Food Technology Research Journal, Vol. 2, issue 2, 75-81, 2023

FTRJ

Mathematical Modeling of Drying Food Waste in Cabinet Dryer with Conventional Tray

*[1]Ahmad Khaloahmadi, [2]Omidreza Roustapour & [3]Behfar Farzaneh

[1,3]Department of Biosystem Mechanics, Islamic Azad University, Eghlid Branch, Eghlid, Iran.

[2]Agricultural Engineering Research, Education, Iran, karaj

[1]Bandarabbas Municipality, Waste Management Organization.

Original Article

Article information

Received 27/7/2023

Revised 20/8/2023

Accepted 24/8/2023

Published 30/8/2023

Available online 1/9/2023

***Keywords*:**
Mathematical Modeling, Drying, Food waste

ABSTRACT

Developing new strategies to reduce food waste is one of the most important challenges for maintaining public health. Drying is an effective method for environmental management. In this paper, mathematical modeling of food waste in cabinet dryers with conventional trays is presented. The drying of food waste was tested at three different temperatures (50, 60, and 70°C) and three different air velocities (1, 1.5, and 2 m/s) with a thickness of 3 cm. Seven models for drying were fitted using the experimental data. To effectively depict the drying behavior of food waste, the most appropriate model was chosen. To assess the accuracy of the fit, the values of the coefficient of determination (R^2), the sum of squared absolute error (SSE), and the root mean square error (RMSE) were taken into consideration. The findings demonstrated that the Logarithmic and Page models were the best options for describing the drying of food waste.

1. Introduction

Food waste is a major source of household waste around the world. Drying is a viable approach for effectively addressing food waste management, yielding both environmental and economic benefits. Drying will reduce the negative effects on the environment by reducing moisture, easing transportation, lowering disposal costs, and diminishing waste odor. Additionally, drying of food waste increases storage time. The modeling of the drying process is one of the most significant aspects of drying technology. Mathematical modeling and simulation of drying curves under various conditions could enhance quality control systems. Also, it is a useful tool for studying the dryers with different heat transfer methods. Several researchers have modeled the drying kinetics of various products. For example, (Tavakolipour and Mokhtarian, 2012) studied pistachio drying kinetics by convective dryer and stated that the Modified Page model showed the best results for predicting the moisture ratio. (Taheri-Garavand, et al., 2011) investigated the monolayer drying kinetics of tomato slices using thin-layer dryer. Their findings indicated that the Midilli model provided an acceptable correlation for predicting the tomato drying curve. (Reppich, et al., 2021) reported that the power function model best describe the drying behavior for Pineapple, Mango, Tomato and Onion in a laboratory oven. Fudholi, et al. (2012) concluded that the Page model showed a better fit for drying seaweed. Also, (Fudholi, et al., 2012) reported that the Page model is the best model for describing the drying curves of chili, and other studies include onions (Arslan and Ozcan, 2010), Bird's eye chilies (Limpaiboon, 2015), carrot (Rostamibaroji et al., 2017), pomegranate (Mazandarani et al., 2017), and Tomato pomace (Badaoui et al., 2020). The present study examined the mathematical modelling of food waste drying in a cabinet dryer with a conventional tray.

3. Materials and Methods

The provision of food waste products from home-made food and fruit shops as well as fruit and vegetable wastes; Non-food waste, including glass, paper, plastic, and metals, was isolated from the trash and shreder-crushed to bits no larger than 20 mm. .

Journal website: https://ftrj.journals.ekb.eg/

Published by Food Technology Research Institute, ARC

*Corresponding Author

Email: Aahmad825@gmail.com

The product was first left in the environment for an hour before being squeezed mechanically under equal pressure to remove some of the water. It was then put into cubic mesh containers with a cross-sectional area of (5×5) cm^2 and placed in three places on a tray with food waste, with a thickness of 3 cm equal to the same weight of 47 g (Fig. 1a). The horizontal sample tray was traversed vertically by hot air. (Fig.1b).The dryer system was activated for 30 minutes prior to each experiment in order to obtain the desired steady-state conditions. Using an anemometer (UNIT UT363, China), the air velocity was adjusted to values of (0.1, 1.5, and 2) m/s with an accuracy of 0.1 m/s.

