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MODEL BASED COMPARISON OF DRYING OF ASPARAGUS (*ASPARAGUS OFFICINALIS* L.) WITH TRADITIONAL METHOD AND MICROWAVE

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Baltacıoğlu, C., Okur, İ., Buzrul., S. (2020). Geleneksel yöntem ve mikrodalga ile kuşkonmazın (*Asparagus officinalis* L.) kurutulmasının model tabanlı karşılaştırılması. *GIDA* (2020) 45(3) 572-580 doi: 10.15237/gida.GD20040

ABSTRACT

In this study, asparagus slices were dried with traditional oven and microwave oven methods. Model based approach was used to investigate the differences and similarities between two drying methods. Weibullian and linear equations were used as the primary and secondary models, respectively. Secondary model integrated into the primary model could successfully be used to describe the moisture ratio of asparagus in one-step procedure. Appropriate fits were obtained for both drying techniques, but microwave drying had slightly better fit than the conventional drying. Tailing was observed for the curves of traditional drying whereas sigmoidal curves were observed for microwave drying. The time parameter (δ) value of the lowest power of the microwave drying (100 W) was just one third of the δ value of the highest temperature of the traditional drying (90 °C) indicating that microwave drying was effective method in terms of time comparing to traditional drying.

Keywords: Drying curves, hot air oven, microwave oven, modeling, Weibullian model

GELENEKSEL YÖNTEM VE MİKRODALGA İLE KUŞKONMAZIN (*ASPARAGUS OFFICINALIS* L.) KURUTULMASININ MODEL TABANLI KARŞILAŞTIRILMASI

ÖZ

Bu çalışmada kuşkonmaz dilimleri farklı sıcaklıklarda geleneksel fırın veya farklı güç seviyelerindeki mikrodalga fırın ile kurutulmuştur. İki kurutma yöntemi arasındaki fark ve benzerliklerin araştırılmasında model tabanlı yaklaşım kullanılmıştır. Birincil ve ikincil modeller olarak sırasıyla Weibullian model ve doğrusal denklem kullanılmıştır. Birincil modele bütünleştirilen ikincil model, tek aşamalı yöntemle kuşkonmazın nem oranını tanımlamak için başarıyla kullanılabilmiştir. Her iki kurutma tekniği için uygun modeller elde edilmiştir, ancak mikrodalgada geleneksel kurutmadan daha yüksek uygunluk görülmüştür. Geleneksel kurutma eğrileri için kuyruklu, mikrodalga kurutma için s-biçimli eğriler gözlenmiştir. Mikrodalga kurutmanın en düşük gücünün (100 W) zaman parametresi (δ) değeri, geleneksel kurutmanın en yüksek sıcaklığının (90 °C) δ değerinin sadece üçte biridir, bu da mikrodalga kurutmanın geleneksel kurutmaya kıyasla zaman açısından etkili bir yöntem olduğunu göstermiştir.

Anahtar kelimeler: Kurutma eğrileri, sıcak hava fırını, mikrodalga fırın, modelleme, Weibullian model

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INTRODUCTION

Asparagus officinalis L. is consumed worldwide due to its high nutritional values rich in bioactive compounds, such as flavonoids, phenolics, and dietary fiber (Wang et al., 2013). This vegetable is native to Europe, Africa and Asia. Although different types of asparagus exist such as white and purple, the most common type is green. Green asparagus (*Asparagus officinalis* L.), which has unique flavor and alterative properties, is a good source of phenolic substances, phytochemicals, including flavonoids, sterols, saponins, oligosaccharides, carotenoids, sulfurated acids, amino acids and fibers. Therefore, green asparagus extracts used for the treatment of many diseases like a cough, rheumatism, neuritis, and different types of cancers such as leukemia, lung cancer, nose cancer, breast cancer and lymphatic gland cancer. Moreover, its extract has a wide range of therapeutic activities such as anti-diabetic, anti-tumor, antifungal, diuretic (Sergio et al., 2018).

