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Research Article

Mathematical Modeling of Microwave-Assisted Foam-Mat Drying of Kefir

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Kefir is a traditional drink produced by the fermentation of milk with kefir grain. In this study, foam-mat drying of kefir using a microwave oven was made, and drying kinetics was determined at various microwave power levels (100, 180, and 300 W). Values of D_{eff} were calculated between 4.8394×10^{-10} and 1.8603×10^{-9} m^2 s^{-1}. Besides, E_a was calculated as 5.28 W g^{-1}. Furthermore, increased drying rates were obtained with increasing microwave powers. In addition, seven drying models were fitted to the moisture ratios obtained from experiments, and Midilli and others' model was found to be the best-fitted model with the highest values (0.9983, 0.9983, and 0.9985 for 100, 180, and 300 W, respectively) of R^2 and the lowest values of χ^2, RSS, and RMSE.

1. Introduction

The foam-mat drying method is a new method that provides drying in a shorter time and at a higher drying speed than the traditional hot air drying method. Foam-mat drying is used for drying liquid or semifluid food materials such as juices and purees of fruit or vegetable. The foam-mat drying method includes two stages: foam formation and drying. In addition, the process of grinding the dried product can be said as the third stage. In the first stage, foam is created by the methods of shaking, whipping, or bubbling by adding a foam stabilizer and/or foaming agent to liquid or semiliquid food. In the second stage, the foam is dried using methods of microwave, oven, tray, or freeze-drying. During drying, moisture is removed from the channels in the foam [1]. This method was applied for the drying of mango [2], yogurt [3, 4], avocado [5], taro [6], apple juice [7], and coconut milk [8]. In addition, as an alternative method of drying, microwave drying provides homogeneous spread of heat and faster rate of drying that saves energy and reduces drying time and cost [9].

Kefir is a food product originating from the Balkans, Eastern Europe, and the Caucasus and later spread to the world due to its beneficial properties. It is an acidic and bubbly fermented beverage with low alcohol content as a result of kefir grains fermenting milk or water [10]. Kefir grains can be characterized as 10-30 mm long structures with an irregular shape and white or yellowish color, resembling cooked rice or cauliflower florets. Kefir grains contain a mixture of bacteria (lactic acid and acetic acid) and yeast cells. It is a nutrient-rich food with protein, vitamins, minerals, calcium, and phosphorus. It is also an important source of probiotics with microflora in its structure. For this reason, it has healing properties against gastrointestinal diseases, some allergies, and hypertension [11].

Drying kinetics is important to explain the relationship between moisture removal and drying process parameters. It provides an understanding of the required moisture removal behavior and suitable drying conditions for each product without large-scale experimentation. Besides, modeling of drying kinetics is required for the development of dryers or transition from laboratory scale to larger scale

[12]. In the literature, there are studies on the drying of kefir such as spray drying [13, 14] and freeze-drying [15, 16]. However, there is no investigation about the microwave or foam-mat drying of kefir. The purpose of this study was drying of kefir by the foam-mat drying method using a microwave oven in order to establish its kinetics of drying. Besides, mathematical modeling was applied to find the best drying model that describes the kefir foam's drying attitude.

2. Materials and Methods

2.1. Foaming and Drying Process of Kefir Foam. Kefir and pasteurized egg white were procured from the local market. In order to obtain kefir foam, kefir (500 g) and pasteurized egg white which was a foaming agent (20%, weight/weight, *w*/*w*) were mixed with domestic mixing equipment (Fakir, Germany) for 5 minutes at its maximum speed (power consumption: 550 W). Then, 50.0 ± 0.30 g foam was spread on a flat plate (diameter: 10 cm, thickness: 5 mm). Drying was carried out with a microwave oven (GW73E, Samsung, South Korea) at 100, 180, and 300 W. Kefir foams were weighed every 30 seconds by removing the plates from the microwave oven, and drying was completed when the samples reached the constant weight. The drying rate of kefir foam was calculated for all microwave powers by

$$\text{Drying rate } (R) = -\frac{\mathrm{G}}{\mathrm{A}} \times \left(\frac{X_{t+1} - X_t}{t_{t+1} - t_t}\right), \tag{1}$$

where R is the rate of drying (g H_2O m^{-2} s^{-1}); G is the dry solid's (DS) weight (g); A is the area of drying (m^2); X_t is the moisture content at any time (g H_2O g^{-1} DS); and t is time (s).

