Modelling the Drying Kinetics of Monkey Cola (*Cola Parchycarpa*)

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ABSTRACT

The need for storage is one of the crucial factors considered in food preservation, due to deterioration and spoilage of food materials. Drying as a means of preservation has been adopted in processing of food materials by exposing the material to heat to heat for the reduction of moisture content to the level unfavorable for mold growth. Monkey cola is a nutritional indigenous seed known with its pleasant taste and medicinal values. Moisture kinetics and drying time were used to examine the drying characteristics of Monkey cola seed. Monkey kola seed and a suitable mathematical model was developed by fitting the drying data gotten from the open sun drying and oven drying of monkey kola at different temperatures (40, 50, 65, 60 and 70^{0}C) to properly predict the drying characteristics of the seed using statistical tools. This gives the highest R^2 and lowest RMSE and provided the long-term performance of correlation for each degree of temperature. The best model fitted for each temperature at 40, 50, 65, 60 and 70^{0}C for oven drying were Diffusion approach, Verma, Hii, and Midili Kucuk models, respectively, and Midili Kucuk model, for open sun drying. Temperature dependence of the effective diffusivity (D_{eff}) coefficient was expressed by an Arrhenius type relationship and the activation energy (E_a) was determined.

Keywords: *Drying Kinetics, Monkey cola, Modelling thin layer models.*

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Highlights of this paper

- Monkey cola seed a perishable biomaterial but is made a more stable product when dried thus enhance food supply and improve seasonal food choice.
- Mathematical model is necessary to simulate drying kinetics of Monkey cola seed.
- Mathematical model helps in assessing the performance evaluation of open sun and oven drying system used in drying Monkey cola seed.

1. INTRODUCTION

Drying, also known as dehydration is an aged and a crucial unit operation involved in food processing. It is the application of hot air to a food material that leads to transfer of moisture within the material to its surface and water removal from the material to the atmosphere. Drying involve both heat and mass transfer operation simultaneously. Drying is the most affordable techniques for food preservation; it reduces spoilage and improves the quality of a product. The major essence of drying food materials is to remove the free water available in the food material. The removal of moisture can be due to concurrent heat and mass transfer from the heat source to the food material. Drying is usually the last step in the series of processing and handling operation. The major aim of drying agricultural produce is to maintain the quality of the product for storage, create an unfavorable environment for mold growth, to eliminate unnecessary water that contribute to the weight of agricultural products and also make packaging of product easier. The main characteristics of dried materials are reduced porosity, high apparent density and reduced sorption capacity that results in colour change. Achievement of drying aid better handling of dried materials, transportation minimization, effective storage, reduction in packing cost and time.

The study of the kinetic model is the rate of reactions that occurred during drying process of each particular product. Drying kinetics must be done in other to evaluate the drying behavior of fruits and vegetables. The drying kinetics helps to understand the process of moisture removal from a food material and it is crucial in determination of the drying conditions, which are significant parameters in equipment design and product quality improvement [1]. The drying kinetics is affected by the type of dryer and behavior of the material to be dried. The most acceptable method for the determination of the drying kinetics of fruit and vegetables is thin-layer drying.

The thin-layer modeling is useful in the determination of the drying kinetics behaviour gotten from the experimental data.

The thin-layer modeling is helpful in the estimation of the drying kinetics from the experimental data gotten from drying. It describes the drying properties, improve and auspicate the drying process and also optimize energy required for drying. The vital aspects of thin-layer drying technology are the modeling of drying process and the design equipment use in drying. Drying model is therefore used to predict the changes and the rate of bio chemical and physical reactions which occurs with drying kinetics. The aim of the research is to select appropriate model that can predict the drying kinetics of monkey cola.

2. MATERIALS AND METHODS

2.1. Monkey Cola

The sample of Monkey Cola (*Cola Parchycarpa*) studied was obtained from its tree in a forest located in Ipetu Ile, Obokun local government, Osun state. The good and healthy fruits were sorted and treated from the contaminated ones and the pod of the fruits was separated from the seeds for further experiments. The seed gotten from the separation was naturally fermented for 2-3 days using banana leaves as the anti-oxidizing and fermentation agent. 100 g of the fermented seed and 50 g of the separated fruit pod were weighed into several separate cans and labelled for thin layer drying experiments.

2.2. Methods

a. Drying

Thin layer drying experiments were carried out at varying degrees of temperature ranging from 35, 40, 45, 50, 60-70°C using electrical laboratory oven (TT-9083; Gallenkamp Devices, UK) and at normal atmospheric temperature using the natural solar drying system (open sun drying). The weight of each sample were checked during drying using the weighing scale at each interval of 1 hour until they were dried to the temperature degree variation of ±1°C for 1g of weighed samples, where there was no moisture content present in the samples.