The preservation of food materials by drying has been carried out since the early recorded history of human civilization. Drying is a preservation method widely used in the food industry, and it is recognized as one of the most common and most energy-consuming food preservation methods (Liu et al., 2016). It is a critical operation to remove moisture of food substances in order to preserve them for longer periods of time (Kucuk et al., 2014). Conventional hot-air drying or traditional drying is the most common drying method for foods but microwave drying is more rapid and highly energy efficient system than the traditional drying (McLoughlin et al. 2003, Al-Harahsheh et al. 2009). Advantages of microwave drying compared to conventional hot air drying are higher drying rate and minimal heating of food items with less water, thus reducing overheating where heat application is not required. (İlter et al., 2018). Although different vegetables such as spinach (Ozkan et al., 2007), green pea (Zielinska et al., 2013) and green bean (Doymaz et al., 2015) were dried by microwave, studies on asparagus were generally done by conventional drying (Bala et al., 2010; Jokic et al., 2009). A notable example of asparagus drying with microwave is the work of Kipcak and İsmail (2018).

One of the important aspects of the drying operation is to describe the change of water content in the food substance via mathematical models (Bi et al., 2015). Although many mathematical models were proposed and used to describe the moisture ratio of certain food products, none of them can be considered as matchless. Moreover, parameters of the models have no concrete meanings so that it is not easy to have a certain idea about the drying process by evaluating these parameters (Karacabey and Buzrul 2017). The objective of this study was to make a model based comparison between traditional oven drying and microwave oven drying. The model selected is very simple and has two interpretable parameters, namely time and shape parameters.

MATERIALS AND METHODS

Material

Asparagus spears were obtained from the local market and stored laboratory refrigerator at +4 °C. The spears were stripped and then cut to desired dimensions by using an adjustable chopper (Sinbo, Turkey). Slices were sized in 30 mm × 40 mm dimensions and sliced at 3 mm in thickness. Moisture of fresh asparagus was expressed as 94.19 ± 0.89%.

Drying

Oven drying was performed in the preheated air circulating oven (Nüve, EN 400, Turkey) at temperatures of 70, 80 and 90 °C. The ventilation hole of the oven was open for two main purposes: (i) for effective drying; (ii) for removing the moisture from the oven without cooking the samples. Asparagus slices were spread as a single layer on the tray attached to the balance (Kern, EW-1500-2M, Germany). The weight of the sample was recorded at regular time intervals by switching off the oven and after the sample weight was recorded, it was replaced in the oven again within 5 sec during drying. The experiments were terminated when the sample weights were unchanged in 3 consecutive measurements.

A programmable domestic microwave oven (Samsung, MW71E, Malaysia) with a maximum output of 800 W and wavelength of 2450 MHz was used for microwave drying. Different power levels (100, 200 and 300 W) were used to determine their effects on drying. The dimensions of the microwave cavity were 307×185×292mm. Weighed asparagus slices (one slice for each run) were spread in a glass dish as a single layer and placed in the center of microwave oven. Initial values of 66.55 and 199.67 W/g values were determined according to selected microwave power values. The sample was removed from the glass petri dish at each 60 sec intervals by switching off the microwave oven and after the sample weight was recorded, it was replaced in the oven again within 5 sec and then drying process continued. All weighing operations were carefully performed and the same procedure was applied in all samples. Fresh air entered the microwave oven on each weighing process. The experiments were terminated when the sample weights were unchanged in 3 consecutive measurements.

Modeling

Theory

Moisture ratio (*MR*) was defined as:

$$MR = \frac{X_w - X_{we}}{X_{w0} - X_{we}} \quad (1)$$

where X_{w0}, X_w, X_{we} are the initial, at a time *t*, and at equilibrium moisture content respectively.