2.2. Drying Kinetics. Effective moisture diffusivity coefficient (D_{eff}) (m^2 s^{-1}) (Equation (2)) (where L is the sample's half thickness (m) and t is time (s)) can be determined if falling rate drying period was observed during drying, long drying terms, and in one dimension of slab geometry by simplified Fick's diffusion equation [17]. Assumptions were made such as diffusivity is constant during the drying period, moisture within the sample is distributed uniformly, and there is no shrinkage (volume change) [18].

$$\mathrm{MR} = \frac{8}{\pi} \exp\left(\frac{-D_{\text{eff}}\pi^2 t}{4 * L^2}\right). \tag{2}$$

The activation energy (E_a) of microwave oven-dried food materials was successfully determined using an Arrhenius-type exponential model [19]. The relation between D_{eff} and E_a was given in Equation (3), where m is raw sample's mass (g) and P is power level of the microwave (W).

$$D_{\text{eff}} = D_0 \exp\left(-\frac{E_a m}{P}\right). \tag{3}$$

2.3. Model Fitting and Data Analysis. Moisture ratio ($\mathrm{MR} = (m_t - m_e)/(m_i - m_e)$) was first calculated, where m_t was the moisture content at any time and m_e and m_i were the equilibrium and initial moisture content (g H_2O g^{-1} DS), respectively, in order to fit the drying data to selected models: Page [20], Peleg [21], Silva and others [22], Henderson and Pabis [23], Wang and Singh [9, 24], Midilli and others [12], and modified Midilli and others [25]. Fitting of drying data to models was made with the software of Sigma Plot (Systat Software Inc., USA) using nonlinear least squares regression analysis.

The predicted and experimental drying data were evaluated to establish the goodness of fit considering four criteria as the correlation coefficient (R^2), residual sum of squares (RSS) (Equation (4)) [26], the reduced chi-square (χ^2) (Equation (5)), and root mean square error (RMSE) (Equation (6)) [27].

$$\mathrm{RSS} = \sum_{i=1}^{N} \left(\mathrm{MR}_{\exp,i} - \mathrm{MR}_{\text{pred},i}\right)^2, \tag{4}$$

$$\chi^2 = \frac{\sum_{i=1}^{N} \left(\mathrm{MR}_{\exp,i} - \mathrm{MR}_{\text{pred},i}\right)^2}{N - n_p}, \tag{5}$$

$$\mathrm{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} \left(\mathrm{MR}_{\exp,i} - \mathrm{MR}_{\text{pred},i}\right)^2}, \tag{6}$$

where $\mathrm{MR}_{\exp}$ and $\mathrm{MR}_{\text{pred}}$ are experimental and predicted moisture ratios, N is the number of experimental data points, and n_p is the number of parameters in the model.

3. Results and Discussion

3.1. Drying Kinetics of Kefir Foam. Kefir foam was dried at three different microwave powers, and the initial moisture content of kefir foam was 9.12 g H_2O g^{-1} DS. Average rates of drying of kefir foam were determined as 1.7643, 4.8305, and 8.6560 g H_2O m^{-2} s^{-1} for 100, 180, and 300 W, respectively (Figure 1). Increase in microwave output power from 100 to 300 W resulted in an increase of 390.62% in drying rate. On the contrary, the drying time also decreased by increased microwave power. Drying time decreased 65.74% and 45.95% from 100 to 180 W and 180 to 300 W, respectively (Figure 2). The reason of faster drying of kefir foam was because the microwave energy was absorbed and transmitted by water molecules, which results in faster boiling of water with uniform heating [28]. Besides, decrease in free moisture content depending on time, where increment in microwave power speeded up the drying process, thus shortened the drying time. The experimental results illustrated that after a short warming up period, during the drying process, falling rate term without constant rate term was monitored for all power levels (Figure 1). In the term of falling rate, the transfer mechanism of water from inner to outer surfaces takes place by diffusion. Qadri and Srivastava [29] dried guava pulp foam which was formed with egg albumin as a foaming agent (8% *w*/*v*) with microwave powers of 480, 560, 640, 720, and 800 W similar to our results; the increase in microwave power caused an increase in mass and heat transfer rate as well as a shortened drying time. Similar