2.3. Moisture Content

The moisture content of the seeds was measured by using the hot air (oven) method set at 103 ±2 °C for 72 hours. Four samples were heated in the oven until there was no change in weight using ASABE S352 method and applied by Okoro and Osunde [2]; Abodenyi, et al. [3]; Oloyede, et al. [4]; Oniya, et al. [5] for sour sop seeds. The moisture content was calculated using Equation 1.

$$\mathrm{M.C}_{(\mathrm{w.b})} = \frac{\mathrm{M_b - M_a}}{\mathrm{M_b - M_c}} \times 100\% \qquad (1)$$

where:

MC_{wb} is moisture content (% wet basis).

M_b is the weight of wet sample (g).

M_a is the weight of oven dried sample (g).

M_c is weight of empty can (g).

2.4. Modeling of the Drying Process

The experimental data gotten from the open sun and oven drying were stated in terms moisture ratio, and drying rate. The moisture ratio (MR) and the drying rate (DR) of the seeds were calculated using the Equations 2 and 3 [6]:

$$MR = \frac{M_t - M_\infty}{M_0 - M_\infty} \qquad (2)$$

$$Drying\ rate = \frac{M_{t+dt} - M_t}{dt} \qquad (3)$$

For these three drying methods, the equilibrium moisture content (M_∞) was presumed to be zero, consequently the equation simplified then become [7, 8].

Where M_t is the moisture content at any given time (g water/g dry matter), M_o is the initial moisture content (g water/g dry matter), M_∞ is the equilibrium moisture content (g water/g dry matter), M_{t+dt} is the moisture content at $t + dt$ (g water/g dry base) and t is drying time (min).

2.5. Effective Moisture Diffusivity

Effective moisture diffusivity can be evaluated using the analytical solution for spherical geometry, as followed Equation 4;

$$MR = \frac{M - M_e}{M_i - M_e} = 6\sum_{n-1}^{\infty} \frac{1}{n^2\pi^2} \exp\left(n^2\pi^2 \frac{D_{eff}t}{r^2}\right) \qquad (4)$$

For the evaluation of the effective moisture diffusivity at different temperature conditions, the slope (ko) was determined by plotting ln(MR) versus time using Equation 5;

$$K_o = \frac{\pi^2 D_{eff}}{4L^2} \quad (5)$$

2.6. Computing the Activation Energy

The activation energy for diffusion was evaluated by using Arrhenius equation [9].

$$D_{eff} = D_0 \exp(-E_a/RT) \quad (6)$$

Activation energy (E_a) was evaluated by plotting ln(D_{eff}) against 1/T.

Where, Do is the constant equivalent to the diffusivity at infinitely high temperature (m^2 min^{-1}),

E_a is the activation energy (kJ/mol), R the universal gas constant (8.314 x 10^{-3} kJ/mol).

T is the absolute temperature (K).

2.7. Statistical Analysis

The drying behavior of Monkey cola seeds was evaluated by plotting the moisture ratio against the drying time. The experimental data were fitted to thirteen thin-layer mathematical models Table 1 to depict the drying process. The numerical calculations of the data were done utilizing the software package, Excel 2016 (Microsoft Inc.). The models' parameters were assessed with the non-linear regression techniques of Marquardt-Levenberg until insignificant error was achieved between experimental and calculated values. The coefficient of determination, R^2; normalized Moisture content against time was changed to moisture ratio. The drying data were input into the thirteen selected thin layer drying models. The models were analysis utilizing statistical tools; coefficient of determination (R^2), sum of estimated error (*SEE*), root mean square error (*RMSE*) and chi-square (X^2) as reported by Chukwunonye, et al. [10] described by Equation 7 to 9. The reduced chi- square (x^2) and RMSE values and the higher R^2 values were selected as the basis for goodness of fit for the model.

Table-1. Models applied to the drying parameter of Soursop seeds.

S/N	Model	Equation	References
1	Newton	$MR = \exp(-kt)$	[11]
2	Henderson and pabis	$MR = a\exp(-kt)$	[12]
3	Page	$MR = \exp(-kt^n)$	[13]
4	Logarithmic	$MR = a\exp(-kt) + c$	[14]
5	Two term	$MR = a\exp(-k_1 t) + b\exp(-k_2 t)$	[15]
6	Vermal	$MR = a\exp(-kt) + (1-a)\exp(-gt)$	[16]
7	Diffusion approach	$MR = a\exp^{-kt} + (1-a)\exp^{-kgt}$	[17]
8	Midili Kucuk	$MR = a\exp(-kt) + bt$	[18, 19]
9	Wang and singh	$MR = 1 + at + bt^2$	[20]
10	Hii	$MR = a\exp(-k_1 t^n) + c\exp(-gt^n)$	[21]
11	Modified Henderson Pabis	$MR = a\exp^{-kt} + b\exp^{-gt} + c\exp^{-ht}$	[22]
12	Modified Page I	$MR = \exp[-(kt^n)]$	[23]
13	Modified Page II	$MR = [-k(\frac{t}{l^2})^2]$	[24]

a, b, c and d are constants and coefficients in the drying models.