Weibull model is one of the simplest equations with two parameters and it was used to describe the drying kinetics of certain foods (Blasco et al., 2006; Corzo et al., 2008). In those studies *e* (exp) base was used in the Weibull model. However, in this study *MR* was modeled by using Weibull-type (Weibullian) model:

$$MR = 10^{\left[-\left(\frac{t}{\delta(T)}\right)^{n(T)}\right]} \quad (2)$$

where $\delta(T)$ is the temperature (*T*) dependent time parameter that describes time to reduce the initial moisture ratio by 90% i.e. it is the time to reduce *MR* to *MR*/10 and $n(T)$ is the temperature dependent and dimensionless shape parameter. Since *MR* ranges from 1.0 to 0.0 the use of base 10 instead of *e* (exp) fits well.

Normally it is expected that $n(T)$ is not dependent on air temperature (Karacabey and Buzrul 2017), so Eq.(2) can be reduced to:

$$MR = 10^{\left[-\left(\frac{t}{\delta(T)}\right)^{n}\right]} \quad (3)$$

i.e., fixed *n* values could be used for all temperature levels.

If microwave oven is used instead of conventional oven Eq.(3) becomes:

$$MR = 10^{\left[-\left(\frac{t}{\delta(P)}\right)^{n}\right]} \quad (4)$$

where *P* is the power of the microwave oven.

The effects of model parameters on the *MR* curves are demonstrated in Figure 1. When $n < 1$ the curve has tailing, when $n = 1$ the curve has concave shape and when $n > 1$ the curve has sigmoidal pattern i.e., starting with convex and ending up with concave shape. All the curves are overlapped at $MR = 0.1$ and $t = 150$ because time parameter (δ) is same for all these curves, therefore, time necessary to reduce initial *MR* (1.0) to *MR*/10 (0.1) is the same point for three different curves (Figure 1a). The parameter *n* is called the shape parameter since the curve's shape is determined by *n*.

In Figure 1b the effect of different δ values are shown. Since *n* value is less than 1 and same for all the curves, tailings are observed for them. Time necessary to reduce initial *MR* (1.0) to *MR*/10 (0.1) is selected as 50, 100 and 200, therefore, each curve has different meeting point (different time values) with the *MR* value of 0.1 (Figure 1b). Note that both Figure 1a and Figure 1b were generated curves with different time (δ) and shape (*n*) parameter values in order to demonstrate the effects of these parameter values on curves' shape.

