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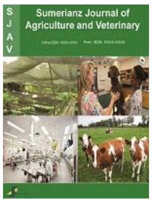

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Study On Activation Energy, Moisture Diffusivity Effectiveness and Mathematical Modelling of Thin Layer Drying Kinetics of Red Pepper (*Capsicum Annum L.)*

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Abstract

The thin-layer drying behavior of red pepper sample was examined using seven mathematical models that were found in the literature. According to the R^2, RMSE, and v^2 values with respect to the experimental and predicted moisture ratios the models were contrasted. The drying process happened throughout the period of falling rates. The findings demonstrated that the most acceptable model is the Midilli model for describing the drying behavior of thin layer pepper samples. The effective moisture diffusivity and moisture content were shown to be correlated by a third order polynomial relationship. As the moisture content of the pepper samples decreased the moisture diffusivity effectiveness increased, with an energy activation of 40.54 KJ/mol, the average effective diffusivity over the temperature range investigated was between 4.7×10^{-9} to 13.3×10^{-9} m^2/sec.

Keywords: Pepper; Effective moisture diffusivity; Energy activation; Moisture ratio and falling rate period.

1. Introduction

Red peppers are consumed and used as flavors all over the world. Due to issues with marketing, storage, and the absence of adequate processing technology, there are significant losses based on the National Nutrient Database of the USDA National Nutrient Database for Standard Reference (Release 19) [1]. Due to their fiery and pungent flavor, which is brought on by the presence of capsaicins, peppers are frequently employed in food products including cakes, meats, chocolates, jellies, sweets, and sauces [2]. Peppers have a preservation function in addition to being used as a spice since they are high in capsaicin, which has strong antioxidant and antibacterial effects [3]. According to Tunde-Akintude, *et al.* [4], pepper provides an abundant and affordable nutritional composition. According to Simonne [5], they naturally include tocopherols, ascorbic acid, provitamin a carotenoids, flavonoids, and phenolic acids which are crucial element [6]. According to Faustino, *et al.* [7], these substances are potent antioxidants that play a crucial role in the body ability to combat free radicals, which lowers the risk of diseases like cancer, heart disease, and arthritis while also slowing the aging process. However, because of the substantial amount of moisture, it is prone to degradation.

Dehydration is among the favored techniques for preserving peppers. But despite this, this procedure typically leads to nutrition loss and other undesired modifications, such as discolouration and darkening depending on the procedure parameters [8]. Despite the fact that dried foods are less nutritious (Miranda *et al.*, 2009), how well they are dried affects their quality [4].

Drying is one of the first approaches to food preservation which involves moisture reduction. Two fundamental techniques for removing moisture from a solid medium are mechanical and thermal approaches [9]. Raw foods are perishable because they contain a lot of moisture. Drying has been used successfully in numerous application used to subdue the microbiological, biochemical and physical degradation of food products because the level of moist available is reduced to a level that enables the shelf life for a long time and results in a considerable loss of volume and weight [10]. This reduces the costs associated with packaging, storage, and transportation.

Local producers claim that it takes roughly seven days in a row for pepper to be sun dried, and that the fruits suffer from unfavorable fermentation, which lowers sales [11]. When the product's actual quality is not competitive, this method is impractical because it is sluggish, labor-intensive, and expensive.

The literature has discussed some earlier research on red pepper dehydration. Under various pretreatments and drying circumstances, Red pepper drying kinetics have undergone analysis Doymaz and Pala [12], Ramesh, *et al.* [13] and Turhan, *et al.* [14] Other writers have discussed how drying affects different quality factors including researcher Lee and Kim [15] studied on the carotenoids and non-enzymatic browning and Sigge, *et al.* [16] worked on the color, L-ascorbic acid, and sugar retention while Carbonell, *et al.* [17] investigated the colour perspective only.

This project goal is to assess and model the mass transfer kinetics during the hot-air drying of red pepper at temperatures of 50 -100°C with a discrepancy of 10°C as well as to investigate how temperature affected kinematic parameters of the suggested models. Calculations were made for the moisture diffusivity effectiveness and how much energy required for complete dehydration.

