the highest R^2 (0.9989) and lowest χ^2 (0.000067) and RMSE (0.0023) values. It was determined that the reduction in the experimentally determined moisture values during the drying process represented better in all drying temperatures and better in the Page and Modified Page models (Table 2). In a study, the drying kinetics of celery slices were investigated under convectional (70, 85 and 100°C), vacuum (50, 60 and 70 kPa) and microwave (190, 375 and 680 W) drying conditions. Authors were determined that Page and Modified Page were the best fitted models (Özkan-Karabacak et al., 2018). In another study, sliced kumquats were dried by using three different drying methods, microwave (375 W), hot air (70 and 80 °C), and vacuum (70 and 80 °C with 100 and 300 mbar). Page and Modified Page models were determined as the best fitted drying methods with the highest R^2 and the lowest RMSE and χ^2 values (Özcan-Sinir et al., 2019).

Table 2: Mathematical modelling of the drying process of artichoke samples

Model name	Pre-treatment	Application (Vacuum)	Model coefficients	R^2	X^2	RMSE
Page	Non-pretreated	10 kPa	n=1.3551 k=0.0029	0.9824	0.000688	0.008030
	Non-pretreated	15 kPa	n=1.2536 k=0.0037	0.9882	0.000648	0.007481
	Non-pretreated	25 kPa	n=1.1649 k=0.0034	0.9652	0.002335	0.013177
	Boiling	10 kPa	n=1.2583 k=0.0031	0.9930	0.000349	0.005097
	Boiling	15 kPa	n=1.6626 k=0.008	0.9829	0.001062	0.008886
	Boiling	25 kPa	n=1.1929 k=0.0092	0.9989	0.000067	0.002313
	Steaming	10 kPa	n=1.2679 k=0.0032	0.9833	0.000703	0.008835
	Steaming	15 kPa	n=1.2627 k=0.0029	0.9774	0.000922	0.008589
	Steaming	25 kPa	n=1.594 k=0.003	0.9172	0.006247	0.025247
Modified Page	Non-pretreated	10 kPa	n=1.3551 k=0.0136	0.9824	0.000688	0.008030
	Non-pretreated	15 kPa	n=1.2536 k=0.0114	0.9882	0.000648	0.007481
	Non-pretreated	25 kPa	n=1.1649 k=0.0076	0.9652	0.002335	0.013177
	Boiling	10 kPa	n=1.2583 k=0.0101	0.9930	0.000349	0.005097
	Boiling	15 kPa	n=1.6626 k=0.008	0.9829	0.001062	0.008886
	Boiling	25 kPa	n=1.1929 k=0.0092	0.9989	0.000067	0.002313
	Steaming	10 kPa	n=1.2679 k=0.0108	0.9833	0.000703	0.008835

	Steaming	15 kPa	n=1.2627 k=0.0097	0.9774	0.000922	0.008589
	Steaming	25 kPa	n=1.594 k=0.0064	0.9172	0.006247	0.025247
Logaritmic	Non-pretreated	10 kPa	k=0.0212 a=1.4102	0.9185	0.039485	0.055541
	Non-pretreated	15 kPa	k=0.0168 a=1.3457	0.9470	0.025609	0.043555
	Non-pretreated	25 kPa	k=0.0108 a=1.3021	0.9146	0.038161	0.050230
	Boiling	10 kPa	k=0.0178 a=1.6991	0.9277	0.074192	0.070038
	Boiling	15 kPa	k=0.0147 a=1.4996	0.9723	0.038294	0.050318
	Boiling	25 kPa	k=0.0137 a=1.3656	0.9774	0.227020	0.039864
	Steaming	10 kPa	k=0.0134 a=1.1289	0.9779	0.008540	0.026677
	Steaming	15 kPa	k=0.0132 a=1.2845	0.9512	0.015849	0.033309
	Steaming	25 kPa	k=0.0102 a=1.4518	0.8528	0.070280	0.076146
Lewis	Non-pretreated	10 kPa	k=0.0182	0.9046	0.008234	0.030009
	Non-pretreated	15 kPa	k=0.0144	0.9427	0.006120	0.024585
	Non-pretreated	25 kPa	k=0.0092	0.9374	0.008051	0.025795
	Boiling	10 kPa	k=0.013	0.9607	0.005958	0.022190
	Boiling	15 kPa	k=0.0116	0.9652	0.012777	0.032495
	Boiling	25 kPa	k=0.011	0.9866	0.002639	0.015412
	Steaming	10 kPa	k=0.0139	0.9331	0.005867	0.028546
	Steaming	15 kPa	k=0.0125	0.8874	0.008085	0.026975
	Steaming	25 kPa	k=0.01	0.8030	0.034235	0.064746
Henderson and Pabis	Non-pretreated	10 kPa	k=0.0209 a=1.4626	0.9264	0.038547	0.060115
	Non-pretreated	15 kPa	k=0.0164 a=1.3949	0.9621	0.025806	0.047224
	Non-pretreated	25 kPa	k=0.0105 a=1.3578	0.9599	0.022279	0.040708
	Boiling	10 kPa	k=0.0146 a=1.3938	0.9760	0.020170	0.038733
	Boiling	15 kPa	k=0.0132 a=1.4152	0.9856	0.020632	0.039174
	Boiling	25 kPa	k=0.0118 a=1.2264	0.9931	0.007040	0.023732
	Steaming	10 kPa	k=0.0157 a=1.3811	0.9501	0.038874	0.005867
	Steaming	15 kPa	k=0.0146 a=1.4885	0.9143	0.036386	0.008085
	Steaming	25 kPa	k=0.0126 a=1.8623	0.8519	0.171661	0.034235