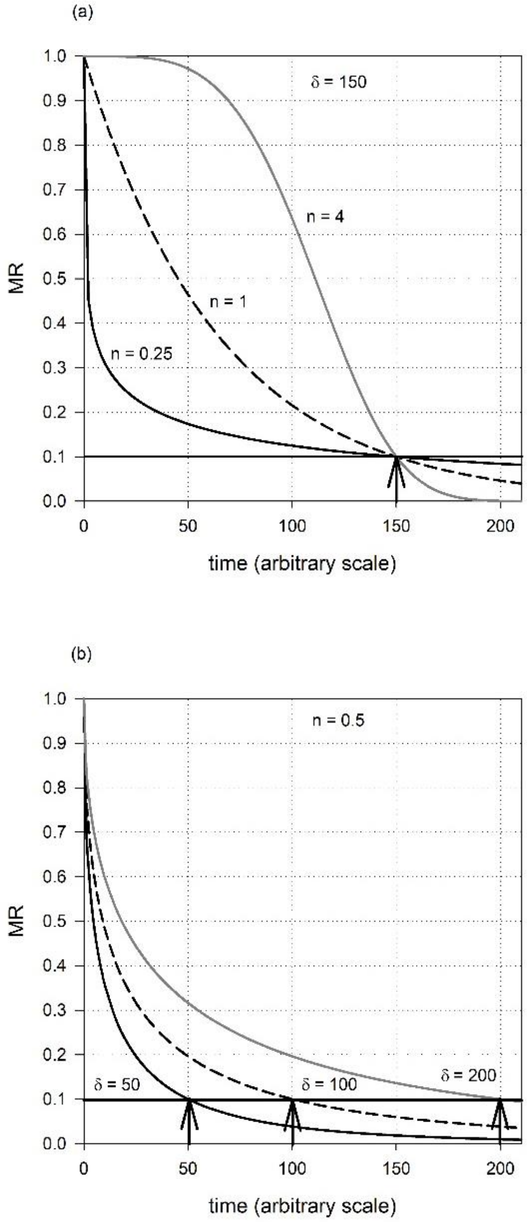

Figure 1. (a): Effect of shape parameter (*n*) of the Weibullian-type model on curve's shape. Time parameter (δ) is equal to 150, (b): Effect of time parameter (δ) of the Weibullian-type model on curve's shape. Shape parameter (*n*) is equal to 0.5. Arrows indicate the overlapping points of the curves where moisture ratio (*MR*) is 0.1.

Dependence of the time parameter $\delta(T)$ on air temperature or $\delta(P)$ on power can be represented by ad hoc empirical equations. It could be possible to use exponential decay function or Arrhenius-type equation (Karacabey and Buzrul 2017). However, since only three temperature or power levels were used in this study it is wise to select linear equation:

$$\delta(T) = c_0 + c_1 T \tag{5}$$

or

$$\delta(P) = c_0 + c_1 P \tag{6}$$

where c_0 and c_1 are the coefficients of the equations.

Note that linear equation is not the only option any other equation with two adjustable coefficients could be also used with the same goodness-of-fit (results not shown).

If Eq.(5) is integrated into Eq.(3) and if Eq.(6) is integrated into Eq.(4) the following models are obtained:

$$MR = 10^{\left[-\left(\frac{t}{c_0 + c_1 T}\right)^n\right]} \tag{7}$$

and

$$MR = 10^{\left[-\left(\frac{t}{c_0 + c_1 P}\right)^n\right]} \tag{8}$$

Eqs. (7) and (8), at least theoretically, can be used to describe the conventional oven and microwave oven drying of asparagus, respectively in one-step.

Model assessment

SigmaPlot® (Version 12.0, Chicago, IL, USA) was used for non-linear regressions to obtain model parameters/coefficients adjusted determination coefficient (R^2_{adj}) and mean square error (MSE) values were used to evaluate the goodness-of-fit of the models.

RESULTS AND DISCUSSION

The fits of Eqs. (7) and (8) are shown in Figure 2 and 3, respectively. The coefficients of the model and their standard errors of two drying methods together with the adjusted determination coefficient (R^2_{adj}) and mean square error (MSE) values are given in Table 1. One-step modeling procedure i.e., secondary models [Eqs. (5) and (6)] integrated into the primary models [Eqs. (3) and (4)] and then applying the integrated models [Eqs. (7) and (8)] in one-step regression could be successfully used for both drying methods.

Nevertheless, microwave drying had slightly better fit than the conventional drying as it had higher R^2_{adj} and lower MSE values (Table 1).