2. Materials and Methods

2.1. Materials

In the city of Yenagoa, the state capital of Bayelsa, Nigeria, there is a well-known market called Swali Market where high-quality fresh red pepper was purchased and stored until the experiments were performed at a 4 °C temperature. The samples were taken out of the freezer and allowed to defrost to room temperature before being used in the assays. The experiment was conducted in the Agricultural and Environmental Engineering labs, Niger Delta University in Bayelsa State, Nigeria, the experiment was conducted in January 2023. The red pepper which had average measurements of 0.6 ±0.1 cm in diameter and 5±1 cm in length and cleaned before being cut in half and into 1.5 cm lengths. The red pepper original moisture content (on a wet basis) was 73.33%, and this value was calculated by drying the pepper in a convection oven at various temperatures until the weight remained constant [18].

2.2. Methods

Each sample was prepped beforehand for drying trials before being placed on the convection oven dryer. A sample was frequently removed from the oven and weighed on an electronic scale with a precision of 0.01 g to quantify moisture loss at intervals of 5 minutes while the oven was calibrated to 50, 60, 70, 80, 90, and 100°C. Average results were recorded for each drying operation, which was performed in triplicate. When the ultimate dry basis moisture content was less than 0.11 g/g, the drying test was terminated and the drying test was stopped when the final dry basis moisture content fell below 0.11 g/g [19, 20]. Plotting the drying rate as a function of moisture and the moisture ratio as a function of time could result in the drying curves. The models shown in Table 1 below were chosen in order to best represent the experimental data amongst the empirical models that are widely used to explain how agricultural products are dried kinetically in technical literature.

2.3. Mathematical Modelling

It's critical to effectively simulate the drying behavior in order to investigate the red pepper drying properties. In this work, the sample's experimental drying data were inputted into seven popular thin-layer drying models. See Table 1.

$$MR = \frac{M_t - M_e}{M_0 - M_e} \quad [21, 22]: \qquad 1$$

$$MR = \frac{M_t}{M_0} \qquad 2$$

2.4. Analysing Errors and Correlation Coefficients

The reduced Chi-square (v^2), correlation coefficient (R^2), and root mean square error (RMSE) metrics were used to assess how well the tested mathematical model represented the experimental data. According to Wang, *et al.* [23]; Egbe, *et al.* [24] and Ozbek and Dadali [25], the fitting technique is better when the R^2 value is larger and the v^2 and RMSE values are lower. Following is a definition of these parameters:

$$R^2 = 1 - \left[\sum_{i=1}^{n}(MR_{pre,i} - MR_{exp,i})^2\right] \qquad 3$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(MR_{pre,i} - MR_{exp,i})^2}{n}} \qquad 4$$

$$V^2 = \frac{\sum_{i=1}^{n}(MR_{pre,i} - MR_{exp,i})^2}{n - k} \qquad 5$$

2.5. Drying Rate

Equation 6 was used to determine the sample drying rate.

$$DR = \frac{M_{t+\Delta t} - M_t}{\Delta_t} \qquad 6$$

Table-1. Models of the thin layer drying curve taken into account

Model name	Model	References
Modified Page	MR = exp $((kt)^n)$	Arslan and Ozcan (2010a,b)
Midilli et al.	MR = a exp (kt^n) + bt	Midilli et al. (2002)
Page	MR = exp (kt^n)	Jangam et al. (2008)
Logarithmic	MR = a exp (kt) + b	Kingsly et al. (2007)
Henderson and Pabis	MR = a exp (kt)	Figiel (2010)
Newton	MR = exp (-kt)	Bahmani et al., (2016)
Wang and Singh	MR = 1 + bt + at^2	Wang et al. (2007)

2.6. Determining the Effectiveness of Moisture Diffusivity and Activation Energy

Food ingredients often go through the drying process during the period of falling rates. Equation. 7 utilizing Fick's second law and taking into account the following assumptions [26]:

1. Moisture is initially evenly distributed across the mass of a sample.
2. Within the context of the center, mass transmission is symmetric.
3. An instantaneous equilibrium is reached between the sample surface moisture content and the air humidity level.
4. The mass transfer at the surface experiences significantly less resistance compared to the interior resistance of the sample.
5. Mass transfer only occurs through diffusion.
6. There is minimal shrinking and a steady diffusion coefficient.