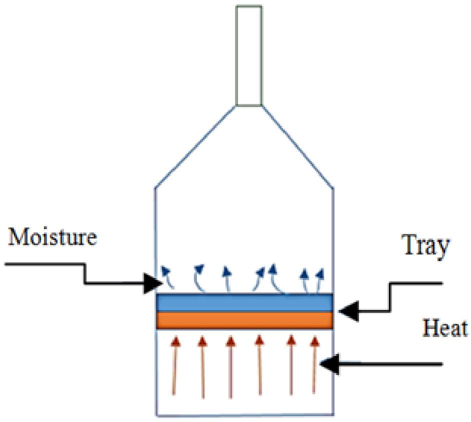

Figure 1. a: Tray containing food waste, b: Drying procedure of food waste in dryer

Dried samples were manually weighed every 30 minutes using an electronic balance having an accuracy of ±0.01 g, (AND GF-600, Japan). Drying continued until the samples' final moisture content reached approximately 10% (wb), then samples were dried in an oven at 105± 1ºC to reach a constant weight. Experiments were conducted at three levels of temperature (50, 60, and 70ºC) and three levels of hot air velocity (1, 1.5, and 2 m/s). Relative humidity and the temperature of the environment were 15-25% and 18-21ºC, respectively.

Moisture Ratio

The moisture ratio (MR) was calculated using Equation (1) (Montero, et al., (2015):

$$MR = \frac{M_d}{M_0} \quad (1)$$

Where, MR is the moisture ratio (dimensionless); M_d is Moisture content at a specific time t (g water per g dry solids), and M_0 is initial moisture content (g water per g dry solids).

Mathematical Modeling

Table 1 displays the fitting of the food waste drying kinetics data to the drying models. The coefficient of determination (R^2), root mean square error (RMSE), and the sum of squared absolute error (SSE) between the experimental and projected moisture ratio values were the metrics used to assess how well the evaluated models fit the experimental data. The following formulae were used to calculate the statistical parameters:

$$SSE = \frac{(MR_{\exp,i} - MR_{per,i})^2}{N} \quad (2)$$

$$RMSE = \{\frac{1}{N}\sum_{i=1}^{n} (MR_{\exp,i} + MR_{per,i})\}^2 \quad (3)$$

Table 1: Mathematical models given by various authors for the drying curves

Model no.	Name	Model equation	References
1	Logarithmic	f(x) = a.exp(-kx)+c	(Yaldiz et al., 2001)
2	Henderson and Pabis	f(x) = a.exp(-kx)	(Henderson and Pabis, 1961(
3	Page	f(x) = exp(-kx^n)	(Page, 1949(
4	Two-term	f(x) = a.exp(-kx)+b.exp(-hx)	(Rahman et al., 1998(
5	Midilli et al.	f(x) = a.exp(-kx^n)+cx	(Midilli et al., 2002(
6	Two term exponential	f(x) = aexp(-kx)+(1-a) exp(-kbx)	(Sharaf-Eldeen et al., 1980(
7	Modified Henderson and Pabis	f(x) = aexp (-kx)+bexp(-gx) +cexp (-hx)	(Karathanos, 1999(

3. RESULTS AND DISCUSSION

Moisture Ratio

The food wastes were dried as a layer with a thickness of 3 mm at the cabinet dryer. The variations in the moisture ratio of the food waste as a function of drying time at different velocities are presented in Figure 2.