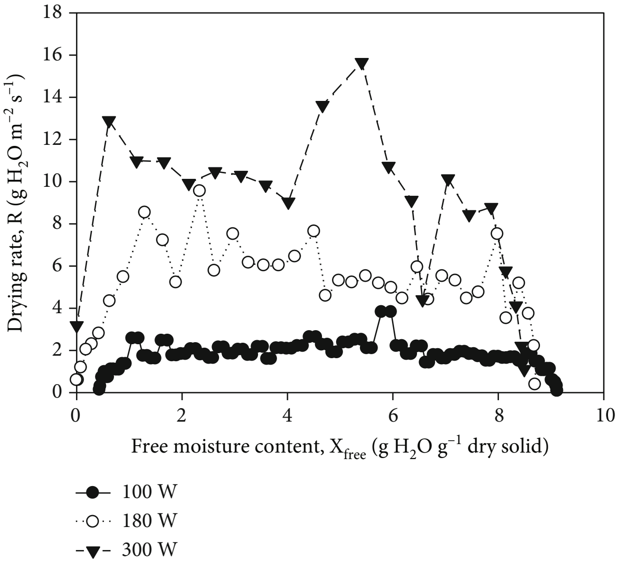

Figure 1: Drying rate against free moisture content of kefir foam.

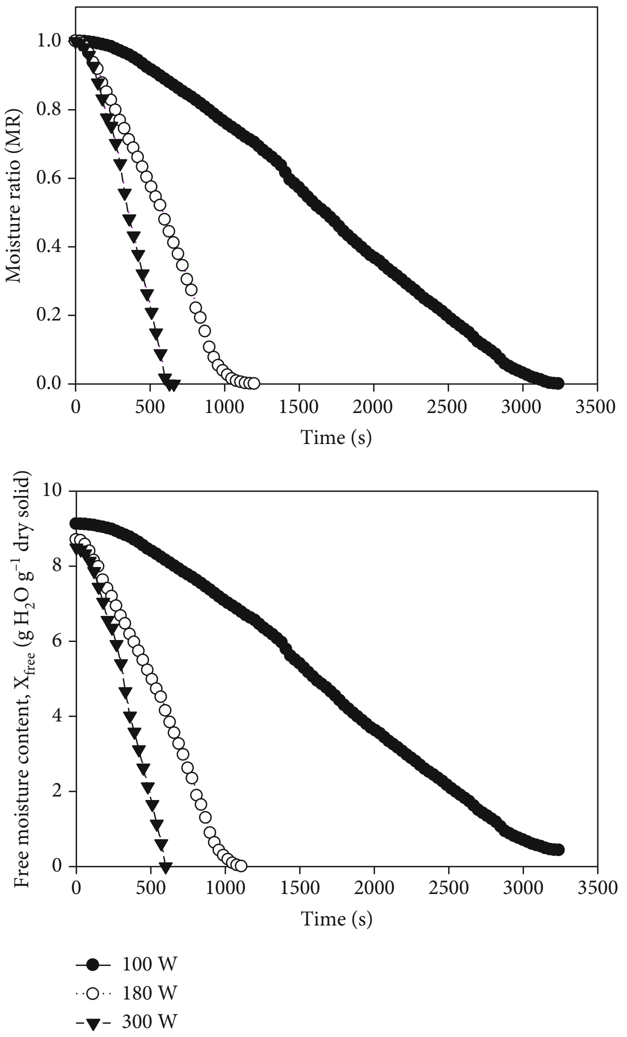

Figure 2: Drying curves of kefir foam.

Table 1: Effective moisture diffusivities and activation energy.

Microwave power	Effective diffusivity (m^2 s^{-1})	Activation energy (E_a)
100 W	4.8394×10^{-10}	5.28 W g^{-1}
180 W	1.8603×10^{-9}	
300 W	2.7173×10^{-9}	

outcomes were recorded in microwave drying of coconut milk [8], Mabonde banana variety [24], garlic puree [28], basil [30], and spinach [31].