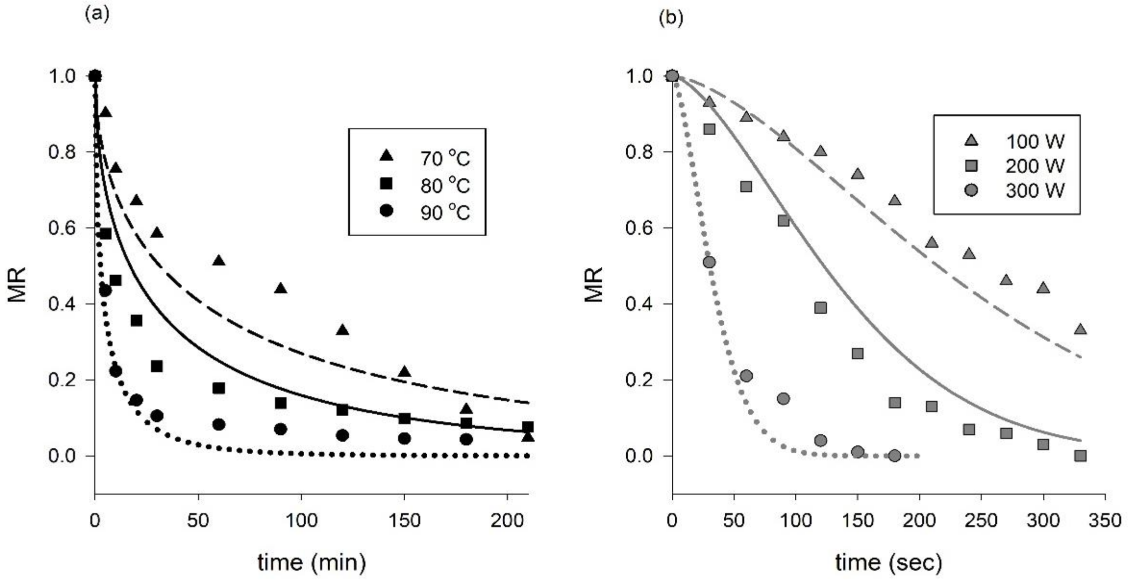

Figure 2. (a): Experimental data points and the fit of Eq.(7) to the traditional drying of asparagus. (b): Experimental data points and the fit of Eq.(8) to the microwave drying of asparagus.

Table 1. Coefficients and their standard errors of two drying methods together with adjusted determination coefficient (R^2_{adj}) and mean square error (MSE) values

	c_0	c_1	n	R^2_{adj}	MSE
Hot oven drying	1175.4 ± 228.2	– 12.8 ± 2.5	0.55 ± 0.05	0.94	0.0064
Microwave drying	666.2 ± 48.0	– 2.0 ± 0.2	1.55 ± 0.14	0.96	0.0055

The shape parameter (n) of traditional drying was less than 1 (0.55) therefore tailing behavior was obvious (Figure 2a) whereas microwave drying had n value of 1.55. Although it was not easy to observe, especially at 300 W, sigmoidal shape (shoulder followed by tailing) could be seen in the early stages at 100 and 200 W (Figure 2b).

Time parameter (δ) values for each drying methods can be calculated by using the c_0 and c_1 values given at Table 1. In Table 2 calculated δ values are given and comparisons can be made by using these values. For instance, δ value at 70 °C was 279.4 min for traditional drying whereas it was 266.2 sec at 200 W for microwave drying. The δ value of the lowest power of microwave drying was just one third of the δ value of the highest temperature of traditional drying (Table 2). This indicated that microwave drying was an effective method in terms of time comparing to traditional drying. Similar drying times were obtained by Kipcak and İsmail (2018) who also dried asparagus with microwave at power levels of 90, 180 and 360 W. Comparison of δ values could be useful to differentiate two drying methods. Karacabey and Buzrul (2017) claimed that δ can also be a useful parameter to design drying experiments.

Table 2. Time parameter (*δ*) values calculated for each drying methods

T (°C)	*ä* (min)	*P* (W)	*ä* (sec)
70	279.4	100	466.2
80	151.4	200	266.2
90	23.4	300	66.2

It could be possible to predict drying curves at different temperature or power levels by using Eqs. (7) and (8) and the values given in Table 1; however, experimental verification is certainly needed. Simulation at any temperature or power levels within the interpolation region is possible. Simulated drying curves at 77 and 84 °C for traditional drying and at 160 and 230 W for microwave drying are shown in Figure 4. These temperature and power levels were totally selected arbitrarily; any temperature and power level could be used within the interpolation region. Tailing and sigmoidal behaviors of traditional drying and microwave drying were observed since $n < 1$ and $n > 1$, respectively. Note that if $n < 1$ and as it approaches to 0 tailing becomes more pronounced i.e., strong tailing is observed. In such a case a sudden drop in moisture ratio may be observed in the early stages of drying and then as the time passes no change occurs in moisture content. Similarly, if $n > 1$ and as it becomes higher and higher, convex shape at the beginning of drying takes the form of shoulder and it is followed by tailing see Figure 1a and Figure 3b for comparison.