$$R^2 = \frac{\sum_{i=1}^{N}(MR_{exp,i} - MR_{exp,avg})(MR_{pre,i} - MR_{pre,ave})}{\sqrt{\sum_{i}^{N}(MR_{exp} - MR_{exp,avg})^2 \sum_{i=1}^{n}(MR_{exp,i} - MR_{exp,avg})^2}} \quad (7)$$

$$x^2 = \frac{\sum_{i}^{N}(MR_{exp,i} - MR_{pre,i})^2}{N-n} \quad (8)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}[MR_{exp,i} - MR_{pre,i})^2}{N-1}} \quad (9)$$

3. RESULTS AND DISCUSSIONS

3.1. Moisture Content

The average initial moisture content of Monkey Cola (*Cola Parchycarpa*) was determined using laboratory method to be around 59.8% (w.b) the seeds were oven dried in laboratory oven (TT-9083; Gallenkamp Devices, UK) to the moisture content of about 5.77% at 70°C, 11.8% at 65°C, 11.4% at 60°C, 13.6% at 50°C and 26.99% at 40°C (w.b) until no further changes in their mass were observed. Sample dried at 40°C showed the highest moisture content of 26.99% while sample dried at 70°C showed the least moisture content value of 5.77%. Sample dried at 70°C had better tendency for longer shelf life due to its lower moisture content. Lower moisture content infers reduction of water and microbial activity on dried food samples as reported by Ajala, et al. [25].

3.2. Drying Characteristics

The drying characteristics of Monkey Kola (*Cola Parchycarpa*) evaluated in this study comprised drying curves showing the relationship between the drying rate, moisture content and drying time. The drying kinetics of the monkey kola seed for the oven and open sun drying were determined and the effect of temperature on the moisture content, moisture ratio and drying rate for the two methods of drying.

The drying curves for thin layer drying of Monkey Cola (*Cola Parchycarpa*) under various temperature conditions in oven and open are shown in Figure 1. The monkey kola seed were dried at varying interval at different temperature of 40, 50, 60, 65 and 70^{0}C respectively to reach constant mass showing moisture ratio decreased continuously with increasing drying time. The rate of drying was very high at the commencement of the drying process at each temperature. with the 65^{0}C having the highest initial value of 10.1783 and the lowest drying rate at 40^{0}C. While, at temperature 65^{0}C the rate of drying and the water content reduction was higher due to the fact that the drying temperature had a significant effect on the drying kinetics of the samples Monkey Cola. According to Kumar, et al. [26] which conforms to the information provided earlier, at higher water content, the increase in temperature has more considerable effect on the drying rates than at lower water content, which is almost negligible at the end. The increase in drying rate as temperature of drying air increases as shown in Figures 2 is due to increased heat transfer gradient between the air and the seeds which favor water evaporation from the seed, as agreed with the experiment carried out on fever leaves by Doymaz [27]. Figures 2. Shows that the drying rate decreases continuously with the decreasing moisture content or increasing drying time. In the drying rate/moisture content graph, at 65^{0}C the drying rate rises as the moisture content reduces to an equilibrium point 0f 10 (%/h) but decreases with the decreasing moisture content. These results are in agreement with the observations of earlier researchers based on thin layer drying of amaranth grains [28]. Also constant drying rate at each temperature were reached at different time interval. The open sun drying had the least drying rate as showed in Figures 2 and 3. The water content reduction was slow due to the significant effect of the unstable atmospheric condition on the drying temperature which also affect the drying kinetics of the samples Monkey Cola. These results are in agreement with the earlier observations [29, 30]. According to Figures 2 and 3 the rate of drying and moisture ratio reduces with increasing drying time.

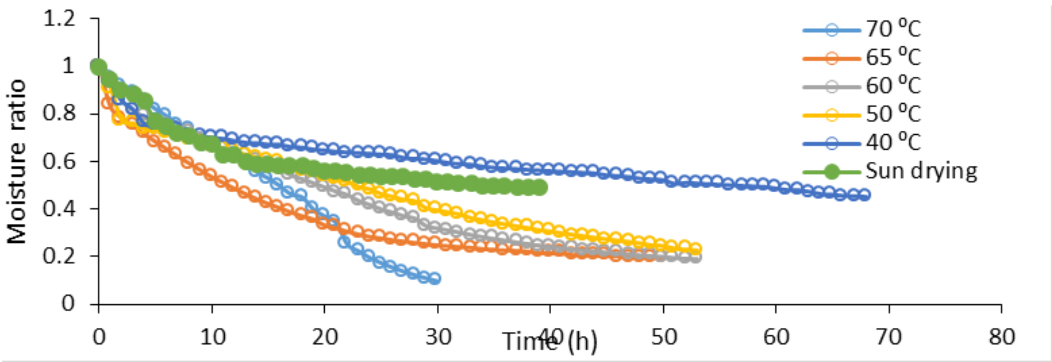

Figure-1. variation of moisture ratio (%wb) of monkey cola seed with drying time (hours).