D_{eff} values of kefir for 100, 180, and 300 W were determined as 4.8394×10^{-10}, 1.8603×10^{-9} and 2.7173×10^{-9} m^2 s^{-1}, respectively (Table 1). When the power level of microwave increased, the effective moisture diffusivity values of kefir foam also increased. The general range for effective moisture diffusivity values was between 10^{-12} and 10^{-8} for food materials [32]. The pretreated and fresh apple pomaces were dried at different microwave powers by Wang et al. [17]. Their effective diffusivity values were found as similar to our findings. Moreover, D_{eff} values of basil leaves dried at microwave power levels of 180, 360, 540, 720, and 900 W were between 2.168×10^{-10} and 7.899×10^{-10} m^2 s^{-1}, increasing by the increments of powers [30]. Furthermore, D_{eff} values of foam-mat-assisted hot air- (60, 65, and 70°C) dried tomato juice samples were observed in between of 2.026×10^{-8} and 3.039×10^{-8} m^2 s^{-1} in which foam was formed by the addition of 20% of egg albumin as a foaming agent [33].

In addition, the activation energy of foam-mat-assisted microwave-dried kefir foam was determined by the modified Arrhenius equation. E_a was determined as 5.28 W/g in this study (Table 1). Similarly, E_a value of yoghurt dried with microwave was found as 3.62 W g^{-1} [32]. Higher activation energy generally indicates that in the sample, water is bounded strongly in the sample structure [34]. However, most of the water in kefir is free moisture; thus, the removal of this water happened in the period of falling rate and E_a value was found low. Besides, foaming process provides air bubbles in the sample structure; in this way, drying or water removal process happens faster with less initial energy input.

3.2. Model Application. The drying data of experiments was evaluated for fitness to seven drying models, and four criteria were used to determine the best-fitted model. According to the reduced chi-square (χ^2), correlation coefficient (R^2), root mean square error (RMSE), and residual sum of squares (RSS), the model of Midilli and others was the best-fitted model to drying data of experiments for kefir foam (Table 2). Values of R^2 were more than 0.98 except for Silva and others (in the range of 0.94-0.95) and Henderson and Pabis (in the range of 0.88-0.91) models. Furthermore, Midilli and others' model and the modified one gave the highest R^2 values (>0.99) with the lowest error values for all microwave powers. Similar to our findings, Midilli and others' model was also found as the best for foam-mat-assisted hot air drying of guava

Table 2: Model parameters and statistical results.

Drying model	Microwave power (W)	k	n	a	b	R^2	χ^2	RMSE	RSS
Page $\mathrm{MR} = \exp(-k \cdot t^n)$	100	1.0035×10^{-7}	2.1268	—	—	0.9942	0.0007	0.0253	0.0699
	180	1.3931×10^{-6}	2.0796	—	—	0.9866	0.0017	0.0399	0.0653
	300	5.7154×10^{-7}	2.3880	—	—	0.9927	0.0010	0.0296	0.0201
Peleg $\mathrm{MR} = 1 - t/(a + bt)$	100	—	—	3971.1532	-0.3035	0.9889	0.0012	0.0348	0.1323
	180	—	—	1170.8875	-0.0772	0.9846	0.0019	0.0429	0.0754
	300	—	—	914.6928	-0.4718	0.9841	0.0021	0.0437	0.0440
Silva and others $\mathrm{MR} = \exp(-a \cdot t - b\sqrt{t})$	100	—	—	9.7043×10^{-4}	-0.0198	0.9516	0.0080	0.0853	0.1672
	180	—	—	2.9054×10^{-3}	-0.0333	0.9453	0.0069	0.0807	0.2673
	300	—	—	4.8658×10^{-3}	-0.0485	0.9395	0.0054	0.0729	0.5786
Henderson and Pabis $\mathrm{MR} = a \cdot \exp(-k \cdot t)$	100	6.0419×10^{-4}	—	1.2080	—	0.9118	0.0098	0.0983	1.0534
	180	1.8402×10^{-3}	—	1.1888	—	0.9087	0.0114	0.1043	0.4460
	300	2.8140×10^{-3}	—	1.1999	—	0.8839	0.0153	0.1181	0.3207
Wang and Singh $\mathrm{MR} = 1 + a \cdot t + b \cdot t^2$	100	—	—	-2.3350×10^{-4}	-3.1559×10^{-8}	0.9904	0.0011	0.0325	0.1150
	180	—	—	-8.4341×10^{-4}	-7.1839×10^{-8}	0.9847	0.0019	0.0427	0.0746
	300	—	—	-9.1678×10^{-4}	-1.1329×10^{-6}	0.9877	0.0016	0.0384	0.0340
Midilli and others $\mathrm{MR} = a \cdot \exp(-k \cdot t^n) + b \cdot t$	100	-0.0101	0.5868	0.9518	-0.0009	0.9983	0.0002	0.0135	0.0199
	180	3.0083×10^{-6}	1.9118	0.9792	-0.0001	0.9952	0.0006	0.0240	0.0235
	300	1.6457×10^{-6}	2.1507	1.0031	-0.0003	0.9985	0.0002	0.0133	0.0041
Modified Midilli and others $\mathrm{MR} = \exp(-k \cdot t^n) + b \cdot t$	100	-0.0052	0.6430	—	-0.0008	0.9979	0.0002	0.0150	0.0246
	180	-0.0099	0.6687	—	-0.0027	0.9925	0.0009	0.0299	0.0366
	300	-0.0172	0.5951	—	-0.0035	0.9957	0.0006	0.0228	0.0120