The initial moisture distribution was uniform, the slab shape was infinite, and the moisture diffusivity was constant.

$$MR = \frac{M - M_e}{M_o - M_e} = \frac{6}{\pi^2}\int_{n=1}^{\infty}\frac{1}{(2n-1)^2}e^{-(2n-1)^2\frac{\pi^2 D_e t}{L^2}} \quad \dots \quad 7$$

$$MR = \frac{8}{\pi^2}\exp\left(\frac{\pi^2 D_{eff} t}{4L^2}\right) \text{ [27]} \quad 8$$

$$MR = \frac{8}{\pi^2} exp\,(-\pi^2 F_0) \text{ [28]} \quad 9$$

$$\text{Thus: } F_0 = 0.1011n(MR) - 0.0213 \quad 10$$

Using Equation (11) to compute the effective moisture diffusivity.

$$D_{eff} = \frac{F_0}{\frac{t}{4L^2}} \quad 11$$

$$D = D_0\, esp\left(-\frac{E_a}{RTa}\right) \quad 12$$

Arrhenius Equation and the activation energy may be computed by ln(D) against $1/T_a$.

Equation (12) the Ea can be derived by a plot of ln(D) against 1/Ta will generate a slope of K_1

$$K_1 = \frac{E_a}{R} \quad 13$$

3. Results and Discussions

For the purpose of calculating the sample moisture ratio, the MR collected are plotted against time in Figure 1.

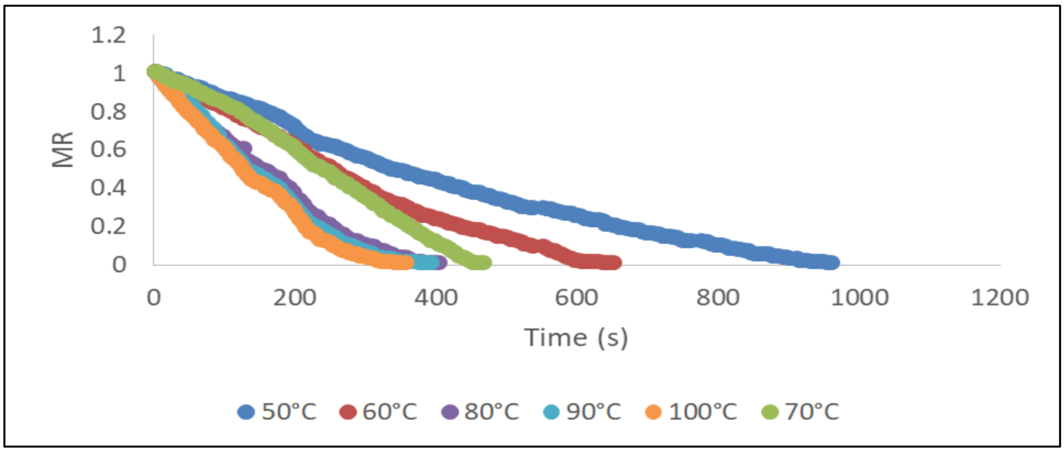

Figure-1. Moisture ratio for red pepper at different temperature

Figure 1 demonstrated that drying times are accelerated by increasing temperature. It was discovered that red pepper drying occurs primarily during the period of falling rates. This demonstrated that internal diffusion was largely responsible for the drying rate of red pepper. The results obtained are similar to other scientists [29, 30]

3.1. Fitting of Drying Curves Red Pepper

These statistical variables come in handy when it comes to analyzing experimental outcomes. As stated in Table 2, the statistical metrics evaluated in this study are R^2, V^2 and RMSE. The Medilli model has the highest R^2 (0.999), and lowest V^2 (0.00004-0.00065) and RMSE (0.00376-0.00598), the Medillli model (V^2)- absolute minimum value is regarded the optimal model for predicting red pepper act of drying Fig. 2 present a relationship between measured and predicted moisture ratio and the grouping or clustering of the moisture ratio values along the graph straight line indicates that it is appropriate to relate the drying properties of red pepper using the Medilli model.

