Academic Research Journal of Technical Vocational Schools

| artes@cumhuriyet.edu.tr | Founded: 2022 Available online, ISSN: 2822-5880 Publisher: Sivas Cumhuriyet Üniversitesi

Determination of drying kinetics and color values of *Tragopogon reticulatus* Boiss. dried by microwave

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ResearchArticle

History

Received: 22/11/2022
Accepted: 19/12/2022

ABSTRACT

In this study *Tragopogon reticulatus* Boiss. (yemlik) was dried by microwave technique. The effects different microwave output power applied on drying kinetics and color of Tragopogon reticulatus Boiss were investigated. The drying process was carried out at four different microwave output power between 180-900 W.Four different models (Newton, Page, Logarithmic, and Henderson and Pabis) were tested to explain the drying behavior of *Tragopogon reticulatus* Boiss. It was found that Logarithmic model describes drying kinetics better in all applied conditions. Drying in the falling rate periods. With the increase of applied microwave output power, at the same time the drying rate increased and the drying time decreased. L* value of fresh samples differed significantly from dried samples. The difference between a*, b*, C* and h* values of the dried and the fresh samples was found to be insignificant (p>0.05).The results showed that the change in color values did not depend on the microwave output power.

Keywords:Tragopogon reticulatus Boiss.,Yemlik, Drying, Microwave, Color

Mikrodalgada kurutulan *Tragopogon reticulatus* Boiss.'in kurutma kinetiği ve renk değerlerinin belirlenmesi

Süreç

Geliş: 22/11/2022
Kabul: 19/12/2022

ÖZ

Bu çalışmada *Tragopogon reticulatus* Boiss. (yemlik) bitkisi mikrodalga tekniği ile kurutulmuştur. Uygulanan farklı mikrodalga çıkış güçlerinin *Tragopogon reticulatus* Boiss.'in kurutma kinetiği ve rengi üzerine etkileri incelenmiştir. Kurutma işlemi 180-900 W arasında olmak üzere dört faklı mikrodalga çıkış gücünde yapılmıştır. Tragopogon reticulatus Boiss.'in kuruma davranışlarını açıklamak için 4 farklı model test edilmiştir. Uygulanan tüm koşullarda Logaritmik modelin kurutma kinetiğini açıklayan en iyi model olduğu saptanmıştır. Kuruma azalan hız periyodunda gerçekleşmiştir. Mikrodalga çıkış gücünün artmasıyla kuruma oranı artmış, kuruma süresi ise azalmıştır. Taze örneklerin L* değeri kurutulmuş örneklerden önemli ölçüde farklılık göstermiştir (p<0.05). Kurutulan örneklerin a*, b*, C* ve h* değerleri ile taze örneklerin değerleri arasındaki fark önemsiz bulunmuştur (P>0.05). Sonuçlar renk değerlerindeki değişimin mikrodalga çıkış gücüne bağlı olmadığını göstermiştir.

Anahtar Kelimeler:Tragopogon reticulatus Boiss., Yemlik, Kurutma, Mikrodalga, Renk

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How to Cite: Sarı F., Uçar Sözmen E., (2022) Determination of drying kinetics and color values of Tragopogon reticulatus Boiss. Dried by microwave, Academic Research Journal of Technical Vocational Schools, 1(2):51-56

Introduction

Tragopogon reticulatus Boiss. a member of the Asteraceae family and known as "yemlik" in Anatolia, is a perennial herbaceous plant (Okcu and Kaplan, 2018). Tragopogon reticulatus Boiss. which is seen in spring, is loved and consumed by people living in rural areas (Kökler and Çetinkaya, 2022). Tragopogon reticulatus Boiss. is hand-picked from the root after it reaches maturity to be collected (Doğan, 2016). It is generally consumed raw, optionally with salt, by making a salad or making a meal. It is also known that dried Tragopogon reticulatus Boiss. leaves are consumed in winter (Aygün, 2019).

Tragopogon reticulatus Boiss.is a plant used for medicinal purposes as well as consumed as food.It is very rich in vitamins A, C, E, B2, B6 and minerals Fe and Ca (Okcu and Kaplan, 2018). It is also stated that Tragopogon reticulatusBoiss.is beneficial for anemia, is good for skin disorders, increases body resistance, protects the body against temperature changes, strengthens the body's defense mechanisms and has the ability to store vitamin A in its structure (Çöteli and Karataş, 2015). It is also known to be good for many diseases such as atherosclerosis, high blood pressure, rheumatism, diabetes, gout and kidney diseases (Baytop, 1984).