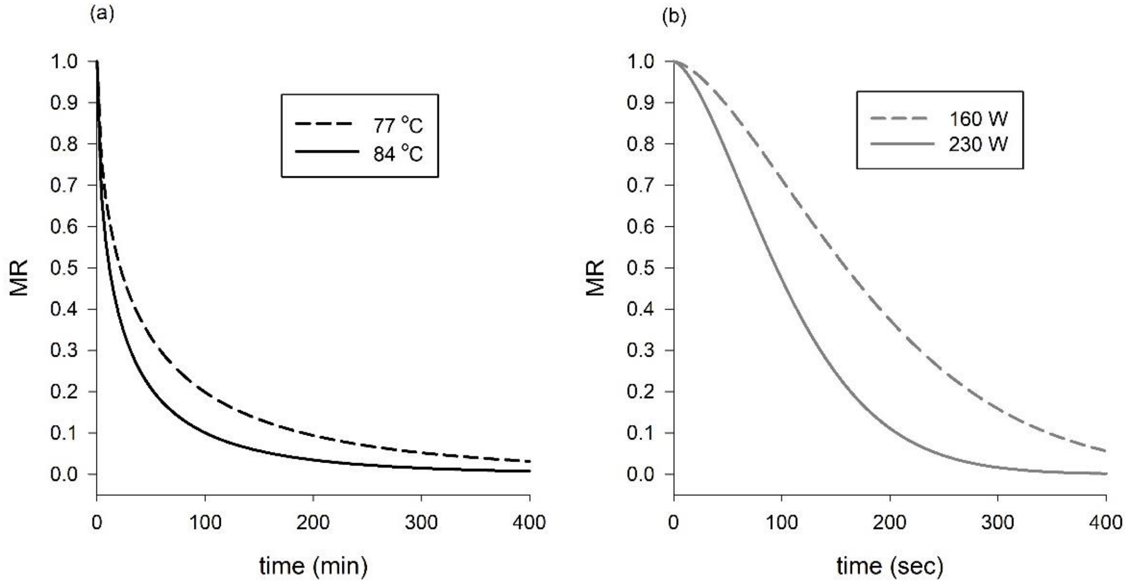

Figure 3. Simulation of (a): traditional drying of asparagus at 77 and 84 °C, (b): microwave drying of asparagus at 160 and 230 W.

A number of models for describing *MR* such as Lewis (Newton) equation (Lewis, 1921), Page (Page, 1949), Modified Page (Overhults et al., 1973), Logarithmic (Asymptotic) model (Chandra and & Singh, 1995), Midilli equation (Midilli et al., 2002), Two-term model (Henderson, 1974) have been proposed. However, the modeling studies on drying are mostly based on the comparisons of the above models. The researchers applied different models to data and they compared the goodness-of-fit of the models and they concluded by finding the best-fit model for the drying data (Ertekin and Ziya Fırat, 2017; Kohli et al., 2018; Akpinar et al., 2003; Menges and Ertekin, 2006; Sacilik and Elicin, 2006; Toğrul, 2005). It should be noted that Page model or modified Page model can also be used with the same degree of goodness-of-fit as the Weibullian model for the drying data of asparagus; however, since the aim was not to compare different models application of other models were not applied to the data.

Traditionally, modeling is done by two-step procedure: (i) fit of the primary model to drying data, (ii) describing the primary model parameters with respect to temperature or power. However, in this study secondary model was integrated into the primary one and regression was performed in one step. The results of the one-step procedure would be three-dimensional surfaces; however, for ease of visualization two dimensional plots were given (Figure 2). The advantages of using one-step procedure were producing more information in one calculation since time and temperature (or power) appeared simultaneously in the integrated model and saving time (Karacabey, 2016).