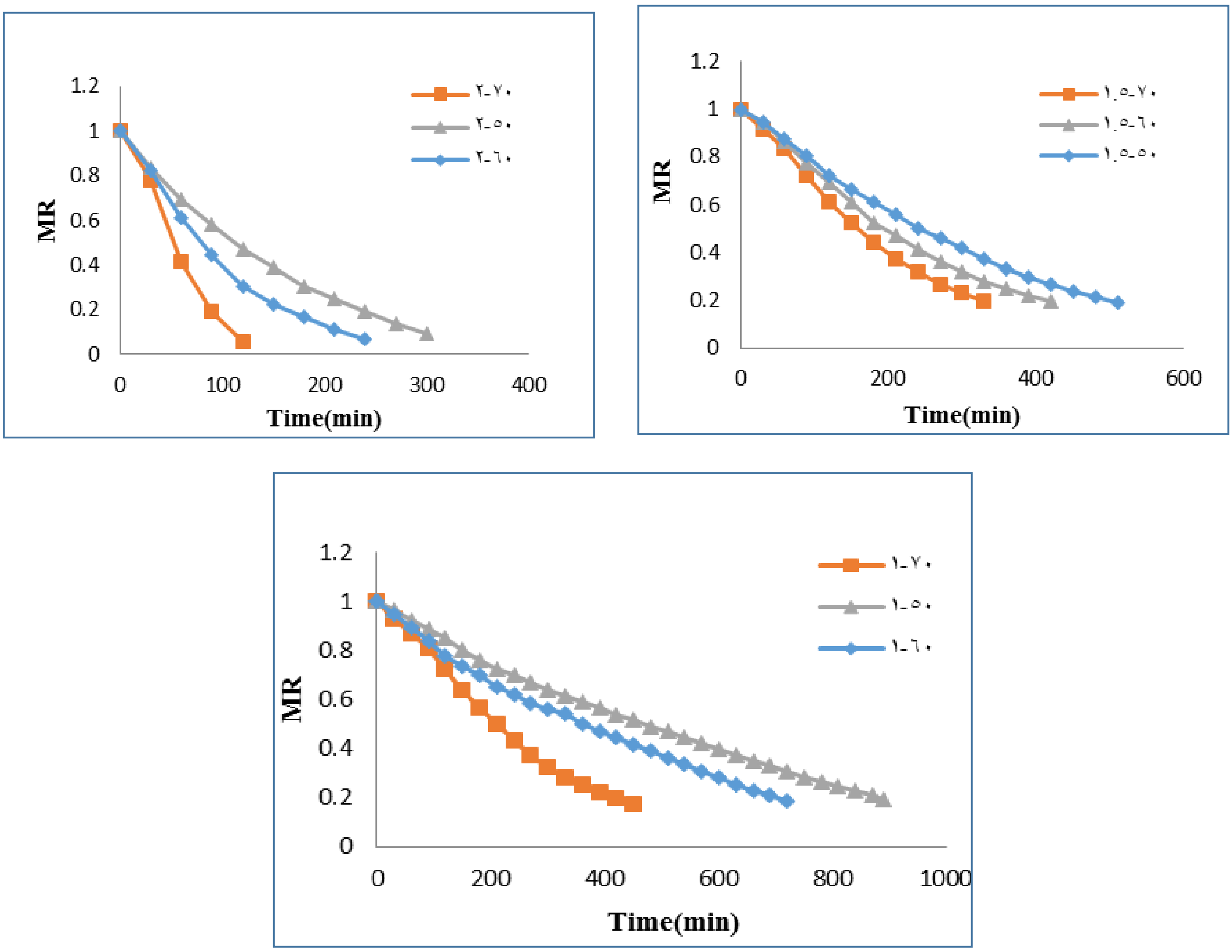

Figure. 4 Drying curves of moisture ratio with drying time at different velocity

Mathematical modeling

In the current study, the drying kinetic curves of food waste were studied at three temperatures, including 50, 60 and 70 °C and air velocities of 1, 1.5, and 2 m/s. Moisture content data were converted to moisture ratio and then fitted to the 7 drying models in terms of statistical parameters: R^2, SSE, and RMSE. These models and the results of the statistical analyses are shown in Tables 2, 3 and 4. The criteria for selecting the best model describing the drying kinetics were the highest R^2 values, and the lowest RMSE and SSE values. The best-fitting model for three temperatures and an air velocity of 1 m/s was bolded in Table 2. Therefore, the best model for this quantity of air velocity of 1m/s is the Logarithmic model, which has the highest value of R^2, the lowest SSE, and the lowest RMSE for temperatures of 50, 60 and 70°C and an air velocity of 1 m/s. Table 3 shows the results of fitting the experimental data to the drying models listed in Table 1 (R^2, RMSE, and SSE). The best-fitting model for temperatures of 50, 60, and 70°C and an air velocity of 1.5 m/s was bolded in Table 3. The criterion for selecting the best model describing the thin layer drying kinetics was the highest R^2 values and the lowest RMSE and SSE values. Therefore, the best model for this quantity of air velocity is the page model, which has the highest value of R^2, the lowest SSE and RMSE for temperature 50 and air velocity 1.5 m/s, the Logarithmic model, and the page model for temperatures 60 and 70°C and air velocity 1.5 m/s. Table 4 shows the best-fitting model for temperatures 50 and 60°c and air velocity of 2 m/s: the Logarithmic model had the highest value of R^2, the lowest SSE and RMSE and the Page model was found to describe best drying food waste with R^2, SEE and RMSE values of 0.9995, 0.0000165 and 0.02154, respectively.

Figure (5) shows the fitting of the Page model with the laboratory data of drying at a temperature of 60 °C and, velocity of 1.5 m/s. According to the figure, the Page model can well describe the behavior of drying food waste.