Agricultural products begin to deteriorate rapidly as they continue their post-harvest respiratory activities (Alibas, 2012). Drying is defined as the process of removing moisture from the product to be dried (Gürel et al., 2016). The purpose of drying is to reduce the water in the product to a level that will slow down or stop the microbiological, enzymatic and chemical reactions (Maskan, 2000; Soysal, 2004). On the other hands the drying process prolongs the shelf life of the products, but also brings advantages such as gaining a concentrated quality in terms of nutrients, reduction in volume and weight during transportation, minimum packaging requirements and making seasonal products available to consumers all year round (Fellows, 1988; Cohen ve Yang, 1995; Demirhan ve Özbek, 2008; Mitra and Meda, 2009). Many methods are used for drying agricultural products.In recent years, microwave drying has been widely used for reasons such as fast drying, less energy consumption and better product quality (Alibas, 2012; Doymaz et al., 2015).

The aim of this study are (1) to drying upTragopogon reticulatus Boiss.usingmicrowave technique(2) to determine the effect of different microwave output power on drying kinetics and to (3) choose the most suitable one among the different mathematical models.In addition, the effect of different microwave output power on color parameters, which is an important quality criterion, was investigated.

Material and methods

Material

Tragopogon reticulatus Boiss. grown in Bademkaya (Sivas, Türkiye, 39° 51' 39.3408'' N, 37° 1' 36.6924'' E) and harvested in May in 2022 was used inthe drying experiment.Before the experiment, the samples were washed with tap water and dried with towel paper to remove excess water from the surface.After, the stems were separated from the leaves and taken to the drying trial.

Methods

Drying process

The samples were dried in a microwave oven (HMT84M651, Bosch, Stuttgart, Germany) at microwave output powers of 180, 360, 600, 900 W. The initial moisture content of the samples was determined in an infrared moisture analyzer (Shimadzu, MOC63u). Approximately 5-6 g samples were arranged on a glass petri dish in a single row and then dried. Weighing was taken every 15 seconds to determine the drying kinetics. A digital weighing device (AND GX 4000) with a sensitivity of 0.01 g was used.

Determination of moisture content

During the drying of the samples, the moisture content value at any time t was calculated as the following equations 1;

$$Mt= (m-DM) /m \quad (1)$$

Where Mt is the moisture content at any time of t (g water/g DM), m is the mass (g) andDM is the amount of dry matter (g).

Determination of drying rate

The drying rate (g water/g DM min) was found by derivatives of the moisture content versus drying time curves.

$$\text{Drying Rate} = -\frac{M_{t+dt}-M_t}{dt} \quad (2)$$

where $Mt+dt$ is the moisture content at $t+dt$ (g water/g DM) and dt is the time between two sample weighing (min).

Determination of moisture ratio

The moisture ratio (MR) of samples during drying was calculated using Eq. (3)

$$MR= \frac{M_t-M_e}{M_o-M_e} \quad (3)$$

where MR is the moisture ratio (dimensionless), Mt is the moisture content at any time of t (g water/g DM), Mo is the initial moisture content (g water/g DM),Me is the equilibrium moisture content (g water/g DM).Equilibrium moisture content (Me) was assumed to be zero in microwave drying of foods.

Mathematical modelling

Four different thin layer drying models were chosen to explain the drying behavior of the samples. These are Newton (equation 4), Page (equation 5), Logarithmic (equation 6), and Henderson and Pabis (equation 7) models.

$$MR=\exp(-k.t) \quad (4)$$

$$MR=\exp(-k.t^n) \quad (5)$$

$$MR=a\exp(-kt)+c \quad (6)$$

$$MR=a\exp(-kt) \quad (7)$$

The fit of the models to the experimental data was determined by nonlinear regression in the MINITAB 17 (State College, PA) statistical program.The best model describing the thin layer drying characteristics of samples were chosen as the the lowest Chi-square (χ2) and RMSE (Root meas square error), and the highest (R2) values of the model. The constants k and n of model equations below were evaluated through nonlinear regression analysis using MINITAB 17 (State College, PA) statistical program.Validation study was also performed to determine the suitable model.Model parameters were calculated using the following equations (Waltherand Moore 2005).

$$RMSE=\left[\frac{1}{N}\sum_{i=1}^{N}\left(MR_{pred,i}-MR_{exp,i}\right)^2\right]^{1/2} \quad (8)$$

$$\chi^2=\frac{\sum_{i=1}^{N}(MR_{pred,i}-MR_{exp,i})^2}{N-z} \quad (9)$$

where N is the number of observations, z is the number of drying constants, MRexp,i is the experimental moisture ratio of ith data and MRpred,i is the predicted moisture ra-tio of ith data.