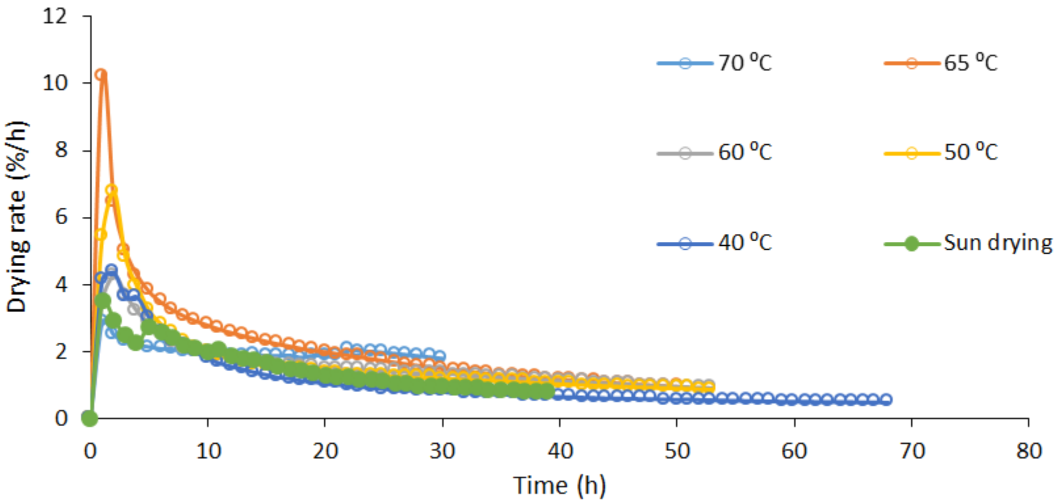

Figure-2. variation of drying rate (%h) of monkey cola seed with drying time (hours).

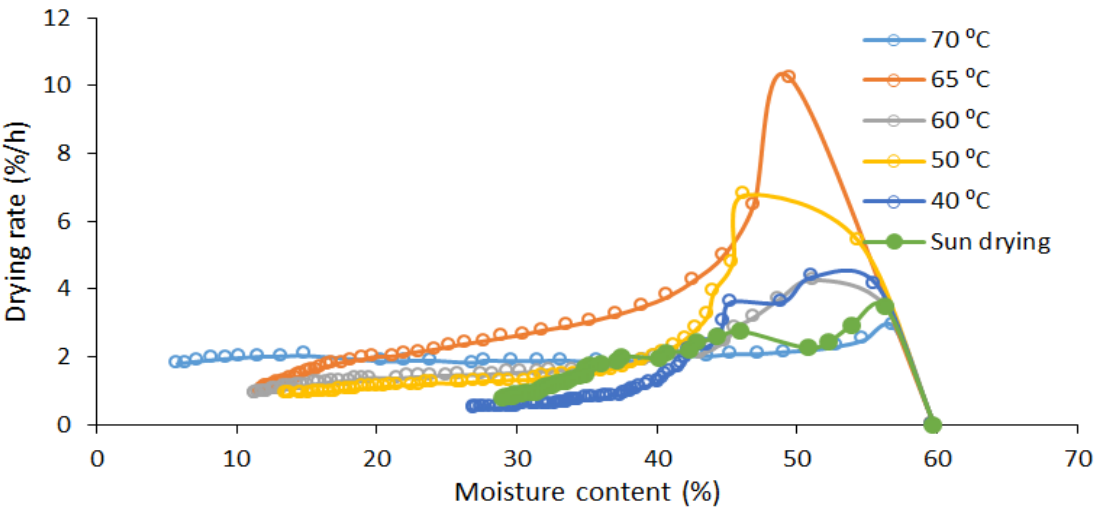

Figure-3. drying rate as a function of moisture content of monkey cola seeds.