Total phenolic content and antioxidant capacity analysis

Antioxidants such as flavonoids, phenolic acids, tannins, vitamin C, and vitamin E are substances that can prevent the harmful effects of radical oxygen species on vital parts or molecules of the human body by avoiding their chain reactions (Oroian and Escriche, 2015). In the drying process, the preservation of antioxidant compounds is quite significant because of their positive health effects. DPPH, FRAP and CUPRAC methods were used to determine the antioxidant activity of dried samples. In our study, the antioxidant capacity of fresh artichoke heart was determined as 38.24±0.29, 107.19±0.34 and 76.54±0.72 μmol TE / g dw with DPPH, CUPRAC and FRAP methods, respectively. One of the research showed that the antioxidant capacity of fresh artichoke heart was between 34.58 to 50.20 μmol TE / g dw with DPPH method (Zakynthinos and Varzakas 2016). The vacuum drying technique caused a significant loss in antioxidant activity compared to fresh artichoke. The boiling water pretreated samples had higher antioxidant capacity than other samples according to antioxidant activity results (Table 3). The highest antioxidant capacity and total phenolic contents were determined in the samples that were subjected to boiling water pretreatment and dried at 10 kPa and 15 kPa. The highest antioxidant capacities in CUPRAC and FRAP assays were determined in boiling water pretreated and 10 kPa dried samples with 23.80±1.11 and 20.28±0.02 μmol TE / g dw, respectively. The highest DPPH activity were determined in boiling water pretreated and 15 kPa dried samples with 6.38±0.01 μmol TE / g dw. Researchers were investigated the effect of pretreatment and drying combination on biochemical parameters of several vegetables. They determined that the total phenolic content and antioxidant capacity with measured DPPH assay decreased after boiling water pretreatment followed by drying (Şat and Özkan, 2015). Heras-Ramírez et al. (2012), clarified that boiling pretreatment before drying had positive effects on the protection of antioxidant activity on apple pomace compared to dried samples without pretreatment.

Determination of total phenolic content was carried out with the Folin-Ciocalteu method and the results showed that a significant decrease determined in total phenolic contents of artichoke. On the other hand, boiled samples contained quite higher total phenolic contents in comparison to non-pretreated samples. In a previous study, researchers expressed that the boiling process had diverse effects on different vegetables. While some vegetables showed an increment in total phenolic contents, others exhibited a loss (Wen et al., 2010).

Table 3: Antioxidant capacity and total phenolics contents of fresh and dried artichoke samples