Color Measurement

Color properties of *Tragopoxgom reticulatus* Boiss were measured by a Minolta CR-400 (Minolta Osaka, Japan). Color values were recorded as L*, a* and b*. Using these values, Chroma (C*) and hue (h*) values were calculated from the following equations.

$$C^* = \sqrt{(a^*)^2+(b^*)^2} \quad (10)$$

$$h^* = \arctan(b^*/a^*) \quad (11)$$

Statistical analysis

Statistical analyzes were analyzed with the MINITAB 17 (State Colege, PA) statistical programand the results were given as the mean ± standard deviation of triplicate measurements.Experimental data were analyzed using analysis of variance (ANOVA). Means were compared by using Tukey Multiple Comparison Test. Values of $p<0.05$ were considered as significantly different.

Results and Discussion

Drying Kinetics

The moisture content variation depending on time during drying of the samples at different output power is given in Figure 1 (a). As can be seen in Figure 1 (a), the initial moisture content of the samples was found to be 6.21 g water/g DM. Since it is accepted that the lowest moisture content of the agricultural products, dried by the microwave can be 0.1 g water/g DM (Maskan, 2000), after drying each microwave power applied until the sample moisture content reach to 0.1 g water/g DM.

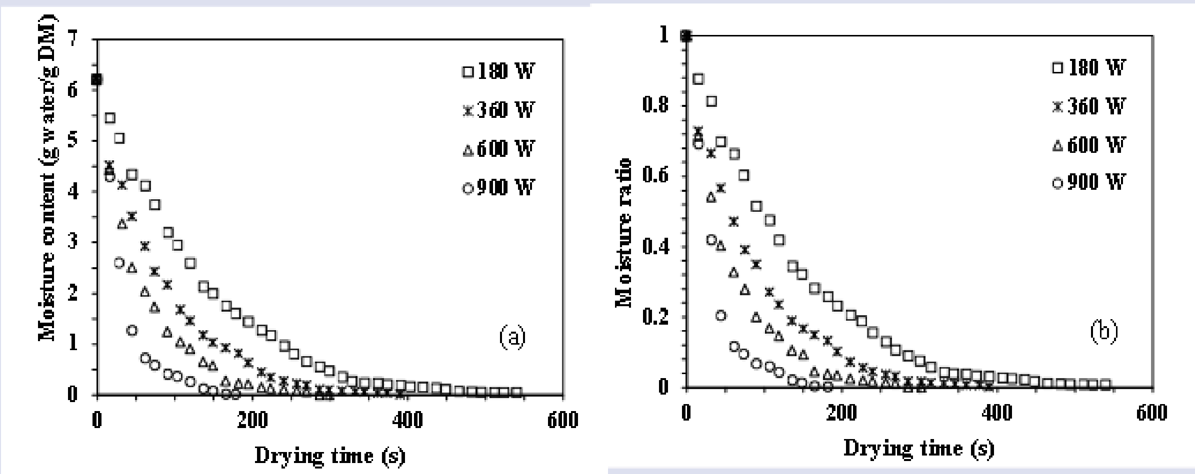

Figure 1. Moisture content (a) and moisture content variation (b) of dried *Tragopogon reticulatus* Boiss. at different microwave output power

Drying times of the samples were540, 390, 300 and 180 s at 180, 360, 600 and 900 W, respectively. The drying time decreased with the increase of microwave output power.

This reduction in drying time was 27.78%, 44.44% and 66.67%, respectively. This situation has also been detected in previous studies (Prabhanjan et al 1995; Soysal, 2004). The change in moisture content of the samples dried at different microwave output power is given in Figure 1 (b). The moisture ratio was expressed as the ratio of the moisture content of the samples to the initial moisture content relative to the dry basis at any drying time (eqution 3.3). As it can be seen in Figure 1 (b), the drying curve was 1 at the beginning of drying, while it approached to zero at the end of drying because there was no separable moisture in the samples. While a rapid decrease was observed in the moisture ratio of the samples at the beginning of drying in all microwave output power, a slow decrease was observed towards the end of the experiments. These rapid decreases in the drying curves show that the water loss in the samples is high. Similar results were observed during drying of parsley (Soysal et al., 2006), mint (Özbek and Dadali, 2007) and green beans (Doymaz et al., 2015). Increasing microwave output power causes higher heat absorption, resulting an increase in product temperature, thus accelerating moisture transfer. In this case, faster drying rate and shorter drying time are seen. This has also been found in previous studies (Soysal et al., 2006; Alibas, 2012; Kumar and Sagar, 2014; Doymaz et al., 2015; Hihat ve ark., 2017).