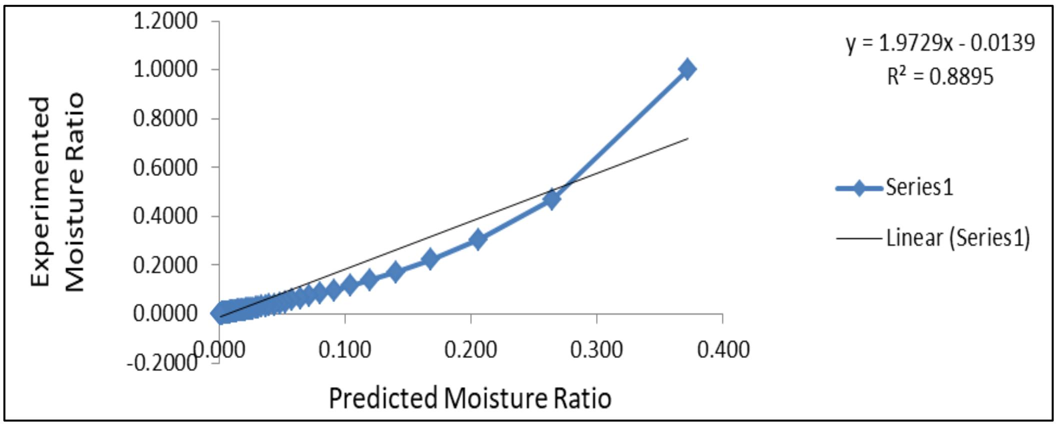

Figure-2. Comparison of the MRexperimented and MRpredicted of red pepper

Table-2. Statistical results obtained from the selected models

Model	Temp °C	Constants and coefficients	R2	v2	RMSE
Newton	50	k = 0.6022	0.790	0.02271	0.14390
	60	k = 0.6847	0.849	0.0175	0.13258
	70	k = 0.7821	0.857	0.03132	0.14117
	80	k = 0.8758	0.857	0.02854	0.13090
	90	k = 0.9029	0.879	0.02883	0.13148
	100	k = 0.9495	0.836	0.03201	0.14086
Henderson and Pabis	50	a = 1.7931; k = 0.7563	0.845	0.04813	0.20857
	60	a = 1.6639; k = 0.8473	0.895	0.03584	0.17769
	70	a = 1.6992; k = 0.9764	0.897	0.04258	0.19198
	80	a = 1.6298; k = 0.9899	0.991	0.03823	0.17759
	90	a = 1.7405; k = 1.2370	0.8752	0.05774	0.21756
	100	a = 1.6147; k = 1.3217	0.8783	0.04473	0.18745
Logarithmic	50	a = 2.077; k = 0.152; b = 1.10	0.997	0.00053	0.02109
	60	a = 3.193; k = 0.099; b = 2.159	0.997	0.00054	0.02072
	70	a = 3.461; k = 0.114; b = 2.394	0.996	0.00698	0.07479
	80	a = 3.260; k = 0.136; b = 2.223	0.997	0.00057	0.02070
	90	a = 4.050; k = 0.110; b = 3.01	0.996	0.00071	0.02293
	100	a = 4.959; k = 0.112; b = 4.00	0.996	0.00085	0.02419
Modified Page	50	k = 0.367; n = 1.799	0.997	0.00049	0.02079
	60	k = 0.537; n = 1.807	0.998	0.00038	0.01816
	70	k = 0.498; n = 1.762	0.998	0.00033	0.01624
	80	k = 0.590; n = 1.799	0.998	0.00038	0.01756
	90	k = 0.634; n = 1.911	0.997	0.00049	0.01999
	100	k = 0.733; n = 1.920	0.998	0.00039	0.01720
Midilli	50	a = 1.004; k = 0.174; b = 0.033; n = 1.563	0.999	0.00005	0.00528
	60	a = 0.998; k = 0.231; b = 0.040; n = 1.540	0.999	0.00007	0.00598
	70	a = 1.000; k = 0.367; b = 0.042; n = 1.585	0.999	0.00004	0.00376
	80	a = 0.998; k = 0.352; b = 0.050; n = 1.439	0.999	0.00004	0.00539
	90	a = 0.004; k = 0.366; b = 0.054 l n = 1.790	0.999	0.00005	0.00541
	100	a = 1.005; k = 0.549; b = 0.061; n = 1.723	0.999	0.00007	0.00584
Wang and Singh	50	a = 0.0040, b = 0.2321	0.995	0.00065	0.02365
	60	a = 0.0051; b = 0.2803	0.994	0.00078	0.02603
	70	a = 0.0052; b = 0.4031	0.994	0.00099	0.02602
	80	a = 0.0100; b = 0.4615	0.995	0.00075	0.02495
	90	a = 0.0021; b = 0.3744	0.994	0.00098	0.02825
	100	a = 0.0140; b = 0.5050	0.994	0.00099	0.02801
Page	50	k = 0.274; n = 1.799	0.997	0.00049	0.02080
	60	k = 0.343; n = 1.807	0.998	0.00037	0.01738
	70	k = 0.394; n = 1.861	0.998	0.00034	0.01623
	80	k = 0.497; n = 1.799	0.998	0.00037	0.01755