	DPPH (μmol TE*/ g DW)	CUPRAC (μmol TE*/ g DW)	FRAP (μmol TE*/ g DW)	TPC (mg GAE**/ 100 g DW)
Fresh Artichoke	38.24±0.29^{a}	107.20±0.35^{a}	76.55±0.72^{a}	836.62±2.81^{a}
Non-pretreated (10 kPa)	5.73±0.04^{e}	1.73±0.01^{e}	1.13±0.02^{g}	73.40±0.45^{h}
Non-pretreated (15 kPa)	5.73±0.02^{e}	1.96±0.07^{e}	0.65±0.04^{g}	81.03±0.33^{g}
Non-pretreated (25 kPa)	5.89±0.07^{de}	1.40±0.08^{e}	0.96±0.06^{g}	72.12±0.34^{h}
Boiled (10 kPa)	6.21±0.02^{bc}	23.80±1.11^{b}	20.28±0.02^{b}	156.10±0.42^{c}
Boiled (15 kPa)	6.38±0.01^{b}	19.70±1.40^{c}	15.26±0.10^{c}	160.24±0.16^{b}
Boiled (25 kPa)	6.22±0.02^{bc}	22.20±0.12^{b}	14.60±0.08^{cd}	149.83±0.34^{e}
Steamed (10 kPa)	6.06±0.04^{cd}	10.40±0.08^{d}	14.39±0.06^{d}	124.54±0.62^{f}
Steamed (15 kPa)	5.91±0.03^{de}	20.17±0.60^{c}	12.97±0.03^{e}	152.97±0.48^{d}
Steamed (25 kPa)	5.85±0.02^{de}	22.63±0.09^{b}	10.33±0.50^{f}	152.44±0.27^{de}

*μmol TE (trolox equivalent) /g dw (dry weight) **GAE: Gallic acid equivalent. Samples shown in different letters in the same row are statistically different (p <0.01)

Color analysis

Color is a significant quality parameter that directly effecting consumer choices. The color parameters of dried artichoke samples were shown in Table 4. In comparison with fresh artichoke heart, *L* (lightness) values were significantly decreased ($p<0.05$) in all of the dried samples. Samples pretreated with boiling water had the highest *L* value (43.11±1.04) under 15 kPa. An important decrease in *L* values was determined in the all samples after vacuum drying. Dried artichoke samples showed higher redness in comparison with fresh artichoke and non-pretreated samples had the best *a* value after the drying process. All dried samples showed an important reduction in *b* (yellowness) values although the sample, boiled as pretreatment and dried at 10 kPa, had the highest *b* value (17.42±0.71). Chroma (*C*) and *h*° (hue angle) values of dried artichokes were decreased in comparison with fresh artichoke. *C* values were used to explain the color intensity and it represents the brown color of dried food materials (Vega-Galvez et al., 2009). Samples pretreated with boiling water and dried at 25 kPa showed the lowest *C* value. In conclusion, the discoloration of dried artichokes was caused by non-enzymatic Maillard browning reactions and the deterioration of color pigments.

Table 4: Color values of fresh and dried artichoke samples

	L	*a*	*b*	*C*	h^{o}
Fresh Artichoke	65.45 ± 3.45^{a}	0.07 ± 0.01^{e}	23.35 ± 0.69^{a}	23.75 ± 0.35^{a}	87.44 ± 1.17^{a}
Non-pretreated (10 kPa)	29.30 ± 1.67^{e}	5.71 ± 0.19^{a}	13.77 ± 0.97^{de}	14.91 ± 0.95^{cd}	67.43 ± 1.07^{d}
Non-pretreated (15 kPa)	30.33 ± 1.62^{e}	6.27 ± 0.29^{a}	15.52 ± 0.60^{bc}	16.75 ± 0.64^{ab}	68.00 ± 0.77^{d}
Non-pretreated (25 kPa)	30.79 ± 0.62^{de}	5.84 ± 0.08^{a}	14.62 ± 0.24^{cd}	15.73 ± 0.23^{abc}	68.22 ± 0.39^{d}
Boiled (10 kPa)	37.86 ± 2.06^{b}	4.56 ± 1.81^{bc}	17.42 ± 0.71^{a}	17.78 ± 0.71^{a}	78.44 ± 0.22^{b}
Boiled (15 kPa)	43.11 ± 1.04^{a}	2.67 ± 0.27^{de}	16.30 ± 0.23^{ab}	16.52 ± 0.24^{b}	80.69 ± 0.90^{a}
Boiled (25 kPa)	36.39 ± 0.58^{b}	2.27 ± 0.19^{e}	11.84 ± 0.28^{f}	12.07 ± 0.26^{d}	79.13 ± 1.02^{ab}
Steamed (10 kPa)	33.02 ± 2.46^{cd}	5.24 ± 0.61^{ab}	15.18 ± 1.33^{bc}	16.06 ± 1.42^{bc}	70.96 ± 1.32^{d}
Steamed (15 kPa)	30.31 ± 1.99^{e}	4.10 ± 0.13^{c}	12.63 ± 1.07^{ef}	13.28 ± 1.06^{d}	71.98 ± 0.94^{d}
Steamed (25 kPa)	33.49 ± 0.89^{c}	3.80 ± 0.27^{cd}	14.29 ± 0.42^{cd}	14.79 ± 0.41^{d}	75.10 ± 1.14^{cc}