The drying rate values of the samples dried at different microwave output powers are given in Figure 2.The drying rates of the samples were found to be 0.0462 g water/g DM at 180 W, 0.0684 g water/gDM at 360 W, 0.1079 g water/gDM at 600 W and 0.2004 g water/g DM at 900 W.

It is seen that the drying rate of the samples increases as the microwave output power increases. The all drying process took place in the falling rate period.

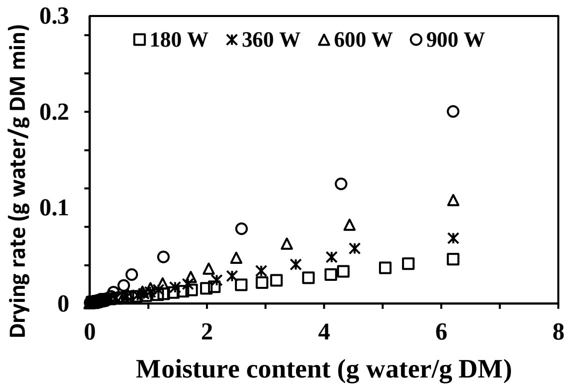

Figure 2. Variation of drying rate of dried samples at different microwave output power

Since the moisture content of the samples is high at the beginning of drying, there is more microwave absorption.This increased moisture diffusion, allowing higher drying rates to be detected.As the drying time progressed, since the moisture content in the samples decreased, the microwave absorption decreased and the drying rate showed a continuous decrease.Similar results were found in previous studies (Funebo and Ohlsson,1998; Maskan, 2000; Sharma ve Prasad, 2001; Soysal,2004; Özkan et al., 2007; Polatçı ve Taşova, 2017).

Mathematical modelling

Four different mathematical models, Newton, Page, Logarithmic and Henderson and Pabis, were tested to describe the behavior of the samples during drying using nonlinear regression analysis method (Equation 4- 7). The kinetic parameters of the applied models are given in Table 1.

Table 1. Statistical results obtained from the modelling of dried *Tragopoxgom reticulatus*

Power (W)	Models	Coefficients	R^2	RMSE	χ^2
180	Newton	k: 0.00772326	0.9973	0.02204	0.00049
	Page	k:0.00469779, n:1.09758	0.9979	0.01631	0.00028
	Logarithmic	a:1.03559, k:0.00718507, c:0.0301566	0.9979	0.01442	0.00023
	Henderson and Pabis	a:1.0219, k:0.00788502	0.9968	0.02115	0.00047
360	Newton	k:0.0124217	0.9935	0.02378	0.00059
	Page	k:0.0172825, n:0,929142	0.9943	0.02017	0.00044
	Logarithmic	a:0.961096, k:0.0114365, c:0.010912	0.9945	0.01972	0.00043
	Henderson and Pabis	a:0,956575, k:0.0118845	0.9942	0.01985	0.00043
600	Newton	k:0.0180144	0.9936	0.02525	0.00067
	Page	k:0.0283851, n:0,893717	0.9972	0.02638	0.00030
	Logarithmic	a:0,963274, k:0.0177392, c:0.00550747	0.9973	0.02233	0.00028
	Henderson and Pabis	a:0,96551, k:0.0173812	0.9929	0.02293	0.00058
900	Newton	k:0.03067	0.9934	0.02420	0.00063
	Page	k:0.0149852, n:1.19663	0.9936	0.02543	0.00076
	Logarithmic	a:1.02944, k:0.0314103, c:0.000614514	0.9944	0.02424	0.00075
	Henderson and Pabis	a:1.02902, k:0.031469	0.9936	0.02419	0.00069

Table 2. Color values of *Tragopogom reticulatus* Boiss. dried at different microwave output power

Power (W)	L*	a*	b*	C*	h*
Fresh	32.67 ± 0.51[a]	-15.01 ± 0.56[a]	26.66 ± 0.21[a]	30.64 ± 0.32[a]	119.50 ± 0.94[a]
180	29.66 ± 0.23[b]	-14.69 ± 0.18[a]	26.01 ± 0.05[a]	29.94 ± 0.10[a]	119.34 ± 0.29[a]
360	29.20 ± 1.35[b]	-14.64 ± 0.23[a]	26.33 ± 0.27[a]	30.13 ± 0.35[a]	119.04 ± 0.13[a]
600	29.32 ± 0.70[b]	-14.69 ± 0.23[a]	26.32 ± 0.48[a]	30.14 ± 0.53[a]	119.14 ± 0.09[a]
900	28.81 ± 0.11[b]	-14.74 ± 0.24[a]	26.42 ± 0.43[a]	30.25 ± 0.49[a]	119.13 ± 0.04[a]