	90	k = 0.525; n = 1.911	0.997	0.00049	0.01999
	100	k = 0.654; n = 1.920	0.999	0.00038	0.01720

3.2. Effective Moisture Diffusivity red pepper

As indicated by the fact that moisture diffusivity increased as the drying temperature was raised, the kinetics may be caused by higher temperatures changing the activity of water molecules and resulting in higher moisture diffusivity, Sacilik [31], Jittanit [32], Doymaz [33], Robert, *et al.* [34] and Egbe and Davies [30] all observed similar findings. The Deff ranged from 4.7 x 10^{-9} to 13.3x$10^{-9}$$m^2$/sec for temperature ranges of 50^0C, 60^0C, 70^0C, 80^0C, 90^0C, and 100^0C with increasing temperature according to Table 3. Zibokere and Egbe [35] and Sacilik [31] found comparable results.

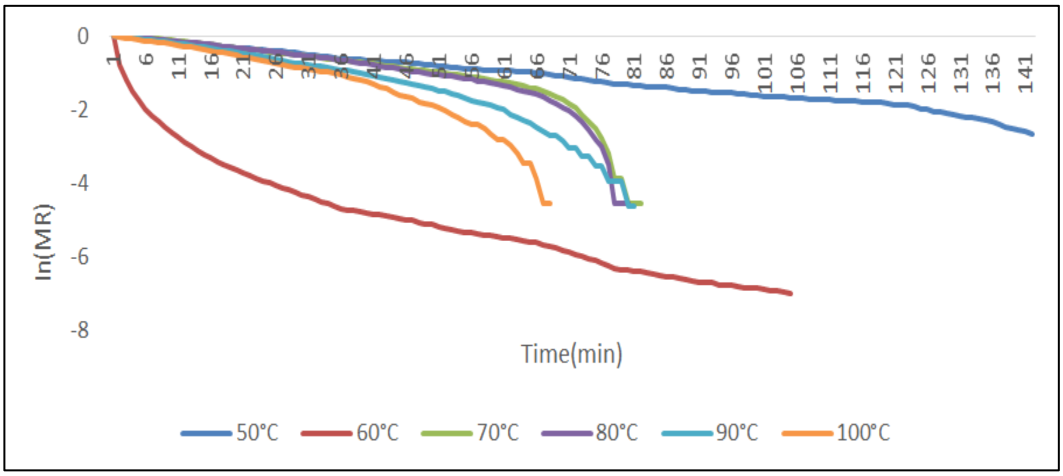

Figure-3. Measurement of Moisture Diffusivity Percentage of red pepper

3.3. Activation Energy for Red Pepper

During drying, the energy that starts mass transfer from a moist biomaterial is referred to as activation energy. The activation energy was derived from the In Deff Versus temp and the Deff was established to obeisance Arrhenius Law. The energy that activates red pepper were found to be 40.54KJ/mol.