MR: moisture ratio; R^2: correlation coefficient; χ^2: reduced chi-square; RMSE: root mean square error; RSS: residual sum of squares. k, n, a, and b are the parameters.

pulp with the highest R^2 (>0.99) and lowest values of RMSE and χ^2 [35]. Moreover, a similar result was obtained for mathematical modeling of freeze-drying data of kefir [16]. On the contrary to our findings, Reis et al. [36] stated that the Page model is the proper one for fitness of the foam-mat drying kinetics when they analyzed the mathematical models. In addition, for hot air foam-mat drying of cantaloupe pulp, the model of Weibull distribution was found as the best-fitted model [37].

Validation of predicted MR values (y) of Midilli and others' model was made by the comparison of experimental MR values (x) of kefir foam, and equations were obtained from the linear regression of both MR values for 100, 180, and 300 W, respectively: $y = 0.0009 + 0.9983x$ ($R^2 = 0.9983$), $y = 0.0021 + 0.9953x$ ($R^2 = 0.9952$), and $y = 0.0008 + 0.9985x$ ($R^2 = 0.9985$). As a result of the regression analysis, it was confirmed that the experimental data showed a very good agreement with the predicted values obtained from this model.

4. Conclusion

Kefir foam was produced by the addition 20% of pasteurized egg white as a foaming agent, then dried with a microwave oven at powers of 100, 180, and 300 W. Drying kinetics were evaluated in terms of rate of drying, time of drying, coefficient of moisture diffusivity, and energy of activation. D_{eff} were determined in the range of 4.8394×10^{-10} and $2.7173 \times 10^{-9}\ \mathrm{m^2\,s^{-1}}$. Increased microwave power level resulted in an increment in drying rate and a decrement in drying time. In addition, seven drying models were applied to drying data of experiments where Midilli and others' model was found to be the best-fitted model when values of R^2, RSS, RMSE, and χ^2 were evaluated. The identification of the drying behavior of kefir can be useful for the design and optimization of drying systems. Furthermore, the viability of the probiotic properties of kefir powder could be a future line of work.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there is no conflict of interest.

References

[1] G. Çalışkan Koç, Y. Tekgül, A. N. Yüksel, A. C. Khanashyam, A. Kothakota, and R. Pandiselvam, "Recent development in foam-mat drying process: influence of foaming agents and foam properties on powder properties," *Journal of Surfactants and Detergents*, vol. 25, no. 5, pp. 539–557, 2022.

[2] P. Rajkumar, R. Kailappan, R. Viswanathan, G. S. V. Raghavan, and C. Ratti, "Foam mat drying of Alphonso mango pulp," *Drying Technology*, vol. 25, no. 2, pp. 357–365, 2007.

[3] M. Malik and A. Sharma, "Optimisation of foam-mat drying of yoghurt and properties of powdered yoghurt," *International Journal of Dairy Technology*, vol. 72, no. 3, pp. 381–387, 2019.