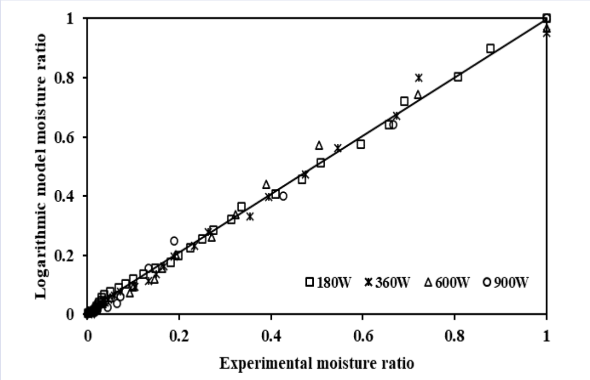

Figure 3. Experimental and predicted (from Logarithmic model) moisture ratios of dried samples at different microwave output power

It is expected that the R2 value should be close to 1 and the RMSE and χ2 values should be as lowest as possible in the fit of a model to the experimental data (Sarsavia et al., 1999; Soysal et al., 2006; Özkan et al., 2007). In the study, the logarithmic model was chosen as the model that best describes the drying behavior of the samples, since the model with the R2 value closest to 1 and the RMSE and χ2 values the smallest (Table 1). As the applied microwave output power increased, an increase was observed in the "k" values of the logarithmic model parameters.This shows that drying takes place in a short time due to the high temperature that occurs with the increase of microwave output power.Similar results have been found in previous studies (Soysal, 2004; Wang et al., 2007; Özkan vd. 2007; Polatçı ve Taşova, 2017). The comparison of the drying time and moisture content of the samples dried at different microwave output power and the values estimated by the logarithmic model is given in Figure 3.

It is seen that there is a very high agreement between the experimental values and the values estimated by the Logarithmic model (Fig.3). Similar results were also found in studies investigating the drying behavior of apricots (Doymaz, 2004), apple slices (Sacilik and Elicin, 2006), pumpkin slices (Doymaz, 2007) and basil (Demirhan and Ozbek, 2008).

Color values

Color is the first sensory quality criterion in the evaluation of foods, and food quality and flavor are closely related to color (Nevado et al., 1995). Consumers prefer the unique color of the food (Tijkens et al., 2001). Therefore, food manufacturers strive to produce attractive products for consumers (Dang et al., 2021). L* value determined in color analysis refers to the brightness and varies between 0 and 100. 0 indicates blackness, while a* value of 100 indicates whiteness (Polatçı ve Taşova, 2017). a* value ranges from -90 to +90, with negative values indicating greenness and positive values indicating redness. b* value ranges from -90 to +90, with negative values indicating blueness and positive values indicating yellowness (Üren, 1999). Color values of fresh and dried *Tragopogon reticulatus* Boiss. are given in Table 2.

L* value of fresh samples differed significantly from dried samples ($p<0.05$). On the other hand the difference between the values of a*, b*, C *and h* of dried samples by microwave and the values of the fresh samples was found to be insignificant ($P>0.05$). In addition, the effect of different microwave output power on the color values of the samples were found to be insignificant ($p>0.05$). This shows that the change in color values is not dependent on microwave output power. Microwave drying caused a slight change in the color of the samples compared to fresh samples, but a good green color was obtained. These results are suitable with the studies by Maskan (2000) and Soysal (2004).

Conclusions

In this study, *Tragopogon reticulatus* Boiss. was dried by microwave technique at 180, 360, 600 and 900 W microwave output power. While the change in humidity of the samples showed a rapid decrease at the beginning of drying, it was observed that it was slow towards the end of the trials, and the fastest drying was obtained at 900 W. In this study, the logarithmic model was found to best describe the drying behavior of Tragopogon reticulatus Boiss. It was observed that drying of samples was realized in falling drying period and drying rate increased but drying time decreased as microwave output power applied increased. This reduction was found to be 66.67% at 900 W. This study showed that the drying behavior of Tragopogon reticulatus Boiss. depends on the microwave output power, while the color parameters are not affected by the microwave. As a result, it is recommended to use 900 W for the drying of *Tragopogon reticulatus* Boiss.

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