*The samples shown in different letters in the same row are statistically different (p <0.01)

CONCLUSION

The drying process is one of the most preferred methods to extend the shelf life of fruits and vegetables for the protection of physicochemical properties and prevention of microbiological degradation. An important reduction in antioxidant activity and total phenolic content was observed in all dried artichoke samples. Artichoke samples pretreated with boiling water had the highest antioxidant and total phenolic contents than non-pretreated and steamed samples. Page and Modified Page models were found to be the best fitted mathematical models for the description of drying characteristics of artichoke slices. All color values (*L*, *a*, *b*, *C* and h^{o}) showed differences according to pretreatments and drying conditions. Consequently, vacuum drying was found as a convenient method of fresh artichoke for consumption during all seasons while protecting its nutritional value.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Abu-Reidah, I.M., Arráez-Román, D., Segura-Carretero, A., Fernández-Gutiérrez, A. (2013). Extensive characterisation of bioactive phenolic constituents from globe artichoke (Cynarascolymus L.) by HPLC-DAD-ESI-

QTOF-MS. Food Chem 141:2269-2277, doi: 10.1016/j.foodchem.2013.04.066.

Apak, R., Güçlü K., Özyürek, M., Karademir, S.E., Altun, M. (2005). Total antioxidant capacity assay of human serum using copper (II)-neocuproine as chromogenic oxidant: The CUPRAC method. Free Radic Res 39: 949-961, doi: 10.1080/10715760500210145.

Arslan, D., Ozcan, M.M. (2010). Study the effect of sun, oven and microwave drying on quality of onion slices. LWT-Food SciTechnol 43: 1121-1127, doi: 10.1016/j.lwt.2010.02.019.

Avhad, M.R., Marchetti, J.M. (2016). Mathematical modelling of drying kinetics of Hass avocado seeds. Ind Crops Prod 91: 76-87, doi: 10.1016/j.indcrop.2016.06.035.

Benzie, I.F.F., Strain, J.J. (1996). The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": The FRAP assay. Anal Biochem 239:70-76, doi: 10.1006/abio.1996.0292.

Beta, T., Nam, S., Dexter, J.E., Sapirstein, H.D. (2005). Phenolic content and antioxidant activity of pearled wheat and roller-milled fractions. Cereal Chem 82: 390-393, doi: 10.1094/CC-82-0390.

Devres, Y.P., Pala, M. (1993). Gıda Sanayiinde Matematiksel Modellemenin Önemi ve Uygulama Alanları. Gıda 18(3): 173-181.

Doymaz, I. (2006). Drying kinetics of black grapes treated with different solutions. J Food Eng 76: 212-217, doi: 10.1016/j.jfoodeng.2005.05.009.

Eljounaidi, K., Comino, C., Moglia, A., Cankar, K., Genre, A., Hehn, A., Bourgaud, F., Beekwilder, J., Lanteri, S. (2015). Accumulation of cynaropicrin in globe artichoke and localization of enzymes involved in its biosynthesis. Plant Sci 239:128-136, doi: 10.1016/j.plantsci.2015.07.020.

Heras-Ramírez, M.E., Quintero-Ramos, A., Camacho-Dávila, A.A., Barnard, J., Talamás-Abbud, R., Torres-Muñoz, J.V., Salas-Muñoz, E. (2012). Effect of Blanching and Drying Temperature on Polyphenolic Compound Stability and Antioxidant Capacity of Apple Pomace. Food Bioprocess Technol 5:2201-2210, doi: 10.13005/bbra/2145.

JMP®, JMP Statistical Software, Version 14. 1989-2019 SAS Institute, Cary, NC 27513, USA.

Katalinic, V., Milos, M., Kulisic, T., Jukic, M. (2006). Screening of 70 medicinal plant extracts for antioxidant capacity and total phenols. Food Chem 94: 550–557, doi: 10.1016/j.foodchem.2004.12.004.

Krokida, M.K., Maroulis, Z.B., Saravacos, G.D. (2001). The effect of the method of drying on the colour of dehydrated products. Int J Food Sci Technol 36: 53-59, doi: 10.1046/j.1365-2621.2001.00426.x.

Lattanzio, V., Kroon, P.A., Linsalata, V., Cardinali, A. (2009). Globe artichoke: A functional food and source of nutraceutical ingredients. J Funct Foods 1:131-144, doi: 10.1016/j.jff.2009.01.002.