[4] A. N. Yüksel, "Development of yoghurt powder using microwave-assisted foam-mat drying," *Journal of Food Science and Technology*, vol. 58, no. 7, pp. 2834–2841, 2021.

[5] G. Çalışkan Koç and A. N. Yüksel, "The foam-mat convective and microwave dried avocado powder: physical, functional, and powder properties," *Latin American Applied Research*, vol. 50, no. 4, pp. 291–297, 2020.

[6] G. Çalışkan Koç, A. N. Yüksel, E. Baş, and S. L. Erdoğan, "Foam mat drying of taro (Colocasia esculenta): the effect of ultrasonic pretreatment and drying techniques on the drying behavior, flow, and reconstitution properties of taro flour," *Journal of Food Process Engineering*, vol. 43, no. 11, 2020.

[7] N. Raharitsifa, D. B. Genovese, and C. Ratti, "Characterization of apple juice foams for foam-mat drying prepared with egg white protein and methylcellulose," *Journal of Food Science*, vol. 71, no. 3, pp. E142–E151, 2006.

[8] P. P. Shameena Beegum, M. R. Manikantan, K. B. Anju et al., "Foam mat drying technique in coconut milk: effect of additives on foaming and powder properties and its economic analysis," *Journal of Food Processing & Preservation*, vol. 46, no. 11, article e17122, 2022.

[9] A. N. Yüksel, "Mikrodalga koşullarinda muzun köpük kurutma özelliklerinin modellenmesi," *GIDA*, vol. 45, no. 6, pp. 1134–1142, 2020.

[10] N. F. Azizi, M. R. Kumar, S. K. Yeap et al., "Kefir and its biological activities," *Foods*, vol. 10, no. 6, p. 1210, 2021.

[11] Z. Ahmed, Y. Wang, A. Ahmad et al., "Kefir and health: a contemporary perspective," *Critical Reviews in Food Science and Nutrition*, vol. 53, no. 5, pp. 422–434, 2013.

[12] D. S. A. Delfiya, K. Prashob, S. Murali, P. V. Alfiya, M. P. Samuel, and R. Pandiselvam, "Drying kinetics of food materials in infrared radiation drying: a review," *Journal of Food Process Engineering*, vol. 45, no. 6, article e13810, 2022.

[13] I. Atalar and M. Dervisoglu, "Optimization of spray drying process parameters for kefir powder using response surface methodology," *Science and Technology*, vol. 60, no. 2, pp. 751–757, 2015.

[14] M. Teijeiro, P. F. Pérez, G. L. De Antoni, and M. A. Golowczyc, "Suitability of kefir powder production using spray drying," *Food Research International*, vol. 112, pp. 169–174, 2018.

[15] P. A. Bolla, M. de los Angeles Serradell, P. J. de Urraza, and G. L. De Antoni, "Effect of freeze-drying on viability andin vitroprobiotic properties of a mixture of lactic acid bacteria and yeasts isolated from kefir," *The Journal of Dairy Research*, vol. 78, no. 1, pp. 15–22, 2011.

[16] H. Isleroglu, "Freeze drying and moisture adsorption kinetics of kefir powder," *Italian Journal of Food Science*, vol. 31, no. 3, 2019.

[17] Z. F. Wang, J. H. Sun, F. Chen, X. J. Liao, and X. S. Hu, "Mathematical modelling on thin layer microwave drying of apple pomace with and without hot air pre-drying," *Journal of Food Engineering*, vol. 80, no. 2, pp. 536–544, 2007.

[18] J. Crank, *Mathematic of Diffusion*, Oxford University Press, London, UK, 2nd edition, 1975.

[19] G. Dadali, D. Kılıç Apar, and B. Özbek, "Microwave drying kinetics of okra," *Drying Technology*, vol. 25, no. 5, pp. 917–924, 2007.

[20] I. G. Branco, T. T. Kikuchi, E. J. S. Argandona, I. C. F. Moraes, and C. W. I. Haminiuk, "Drying kinetics and quality of uvaia (Hexachlamys edulis (O. Berg)) powder obtained by foam-mat drying," *International Journal of Food Science & Technology*, vol. 51, no. 7, pp. 1703–1710, 2016.