3.3. Effective |Moisture Diffusivity

Fick's diffusion equation and Slab geometry were used for calculation of effective diffusivity by method of slopes expressed in equation and is shown in Table 2. The value of moisture diffusivity determined were 0.955, 2.379, 3.212, 3.435, and 6.945$\times$ $10^{-10}m^2/s$ for 40, 50, 60, 65 and 70^{0}C temperatures respectively, while the effective moisture diffusivity for open sun drying is $1.439 \times 10^{-10}m^2/s$. The effective diffusivity value of monkey cola seeds for oven drying ranged from 0.955 $\times$ 10^{-10} to 6.945$\times$ $10^{-10}m^2/s$. This was used to determine the value of the predicted moisture diffusivity for oven drying method also which ranged from 0.936 $\times$ $10^{-10}m^2/s$ to

6.822$\times 10^{-10} m^2/s$. And the open sun having the value of 1.410 $\times 10^{-10} m^2/s$ it can be seen that the effective diffusivity values increased greatly with increasing temperature, which in turns increased the vapor pressure. Similar trends were found in products such as grapefruit seeds [31] and grape seeds [32]. This indicates that as the moisture content decreases, the permeability to vapor increased, provided the pore structure remains open. Sharma and Prasad [33] also reported a similar trend in the variation in the moisture diffusivity with moisture content, as a result, it leads to fast drying.

3.4. Activation Energy

The value of the activation energy (Ea) was determined by exploiting the Arhenius equation. The relationship between the effective diffusivities and temperature is assumed in the Arrhenius form of the type using Equation 10,

$$D_{eff} = D_o \exp\left(-\frac{E_a}{R(T + 273.15)}\right) \quad (10)$$

The activation energy was calculated by plotting $\ln(D_{eff})$ versus the reciprocal of the temperature$\left(\frac{1}{T + 273.15}\right)$ as show in Table 2. The activation energy for the temperature at 40, 50, 60, 65 and 70^{0}C were 51.224, 51.223, 51.237, 51.237 and 51.240 respectively, while the activation energy value for open sun drying is 51.747. The activation energy values for the oven drying were found to be within the range of 51.224-51.240kj/mol, this shows that values also increased with increasing temperature. According to Zogzas, et al. [34] the activation energy for farm products ranges from 12.7 to 110KJ mol. It is highlighted that in the drying processes, the lesser the activation energy, the greater the water diffusion within the product [35, 36].

Table-2. Effective diffusivities of drying monkey cola seed at different temperatures in oven and open sun.

Temperature	70 ^{0}C	65 ^{0}C	60 ^{0}C	50 ^{0}C	40 ^{0}C	Open sun
D_{eff} (10^{-10})	6.945	3.435	3.212	2.379	0.955	1.439
D_o (10^{-10})	6.822	3.372	3.153	2.334	0.936	1.410
E_a (kj/mol)	51.240	51.237	51.237	51.233	51.224	51.747

3.5. Evaluating of Mathematical Model

The drying curves obtained from experimental drying methods were fitted with moisture ratio equations into the thirteen (13) thin layer drying models. The best drying model was selected based on the maximum coefficient of determination (R^2), minimum values of reduced chi-square (X^2), and the percentage of root mean square error (*RMSE*).

3.6. Modelling the Drying Kinetics of Monkey Cola (Oven Drying Method)

The drying data gotten from the oven drying of monkey cola at different temperatures (35, 40, 50, 60 and 70^{0}C) were fitted into the thirteen (13) thin layer drying models, this gives the highest R^2 and lowest RMSE and provided the long-term performance of correlation for each degree of temperature , the best drying model fitted for the temperature at 40^{0}C is Diffusion approach having the highest R^2 of 0.8709,lowest chi square of 0.0088 and RMSE of 0.0521, Verma *et al* for 50^{0}C with the highest R^2 of 0.9927,lowest chi square of 0.0003 and RMSE of 0.0163, Hii *et al* for 60, 65^{0}C with the highest R^2 of 0.9945 and 0.9965,lowest chi square of 0.0003 and 0.0002 and RMSE of 0.0167 and 0.0118 and Midili *et al* for 70^{0}C having the highest R^2 of 0.9946,lowest chi square of 0.0005 and RMSE of 0.0206. From the analysis, the model fitted at an average temperature is Hii *et al.* Modified Henderson and Pabis is the most appropriate model having the highest R^2 of 0.8512, lowest chi square of 0.0029 and RMSE of 0.0521 for open sun drying Table 3.

3.7. Validation of Model Used

Figure 4 and 5 shows the comparison of the predicted and experimental values for the oven drying and open sun drying at different temperatures. The model used is validate to check the suitability of the model in predicting the drying of the samples, it is validated by plotting a graph of predicted moisture ratio against experimented moisture ratio, if the coefficient of determination (R^2) determined from the graph is ≥ 0.75 the model is valid and it can be used to predict the drying curve. The graphs of predicted moisture ratio and experimented moisture ratios for the monkey cola seed under the varying temperature conditions of oven drying had an average maximum coefficient of determination (R^2) of 0.9965 and open sun drying had 0.9997. This indicated that all the models derived for drying of monkey cola seed under the two methods can correctly predict the drying characteristics of seed and are valid.