Lombardo, S., Pandino, G., Ierna, A., Mauromicale, G. (2012). Variation of polyphenols in a germplasm ollection of globe artichoke. Food Res Int 46:544-551.

McBean, D.M.G., Johnson, A.A., Pitt, J.I. (1964). The absorption of sulfur dioxide by fruit tissue. J Food Sci 29: 257–260, doi: 10.1111/j.1365-2621.1964.tb01728.x.

Oroian, M., Escriche, I. (2015). Antioxidants: Characterization, natural sources, extraction and analysis. Food Res Int 74:10–36, doi: 10.1016/j.foodres.2015.04.018.

Overhults, D.D., White, G., Hamilton, M.E., Ross, I.J. (1973). Drying soybeans with heated air. Transactions of the ASAE 16: 195-200, doi: 10.13031/2013.37459.

Özcan-Sinir G, Özkan-Karabacak A, Tamer CE, Copur OU. (2019). The effect of hot air, vacuum and microwave drying on drying characteristics, rehydration capacity, color, total phenolic content and antioxidant capacity of kumquat (Citrus japonica). Food Sci Technol (Campinas) 39(2): 475-484, doi:10.1590/fst.34417

Özkan-Karabacak A, Suna S, Tamer CE, Copur OU. (2018). Effects of oven, microwave and vacuum drying on drying characteristics, colour, total phenolic content and antioxidant capacity of celery slices. Qual Assur Saf Crop 10(2): 193–205, doi: 10.3920/QAS2017.1197

Özkan-Karabacak, A. (2019). Effects of different drying methods on drying characteristics, colour and in-vitro bioaccessibility of phenolics and antioxidant capacity of blackthorn pestil (leather). Heat Mass Transfer 55(10): 2739-2750, doi: 10.1007/s00231-019-02611-3.

Pandino, G., Lombardo, S., Lo Monaco, A., Mauromicale, G. (2013). Choice of time of harvest influences the polyphenol profile of globe artichoke. J Funct Food 5:1822-1828.

Sagar, V.R., Suresh K.P. (2010). Recent advances in drying and dehydration of fruits and vegetables: a review. J Food Sci Technol 47: 15-26, doi: 10.1007/s13197-010-0010-8.

Sarsavadiva, P., Sawhney, R., Pangavhane, D.R., Sing, I. (1999). Drying behaviour of brined onion slices. J Food Eng 40: 219-226.

Şat, İ. Özkan Ö. (2015). Haşlama ve Kurutmanın Bazı Sebzelerin Bileşimi Üzerine Etkisi. ADYÜ Mühendislik Bilimleri Dergisi 2(3): 54-62.

Vega-Galvez, A., Di Scala, K., Rodríguez, K., Lemus-Mondaca, R., Miranda, M., López, J., Perez-Won, M. (2009). Effect of air-drying temperature on physico-chemical properties, antioxidant capacity, colour and total phenolic content of red pepper (Capsicum annuum, L. var. Hungarian). Food Chem 117:647-663, doi: 10.1016/j.foodchem.2009.04.066.

Vitali, D., VedrinaDragojevic, I., Sebecic, B. (2009). Effects of incorporation of integral raw materials and dietary fibre on the selected nutritional and functional properties of biscuits. Food Chem 114: 1462–1469, doi: 10.1016/j.foodchem.2008.11.032.

Wen, T.N., Prasad, K.N., Yang, B., Ismail, A. (2010). Bioactive substance contents and antioxidant capacity of raw and blanched vegetables. Innov Food Sci Emerg Technol 11: 464-469, doi: 10.1016/j.ifset.2010.02.001.

Westerman, P.W., White, G.M., Ross, I.J. (1973). Relative humidity effect on the high temperature drying of shelled corn. Transactions of the ASAE 16: 1136-1139, doi: 10.13031/2013.37715.

Yagcioglu, A. (1999). Drying technique of agricultural products. Ege University, Faculty of Agriculture Publications No. 536, Bornova, Izmir, Turkey, doi: 10.12691/ajfst-4-4-5.

Zakynthinos, G., Varzakas, T. (2016). Mikromani'S Artichoke (Cynara Cardunculus Var. Scolymus) - A Mediterranean Nutraceutical. Curr Res Nutr Food Sci 4(1): 16-18. doi:10.12944/CRNFSJ.4.1.03

Zhang, D., Hamauzu, Y. (2004). Phenolics, ascorbic acid, carotenoids and antioxidant activity of broccoli and their changes during conventional and microwave cooking. Food Chem 88: 503-509, doi: 10.1016/j.foodchem.2004.01.065.