[21] W. P. Da Silva, A. F. Rodrigues, C. M. D. P. S. E. Silva, D. S. De Castro, and J. P. Gomes, "Comparison between continuous and intermittent drying of whole bananas using empirical and diffusion models to describe the processes," *Journal of Food Engineering*, vol. 166, pp. 230–236, 2015.

[22] A. N. Yüksel and G. Çalışkan Koç, "Hot-air and microwave-assisted foam-mat drying of avocado," in *Theory and Research in Engineering*, A. Hayaloğlu, Ed., pp. 367–382, Gece Publishing, Ankara, Turkey, 2020.

[23] E. K. Akpinar, Y. Bicer, and C. Yildiz, "Thin layer drying of red pepper," *Journal of Food Engineering*, vol. 59, no. 1, pp. 99–104, 2003.

[24] A. O. Omolola, A. I. O. Jideani, and P. F. Kapila, "Modeling microwave drying kinetics and moisture diffusivity of Mabonde banana variety," *International Journal of Agricultural and Biological Engineering*, vol. 7, no. 6, pp. 107–113, 2014.

[25] Z. Erbay and F. Icier, "A review of thin layer drying of foods: theory, modeling, and experimental results," *Critical Reviews in Food Science and Nutrition*, vol. 50, no. 5, pp. 441–464, 2010.

[26] W. A. M. Mcminn, "Thin-layer modelling of the convective, microwave, microwave-convective and microwave-vacuum drying of lactose powder," *Journal of Food Engineering*, vol. 72, no. 2, pp. 113–123, 2006.

[27] G. Jeevarathinam, R. Pandiselvam, T. Pandiarajan et al., "Design, development, and drying kinetics of infrared-assisted hot air dryer for turmeric slices," *Journal of Food Process Engineering*, vol. 45, no. 6, article e13876, 2022.

[28] I. Ilter, S. Akyil, E. Devseren, D. Okut, M. Koc, and F. K. Ertekin, "Microwave and hot air drying of garlic puree: drying kinetics and quality characteristics," *Heat and Mass Transfer*, vol. 54, no. 7, pp. 2101–2112, 2018.

[29] O. S. Qadri and A. K. Srivastava, "Microwave-assisted foam mat drying of guava pulp: drying kinetics and effect on quality attributes," *Journal of Food Process Engineering*, vol. 40, no. 1, article e12295, 2017.

[30] E. Demirhan and B. Ozbek, "Microwave-drying characteristics of basil," *Journal of Food Processing & Preservation*, vol. 34, no. 3, pp. 476–494, 2010.

[31] I. A. Ozkan, B. Akbudak, and N. Akbudak, "Microwave drying characteristics of spinach," *Journal of Food Engineering*, vol. 78, no. 2, pp. 577–583, 2007.

[32] A. N. Yüksel, "The effect of microwave output power on drying kinetics of yoghurt and mathematical modeling of drying curves," *Latin American Applied Research*, vol. 51, no. 2, pp. 127–131, 2021.

[33] D. M. Kadam and S. Balasubramanian, “Foam mat drying of tomato juice,” *Journal of Food Processing & Preservation*, vol. 35, no. 4, pp. 488–495, 2011.

[34] R. A. Chayjan, M. Kaveh, and S. Khayati, “Modeling drying characteristics of hawthorn fruit under microwave-convective conditions,” *Journal of Food Processing & Preservation*, vol. 39, no. 3, pp. 239–253, 2015.

[35] R. M. G. Maciel, M. R. A. Afonso, J. M. C. Da Costa, L. S. Severo, and N. D. De Lima, “Mathematical modeling of the foam-mat drying curves of guava pulp,” *Revista Brasileira de Engenharia Agrícola e Ambiental*, vol. 21, no. 10, pp. 721–725, 2017.

[36] F. R. Reis, A. C. S. De Moraes, and M. L. Masson, “Impact of foam-mat drying on plant-based foods bioactive compounds: a review,” *Plant Food for Human Nutrition*, vol. 76, no. 2, pp. 153–160, 2021.

[37] M. R. Salahi, M. Mohebbi, and M. Taghizadeh, “Foam-mat drying of cantaloupe (Cucumis melo): optimization of foaming parameters and investigating drying characteristics,” *Journal of Food Processing & Preservation*, vol. 39, no. 6, pp. 1798–1808, 2015.