Table-3. Evaluation of Moisture Diffusivity Effectiveness

Temperature (°C)	Average Effective Diffusivity
50	4.7×10^{-9}
60	7.4×10^{-9}
70	10.3×10^{-9}
80	11.7×10^{-9}
90	12.5×10^{-9}
100	13.3×10^{-9}

4. Conclusion

Six different drying air temperatures were tested on the drying behavior of red pepper slices in a laboratory dryer. To fit the experimental results and explain the drying behavior of red pepper, seven models from the literature were used. The statistical study conducted on all models led researchers to the conclusion that the Medilli model produced the best outcomes. Additionally, this study's findings were in good accord with the outcomes of the trial. It may be stated that air temperature affects drying time since with an increase in air temperature, drying time decreases during a period of falling rate. The findings indicate that a Medilli model could accurately predict the drying properties of red pepper under conditions of air velocity of 2 m/s and temperature range of 50 to 100 °C. The Arrhenius equation which shows that the logarithm of the diffusivity exhibits a linear behavior versus the reciprocal of the absolute temperature, describes how temperature affects diffusivity. 40.54 KJ/mol was the associated activation energy.

Reference

[1] USDA National Nutrient Database for Standard Reference (Release 19), 2006.
[2] Carvalho, S. I. C., 2006. "Pimentas do gênero capsicum no Brasil. Embrapa Hortaliças." *Embrapa Hortaliças Documentos*, p. 27.
[3] Reifschneider, F. J. B., 2000. *Capsicum: Pimentas e pimentões do Brasil*. Brasília: Embrapa, p. 113.
[4] Tunde-Akintude, T. Y., Akintude, B. O., and Fagbeja, A., 2011. "Effect of blanching methods on drying kinetics of bell pepper." *African Journal of Food, Agriculture, Nutritional and Development*, vol. 11, pp. 5457-5474.

[5] Simonne, A. H., 1997. "Ascorbic acid and provitamin A contents in unusually colored bell peppers (*Capsicum annuum* L.)." *Journal of Food Composition and Analysis*, vol. 10, pp. 299-311. Available: http://dx.doi.org/10.1006/jfca..0544

[6] Ishikawa, K., 1998. "The contents of capsaicinoids ant their phenolic intermediates in the various tissues of plants of Capsimum annuum." *Capsicum and Eggplant Newsletter*, vol. 17, pp. 22-25.

[7] Faustino, J. M. F., Barroca, M. J., and Guiné, R. P. F., 2007. "Study of the drying kinetics of green bell pepper and chemical characterization." *Food and Bioproducts Processing*, vol. 85, pp. 163-170.

[8] Kim, S., 2006. "Effect of drying in antioxidant activity and changes of ascorbic acid and color by different drying and storage in Korean red pepper (*Capsicum annuum* L.)." *International Journal of Food Science and Technology*, vol. 41, pp. 90-95.

[9] Karimi, F., 2010. "Applications of superheated steam for the drying of food products." *Int. Agrophysics*, vol. 24, pp. 195-204.

[10] Zielinska, M. and Markowski, M., 2010. "Air drying characteristics and Effective moisture diffusivity of carrots." *Chem. Eng. Process*, vol. 49, pp. 212–218.

[11] Soysal, Ayhan, Z., Esturk, O., and Arikan, M. F., 2009. "Intermittent microwave–convective drying of red pepper: drying kinetics, physical (colour and texture) and sensory quality." *Biosyst. Eng.*, vol. 103, pp. 455–463.

[12] Doymaz, I. and Pala, M., 2002. "Hot-air drying characteristics of red pepper." *Journal of Food Engineering*, vol. 55, pp. 331-335. Available: http://dx.doi.org/10.1016/S0260-8774(02)00110-3

[13] Ramesh, M. N., Wolf, W., Tevini, D., and Jung, G., 2001. "Influence of processing parameters on the drying of spice paprika." *Journal of Food Engineering*, vol. 49, pp. 63–72.

[14] Turhan, M., Turhan, K. N., and Sahbaz, F., 1997. "Drying kinetics of red pepper." *Journal of Food Processing and Preservation*, vol. 21, pp. 209-223. Available: http://dx.doi.org/10.1111/j.1745-4549.1997

[15] Lee, D. S. and Kim, H. K., 1989. "Carotenoid destruction and nonenzimatic browning during red pepper drying as functions of average moisture content and temperature." *Korean Journal of Food Science and Technology*, vol. 21, pp. 425–429.

[16] Sigge, G., Hansmann, C., and Joubet, E., 1999. "Optimizing the dehydration conditions of green peppers (Capsicum annuum L.): Quality criteria." *Journal of Food Quality*, vol. 22, pp. 425–439.