CONCLUSION

Asparagus slices were dried with traditional oven or microwave oven. The differences between two drying methods were investigated via model based approach. Weibullian-type equation as a primary model and linear equation as a secondary model were used together to describe the moisture ratio of asparagus in one-step procedure. Results revealed that integrated model produced reasonable fits for both drying methods ($R^2_{adj} \geq 0.94$ and $MSE \leq 0.0064$). Still microwave drying had slightly better fit than the conventional drying as it had higher R^2_{adj} and lower MSE values. Tailing was observed for curves of traditional drying whereas sigmoidal curves were observed for microwave drying. Comparisons of time parameter (δ) values for each drying methods indicated that microwave drying was more effective than traditional drying in terms of time.

Nomenclature

X_{w0} initial moisture content (g water/g dry weight)
X_w moisture content at a time t (g water/g dry weight)
X_{we} moisture content at equilibrium (g water/g dry weight)
MR moisture ratio (dimensionless)
$\delta(T)$ temperature dependent time parameter that describes time to reduce the initial moisture ratio by 90% (min)
$\delta(P)$ power dependent time parameter that describes time to reduce the initial moisture ratio by 90% (min)
$n(T)$ temperature dependent and dimensionless shape parameter (dimensionless)
n temperature independent and dimensionless shape parameter (dimensionless)
c_0 model coefficient of linear equation (min)
c_1 model coefficient of linear equation (min/°C or min/W)
R^2_{adj} adjusted determination coefficient
MSE mean square error

STATEMENT OF CONFLICT OF INTEREST

We declare that there are no conflicts of interest among the authors.

AUTHORS' CONTRIBUTIONS

CB designed the research and made the drying process. CB, SB and İO wrote the paper. SB made the model based comparison. All authors have read and approved the final article.

REFERENCES

Akpinar, E. K., Bicer, Y., Midilli, A. (2003). Modeling and experimental study on drying of apple slices in a convective cyclone dryer. *J Food Process Eng*, 26(6): 515–541.

Al-Harahsheh, M., Al-Muhtaseb, A. H., Magee, T. R. A. (2009). Microwave drying kinetics of tomato pomace: Effect of osmotic dehydration. *Chem Eng Process: Process Intensification*, 48(1): 524–531.

Bala, B. K., Hoque, M. A., Hossain, M. A., Uddin, M. B. (2010). Drying characteristics of asparagus roots (*Asparagus racemosus* wild.). *Drying Technol*, 28(4): 533–541.

Bi, J., Yang, A., Liu, X., Wu, X., Chen, Q., Wang, Q., Wang, X. (2015). Effects of pretreatments on explosion puffing drying kinetics of apple chips. *LWT - Food Sci Technol*, 60(2): 1136–1142.

Blasco, M., García-Pérez, J. V., Bon, J., Carreres, J. E., Mulet, A. (2006). Effect of blanching and air flow rate on turmeric drying. *Food Sci Technol Int*, 12(4), 315–323.

Chandra, P. K., Singh, R. P. (1995). *Applied Numerical Methods for Food and Agricultural Engineers*. CRC Press, Boca Raton, Florida, USA512 p, , ISBN 9780849324543.

Corzo, O., Bracho, N., Pereira, A., Vásquez, A. (2008). Weibull distribution for modeling air drying of coroba slices. *LWT - Food Sci and Technol*, 41(10): 2023–2028.

Doymaz, I., Kipcak, A. S., Piskin, S. (2015). Microwave drying of green bean slices: Drying kinetics and physical quality. *Czech J Food Sci*, 33(4): 367–376.

Ertekin, C., Ziya Fırat, M. (2017). A comprehensive review of thin-layer drying models used in agricultural products. *Crt Rev Food Sci Nutr*, 57(4):701-717.

İlter, I., Devseren, E., Okut, D., Koç, M, Kaymak Ertekin, F. (2018). Microwave and hot air drying of garlic puree: drying kinetics and quality characteristics. *Heat Mass Transfer*, 54: 2101-2112.