Table 2. Results of statistical analyses obtained from the modeling of food waste drying at velocity 1m/s.

T(c°)	R^2	RMSE	SSE	Model equation
50	0.9965	0.01347	0.004172	f(x) = aexp(-kx)+c
60	0.9984	0.01027	0.001898	
70	0.999	0.008393	0.0006339	
50	0.9721	0.03707	0.03297	f(x) = aexp(-kx)
60	0.9903	0.02427	0.01119	
70	0.9719	0.04248	0.01804	
50	0.9925	0.01745	0.005019	f(x) = exp(-kx^n)
60	0.9948	0.01778	0.006009	
70	0.995	0.01795	0.003222	
50	0.9914	0.02251	0.01013	f(x) = aexp(-kx)+bexp(-gx)+cexp(-hx)
60	0.9978	0.01309	0.002572	
70	0.973	0.05379	0.01736	
50	0.8932	0.04227	0.1264	f(x) = aexp(-kx)+bexp(-hx)
60	0.9957	0.01704	0.004938	
70	0.8742	0.1006	0.08091	
50	0.1154	0.2181	1.046	f(x) = aexp(-kx^n)+cx
60	0.1742	0.2371	0.9557	
70	0.2291	0.249	0.4959	
50	0.9653	0.04227	0.04109	f(x) = aexp(-kx)+(1-a) exp(-kbx)
60	0.9907	0.02439	0.0107	
70	0.9647	0.05026	0.02273	

Table 3: Results of statistical analyses obtained from the modeling of food waste drying at velocity 1.5m/s

T(c°)	R^2	RMSE	SSE	Model equation
50	0.9986	0.01001	0.001103	f(x) = aexp(-kx)+c
60	0.9971	0.01505	0.001586	
70	0.2826	0.2793	0.4682	
50	0.9856	0.03136	0.0118	f(x) = aexp(-kx)
60	0.9754	0.04119	0.01357	
70	0.9653	0.05691	0.02267	
50	0.9981	0.01141	0.001562	f(x) = exp(-kx^n)
60	0.9997	0.004741	0.0001798	
70	0.9991	0.009188	0.0005909	
50	0.9855	0.03841	0.0118	f(x) = aexp(-kx)+bexp(-gx)+cexp(-hx)
60	0.9705	0.0638	0.01628	
70	0.993	0.01242	0.0004631	
50	0.9975	0.01432	0.002051	f(x) = aexp(-kx)+bexp(-hx)
60	0.9992	0.00848	0.0004314	
70	0.9836	0.04622	0.01068	
50	0.2136	0.2534	0.6421	f(x) = aexp(-kx^n)+cx
60	0.7799	0.1423	0.1215	
70	0.4675	0.2636	0.3475	
50	0.9771	0.04127	0.6421	f(x) = aexp(-kx)+(1-a) exp(-kbx)
60	0.9878	0.04231	0.00761	
70	0.9881	0.4027	0.9731	

Table 4: Results of statistical analyses obtained from the modeling of food waste drying at velocity 2m/s

T(c°)	R^2	RMSE	SSE	Model equation
50	0.9998	0.005068	0.0001798	f(x) = aexp(-kx)+c
60	0.9987	0.01469	0.000863	
70	0.9871	0.07512	0.005643	
50	0.985	0.03963	0.01257	f(x) = aexp(-kx)
60	0.9785	0.05374	0.05374	
70	0.9217	0.131	0.03433	
50	0.9962	0.01984	0.00315	f(x) = exp(-kx^n)
60	0.9963	0.02222	0.002468	
70	0.9995	0.02154	0.0000165	
50	0.9898	0.04631	0.008577	f(x) = aexp(-kx)+bexp(-gx)+cexp(-hx)
60	0.9957	0.05365	0.002879	
70	0.9662	0.04247	0.003607	
50	0.8556	0.1419	0.1209	f(x) = aexp(-kx)+bexp(-hx)
60	0.9695	0.08251	0.02042	
70	0.9272	0.06194	0.03194	
50	0.3573	0.2995	0.5382	f(x) = aexp(-kx^n)+cx
60	0.462	0.3467	0.3607	
70	0.5121	0.323	0.214	
50	0.983	0.04509	0.01423	f(x) = aexp(-kx)+(1-a) exp (-kbx)
60	0.9755	0.06404	0.0164	
70	0.9147	0.1934	0.03741	

4. Conclusions

The drying kinetics of the food waste were investigated in a cabinet dryer with a conventional tray at drying temperatures of 50, 60, 70°C and velocities of 1, 1.5, and 2 m/s. The results indicated that the Logarithmic and Page models were the most suitable to describe the food waste drying process. The minimum drying conditions were 70 °C and 2 m/s and the maximum drying conditions were 50 °C and 1 m/s.