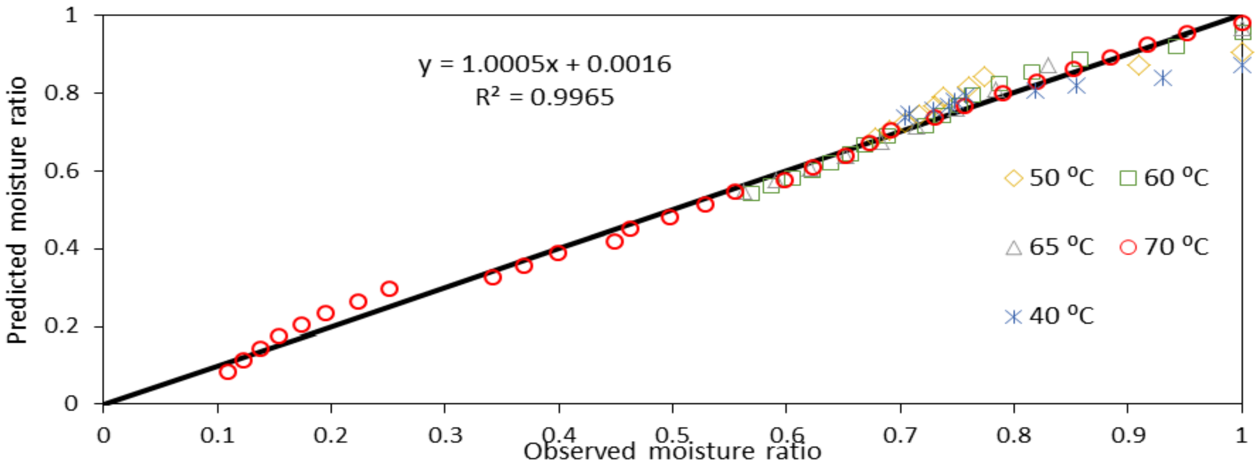

Figure-4. plot of Experimental MR against predicted MR for monkey cola seed in oven.

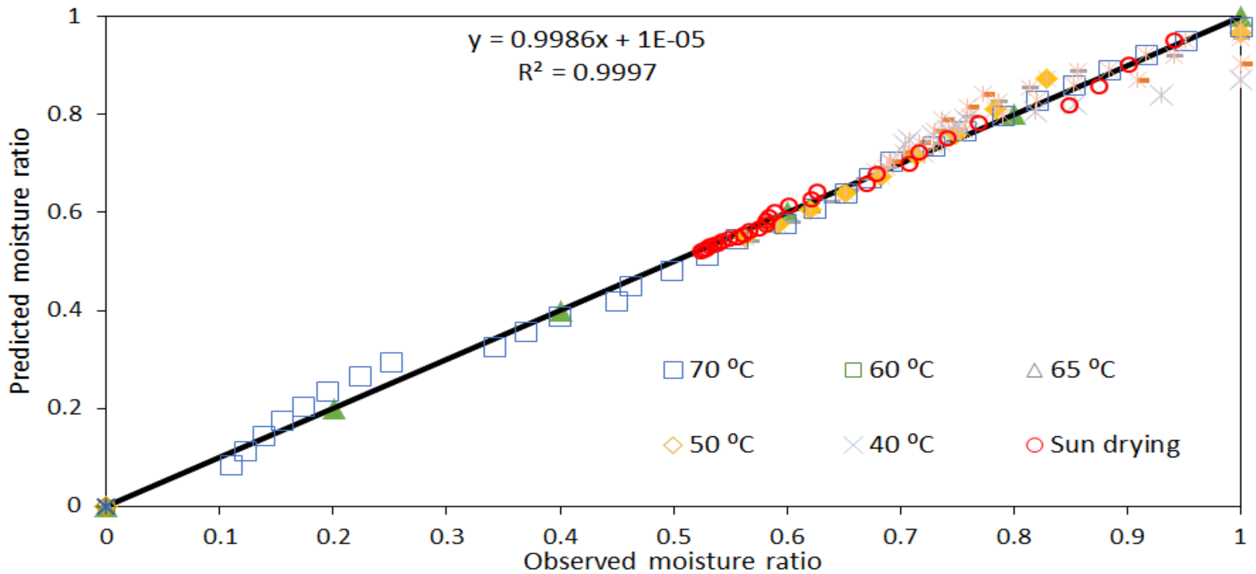

Figure-5. Plot of Experimental MR against predicted MR for monkey cola seed under open sun.