Jokic, S., Mujic, I., Martinov, M., Velic, D., Bilic, M., Lukinac, J. (2009). Influence of Drying Procedure on Colour and Rehydration Characteristic of Wild Asparagus. *Czech J Food Sci*, 27(3): 171–177.

Karacabey, E. (2016). Evaluation of Two Fitting Methods Applied for Thin-Layer Drying of Cape Gooseberry Fruits. *Braz Arc Biol Technol*, 59(0): 1–10.

Karacabey, E., Buzrul, S. (2017). Modeling and predicting the drying kinetics of apple and pear: Application of the weibull model. *Chem Eng Comm*, 204(5): 573–579.

Kipcak, A. S., Ismail, O. (2018). Comparison of the microwave drying kinetics of culture and natural asparagus. *Acta Sci Technol*, 40(1): 39922.

Kohli, D., Shahi, N. C., Kumar, A. (2018). Drying Kinetics and Activation Energy of Asparagus Root (Asparagus racemosus Wild.) for Different Methods of Drying. *Curr Res Nutr Food Sci,* 6(1): 191-202.

Kucuk, H., Midilli, A., Kilic, A., Dincer, I. (2014). A Review on Thin-Layer Drying-Curve Equations. *Drying Technol*, 32(7): 757–773.

Lewis, W. K. (1921). The Rate of Drying of Solid Materials. *Ind and Eng Chem*, 13(5): 427–432.

Liu, Z., Zhang, M., Wang, Y. (2016). Drying of restructured chips made from the old stalks of Asparagus officinalis: Impact of different drying methods. *J Sci Food Agric*, 96(8): 2815–2824.

McLoughlin, C. M., McMinn, W. A. M., Magee, T. R. A. (2003). Microwave drying of multi-component powder systems. *Drying Technol*, 21(2): 293–309.

Menges, H. O., Ertekin, C. (2006). Mathematical modeling of thin layer drying of Golden apples. *J Food Eng*, 77(1): 119–125.

Midilli, A., Kucuk, H., Yapar, Z. (2002). A new model for single-layer drying. *Drying Technol*, 20(7): 1503–1513.

Overhults, D. G., White, G. M., Hamilton, H. E., Ross, I. J. (1973). *Drying Soybeans With Heated Air*. Biosystem and Agricultural Engineering Faculty Publications, University of Kentucky. p 112–113.

Ozkan, I. A., Akbudak, B., Akbudak, N. (2007). Microwave drying characteristics of spinach. *J Food Eng*, 78(2): 577–583.

Page, GE. (1949). *Factors Influencing the Maximum Rates of Air Drying Shelled Corn in Thin Layers*. Purdue University.

Henderson, S. M. (1974). Progress in Developing the Thin Layer Drying Equation. *Transactions ASAE*, 17(6): 1167–1168.

Sacilik, K., Elicin, A. K. (2006). The thin layer drying characteristics of organic apple slices. *J Food Eng*, 73(3): 281–289.

Sergio, L., Cantore, V., Spremulli, L., Pinto, L., Baruzzi, F., Di Venere, D., Boari, F. (2018). Effect of cooking and packaging conditions on quality of semi-dried green asparagus during cold storage. *LWT*, 89: 712–718.

Toğrul, H. (2005). Simple modeling of infrared drying of fresh apple slices. *J Food Eng*, 71(3): 311–323.

Wang, J., Liu, Y., Zhao, J., Zhang, W., Pang, X. (2013). Saponins extracted from by-product of Asparagus officinalis L. suppress tumour cell migration and invasion through targeting Rho GTPase signalling pathway. *J Sci Food Agric*, 93(6): 1492–1498.

Zielinska, M., Zapotoczny, P., Alves-Filho, O., Eikevik, T. M., Blaszczak, W. (2013). A multi-stage combined heat pump and microwave vacuum drying of green peas. *J Food Eng*, 115(3): 347–356.