References

Arslan, D., and Ozcan, M. M. (2010). Study the effect of sun, oven and microwave drying on quality of onion slices. LWT-Food Science and Technology, 43(7): 1121-1128.

Badaoui, O., Hanini, S., Djebli, A., Haddad, B., and Benhamou, A. (2020). Experimental and modelling study of tomato pomace waste drying in a new solar greenhouse: evaluation of new drying models. Renewable Energy, 133: 144-155.

Fudholi, A., Ruslan, M. H., Haw, L. C., Mat, S., Othman, M. Y., Zaharim, A., and Sopian, K. (2012). Mathematical modeling of brown seaweed drying curves, WSEAS Int. Conf. on Applied Mathematics in Electrical and Computer Engineering, USA.

Fudholi, A., Ruslan, M. H., Othman, M. Y., Zaharim, A., Sopian, K., and Arranz, J. I. (2012). Solar open drying kinetics method for drying chilies WSEAS Int. Conf. on Advances inEnvironment, Biotechnology and Biomedicine, Chech Republic.

Henderson, S. M., and Pabis, S. (1961). Grain drying theory II: Temperature effects on drying coefficients. Journal of Agricultural Engineering Research, 6, 5.

Koyuncu, T., Tossun, I., and pinar, Y. (2007). Drying characteristic and heat energy riquirment of cornelian cherry fruits. Journal OF Food Engineering, 78: 735-739.

Karathanos, V.T. (1999). Determination of water content of dried fruits by drying kinetics. Journal OF Food Engineering, 39: 337–344.

Limpaiboon, k. (2015). Mathematical Modeling of Drying Kinetics of Bird's Eye Chilies in a Convective Hot-Air Dryer. Walailak J. Sci. and Tech, 12(2): 219-227.

Mazandarani, Z., Aghajani, N., Daraei Garmakhany, A., Bani Ardalan, M.J., and Nouri, M. (2017). Mathematical modeling of thin layer drying of pomegranate (Punica granatum L.) arils: various drying methods. J. Agr. Sci. Tech, 19: 10.

Midilli, A., Kucuk, H., and Yapar, Z. (2002). A new model for single layer drying. Drying Technology, 20(10): 1503-1603.

Montero, I., Miranda, M.T., Sepúlveda, F.J., , A., J. I., Rojas, C.V.,and Nogales, S., 2015. Solar dryer application for olive oil mill wastes. Energies. 8: 14049–14063

Page, G.E. (1949). Factors influencing the maximum rates of air drying shelled corn in thin layers purdue, University Purdue,USA.

Rahman, M.S., Perera, C.O., and Thebaud, C. (1998). Desorption isotherm and heat pump drying kinetics of peas. Food Research International, 30: 485-492.

Reppich, M., Jegla, Z., Grondinger, J.,Azouma, Y.O., and Turek, V. (2021). Mathematical modeling of drying processes of selected fruits and vegetables. Chemie Ingenieur Technik, 93 (10):1581–1589.

Rostamibaroji, R., Seiiedlouheris, S.S., and Dehghannya, J. (2017). Mathematical simulation of heat and mass transfer in convectional drying of carrot, pretreated by ultrasound and microwave. Journal of Agricultural Machinery, 7(1): 97-113.

Sharaf-Eldeen, Y.I., Blaisdell, J.L., and Hamdy, M. Y. (1980). A model for ear corn drying. Transaction of the ASAE, 23: 1261–1271.

Tavakolipour, H., and Mokhtarian, M. (2012).Neural network approaches for prediction of pistachio drying kinetics.International Journal of Food Engineering,8(3).

Taheri-Garavand, A., Rafiee, S., and Keyhani, A. (2011). Mathematical modeling of thin layer drying kinetics of tomato influence of air dryer conditions. International Transaction Journal of Engineering, Management,& Applied Sciences &Technologies, 2(2).

Yaldiz, O., Ertekin, C., and Uzun, H.I. (2001). Mathematical modeling of thin layer solar drying of Sultana grapes. Energy,26(5): 457-464.