[17] Carbonell, J. V., Pin, A. F., Yusa, V., and Pen, A. J. L., 1986. "The dehydration of paprika."

[18] Kashani, N. M., Tabil, L. G., Mortazavi, A., Safe, K. A., Nakhaei, M., and Nikkho, M., 2002. "Effect of drying methods on quality of pistachio nuts. ASAE/CSAE North-Central Intersectional Meeting. Saskatchewan, Canada, Paper No: MBSK 02-213."

[19] Amini, G., Salehi, F., and Rasouli, M., 2021. "Drying Kinetics of Basil Seed Mucilage in an Infrared Dryer: Application of GA-NN and ANFIS for Prediction of Drying Time and Moisture Ratio." *J. Food Process. Pres*, vol. 45, p. 15258.

[20] Topuz, A., Gur, M., and Gul, M. Z., 2003. "An experimental and numerical study of fluidized bed drying of hazelnuts." *Applied Thermal Eng.*, vol. 24, pp. 1535-1547.

[21] Evin, A., 2011. "Thin layer drying kinetics of Gundelia tournefortii L." *Food Bioprod. Process*, vol. 90, pp. 323–332.

[22] Soysal, Oztekin, S., and Eren, O., 2006. "Microwave drying of parsley: modelling, kinetics, and energy aspects." *Biosyst. Eng.*, vol. 93, pp. 403– 413.

[23] Wang, Z., Sun, J., Chen, F., Liao, X., and Hu, X., 2007. "Mathematical modelling on thin layer microwave drying of apple pomace with and without hot air pre-drying." *J. Food Eng.*, vol. 80, pp. 536-544.

[24] Egbe, Tariebi, K., Okosemiefa, M. R., Nwangwu, U., and Akpan, F. A., 2021a. "Studying the thin layer drying kinetics of african giant snail (achatina achatina)." *Journal of Food Processing Technology*, vol. 12, pp. 1-7.

[25] Ozbek, B. and Dadali, G., 2007. "Thin-layer drying characteristics and modelling of mint leaves undergoing microwave treatment." *J. Food*,

[26] Crank, J., 1975. *Mathematics of diffusions*. 2nd ed. London: Oxford University Press.

[27] Sharma, G. P., Verma, R. C., and Pathare, P. B., 2005. "Thin-layer infrared radiation drying of onion slices." *J. Food Eng.*, vol. 67, pp. 361–366.

[28] Sharma, G. P. and Prasad, S., 2004. "Effective moisture diffusivity of garlic cloves undergoing microwave-convective drying " *J. Food Eng.*, vol. 65, pp. 609–617.

[29] Egbe, Ebiyeritei, W., Davies, R., and Tulagha, I., 2021b. "Modelling on the effect of temperature on the dehydration kinetics of Rapana venosa meaty (*Veined rapa whelk*)." *Agricultural Engineering International: CIGR Journal Open access*, vol. 23, pp. 280-287. Available: http://www.cigrjournal.org

[30] Egbe and Davies, R. M., 2021. "Estimating the drying kinetics and effective moisture. Diffusivity of fresh water prawn (macrobrachium rosenbergii)." *Sumerianz Journal of Agriculture and Veterinary*, vol. 4, pp. 40-48.

[31] Sacilik, K., 2007. "Effect of drying methods on thin-layer drying characteristics of hull-less seed pumpkin." *Journal of Food Engineering*, vol. 79, pp. 23-30.

[32] Jittanit, W., 2011. "Kinetics and temperatures dependent moisture diffusivity of pumpkin seeds during drying." *Kasetsart Journal*, vol. 45, pp. 147-158.

[33] Doymaz, I., 2004. "Drying kinetics of while mulberry." *Journal of food Engineering*, vol. 61, pp. 341-346. Available: http://dx.doi.org/10.1016/

[34] Robert, J. S., David, R. K., and Olga, P., 2008. "Drying kinetics of pumpkin seeds grape seeds." *Journal of Food Engineering*, vol. 89, pp. 460-465.

[35] Zibokere, D. S. and Egbe, E. W., 2019. "Thin-layer Drying Kinetics of Palm Weevil Larvae (*Rhynchophorus feruguneus larvae*)." *Annals of Applied Science*, vol. 5, pp. 40-46.