4. CONCLUSION

Drying is one of the aged methods used to preserve the quality of agricultural produce for availability throughout the year, as well as reduce post-harvest loses. In this study, the various drying techniques (open and oven) used were capable to preserve the quality of the seed. Thirteen thin-layer model equations were used in testing the drying kinetics carried out on the thin-layer drying behavior of monkey cola seeds. It was observed that

Two term model is the best and most appropriate in predicting drying kinetics of soursop seeds under the varying drying methods of study. It had highest R^2 of 0.9993, lowest Chi square of 0.000, and RMSE of 0.0047, highest R^2 of 0.991, Chi square of 0.0003, and RMSE of 0.0157 and highest R^2 of 0.9961, Chi square of 0.0085 and lowest RMSE of 0.0093 for open, oven and oven drying methods respectively. The validation results established good concert between the experimental and predicted drying variables, however, two term model equation could be used satisfactorily to predict thin layer drying of monkey cola seeds for open sun and oven drying method respectively. It is highlighted that in the drying processes, the lesser the activation energy, the greater will be water diffusion within the product.

Table-3. Drying constant and coefficients of mathematical models of non-regression model of monkey cola in oven at different temperatures and open sun drying.

Temperature	Model	Model constant	R^2	RMSE	X^2
40 ^{0}C	Newton	K = 0.0163	0.8786	0.0891	0.0081
	Henderson and Pabis	k = 0.0093, a = 0.8051	0.8597	0.0381	0.0015
	Page	k = 0.0823, n = 0.5418	0.9657	0.0295	0.0009
	Logarithmic	k = 0.0107, a = 0.7522, c = 0.0626	0.8637	0.0376	0.0015
	Two term	k = 0.0226, g = 0.0315, a = 2.6029, c = -1.816	0.7700	0.0520	0.0029
	Vermal	k = 0.7386, g = 0.0114, a = 0.1592	0.9549	0.0328	0.0011
	Diffusion approach	k = 0.0219, g = 1.0107, a = 23.9471	0.8769	0.0912	0.0088
	Midili Kucuk	k = 0.0314, b = 0.0007, a = 0.862, n = 0.7472	0.9505	0.0247	0.0006
	Wang and smith	a = -0.0205, b = 0.0002	0.8599	0.0661	0.0045
	Hii	k = 0.0375, g = -0.147, a = 0.8714, c = 0, n = 0.675	0.9547	0.0236	0.0006
	Modified Henderson and Pabis	k = -5.3985, a = -0.0466, g = 5.4491, b = -0.0465, h = 0.7854, c = 0.0175	0.9389	0.0276	0.0008
	Modified Page I	k = 0.01, n = 0.5136	0.9785	0.0251	0.0006
	Modified Page II	k = 0.8392, a = 0.0003, n = 0.7881, L = 0.0043	0.9359	0.0281	0.0008
50 ^{0}C	Newton	k = 0.0313	0.9817	0.0534	0.0029
	Henderson and pabis	k = 0.0259, a = 0.8732	0.9826	0.0252	0.0007
	Page	k = 0.0823, n = 0.7119	0.9773	0.0290	0.0009
	Logarithmic	k = 0.0295, a = 0.8242, c = 0.0589	0.9823	0.0254	0.0007
	Two term	k = 0.0292, g = 0.0309, a = 2.6877, c = -1.8162	0.9825	0.0252	0.0007
	Vermal	k = 0.7364, g = 0.0243, a = 0.1633	0.9927	0.0163	0.0003
	Diffusion approach	k = 0.0312, g = 0.9999, a = 24.6214	0.9817	0.0534	0.0030
	Midili Kucuk	k = 0.0326, b = 0.0007, a = 0.8944, n = 0.9633	0.9822	0.0254	0.0007
	Wang and smith	a = -0.0303, b = 0.0003	0.9647	0.0539	0.0030
	Hii	k = 0.0394, g = -0.1466, a = 0.9058, c = 0, n = 0.8927	0.9838	0.0243	0.0007
	Modified Henderson and Pabis	k = -5.3743, a = -0.0343, g = 5.2658, b = -0.0346, h = 0.9673, c = 0.0177	0.9812	0.0261	0.0008
	Modified Page I	k = 0.03, n = 0.7222	0.9778	0.0290	0.0009
	Modified Page II	k = 0.9076, a = 0.0003, n = 0.8906, L = 0.0043	0.9839	0.0242	0.0006

60 ^{0}C	Newton	k = 0.0365	0.9935	0.0277	0.0008
	Henderson and pabis	k = 0.0338, a = 0.9417	0.9933	0.0182	0.0003
	Page	k = 0.0542, n = 0.8786	0.9924	0.0198	0.0004
	Logarithmic	k = 0.0386, a = 0.8934, c = 0.0598	0.9935	0.0180	0.0003
	Two term	k = 0.0319, g = 0.0312, a = 2.7569, c = -1.8188	0.9929	0.0189	0.0004
	Vermal	k = 0.5178, g = 0.0323, a = 0.0886	0.9943	0.0169	0.0003
	Diffusion approach	k = 0.0362, g = 1, a = 25.2481	0.9935	0.0286	0.0009
	Midili Kucuk	k = 0.0349, b = 0.0008, a = 0.9486, n = 1.0132	0.9937	0.0178	0.0003
	Wang and smith	a = -0.033, b = 0.0003	0.9917	0.0290	0.0009
	Hii	k = 0.0386, g = -0.1573, a = 0.958, c = 0, n = 0.9704	0.9945	0.0167	0.0003
	Modified Henderson and Pabis	k = -5.244, a = -0.0252, g = 4.9145, b = -0.0262, h = 1.2522, c = 0.0181	0.9944	0.0168	0.0003
	Modified Page I	k = 0.0361, n = 0.8758	0.9927	0.0196	0.0004
	Modified Page II	k = 0.9695, a = 0.0003, n = 0.9153, L = 0.0042	0.9934	0.0181	0.0004
65 ^{0}C	Newton	k = 0.0569	0.9883	0.0495	0.0025
	Henderson and pabis	k = 0.0391, a = 0.8294	0.9520	0.0451	0.0021
	Page	k = 0.15, n = 0.641	0.9891	0.0208	0.0005
	Logarithmic	k = 0.0772, a = 0.7498, c = 0.1779	0.9946	0.0147	0.0002
	Two term	k = 0.0391, g = 0.0391, a = 8.7107, c = -7.8813	0.9520	0.0451	0.0022
	Vermal	k = 0.1154, g = 0.0134, a = 0.6439	0.9907	0.0215	0.0005
	Diffusion approach	k = 0.0495, g = 1, a = 27.5739	0.9731	0.0709	0.0053
	Midili Kucuk	k = 0.091, b = 0.0025, a = 0.9565, n = 0.8572	0.9960	0.0126	0.0002
	Wang and smith	a = -0.0454, b = 0.0006	0.9714	0.0592	0.0037
	Hii	k = 0.1035, g = -0.1648, a = 0.9644, c = 0.0029, n = 0.7828	0.9965	0.0118	0.0002
	Modified Henderson Pabis	k = -3.8577, a = 0.0273, g = 2.757, b = 0.0196, h = 2.0228, c = 0.0525	0.9946	0.0147	0.0002
	Modified Page I	k = 0.0518, n = 0.641	0.9891	0.0208	0.0005
	Modified Page II	k = 1.0075, a = 0.0028, n = 0.6346, L = 0.0018	0.9892	0.0208	0.0005
70 ^{0}C	Newton	k = 0.0516	0.9559	0.0721	0.0054
	Henderson and pabis	k = 0.0567, a = 1.0799	0.9483	0.0653	0.0046
	Page	k = 0.0122, n = 1.5041	0.9831	0.0383	0.0016
	Logarithmic	k = 0.0154, a = 2.5084, c = -1.4897	0.9914	0.0262	0.0008
	Two term	k = 0.1084, g = 0.1183, a = 11.9867, c = -11.044	0.9811	0.0393	0.0018
	Vermal	k = 0.0045, g = -0.0005, a = 6.8512	0.9944	0.0211	0.0005
	Diffusion approach	k = 0.1079, g = 1.0077, a = 114.8372	0.9783	0.0420	0.0019
	Midilli Kucuk	k = 0.0074, b = -0.0305, a = 0.9928, n = 0.3756	0.9946	0.0206	0.0005
	Wang and smith	a = -0.0336, b = 0.0001	0.9944	0.0211	0.0005
	Hii	k = 0.0063, g = -0.0006, a = 4.0365, c = -3.0565, n = 1.0683	0.9946	0.0206	0.0005
	Modified Henderson and Pabis	k = -11.3347, a = 0.1183, g = 5.7902, b = 0.1081, h = 6.4863, c = 0.1091	0.9811	0.0393	0.0019

	Modified Page I	k = 0.0535, n = 1.5041	0.9831	0.0383	0.0016
	Modified Page II	k = 0.9243, a = 0.0119, n = 1.8134, L = 1.7207	0.9888	0.0298	0.0010
Sun drying	Newton	k = 0.0255	0.8741	0.0789	0.0064
	Henderson and pabis	k = 0.0182, a = 0.8566	0.8512	0.0521	0.0029
	Page	k = 0.1166, n = 0.5187	0.9623	0.0265	0.0007
	Logarithmic	k = 0.1096, a = 0.5058, c = 0.4941	0.9933	0.0110	0.0001
	Two term	k = 0.018, g = 0.018, a = 9.2632, c = -8.407	0.8511	0.0521	0.0030
	Vermal	k = 0.1096, g = -0.0002, a = 0.5082	0.9932	0.0111	0.0001
	Diffusion approach	k = 0.0255, g = 1, a = 97.6266	0.8741	0.0789	0.0067
	Midili Kucuk	k = 0.09, b = 0.0072, a = 1.0184, n = 0.7732	0.9896	0.0137	0.0002
	Wang and smith	a = -0.0355, b = 0.0006	0.9525	0.0370	0.0014
	Hii	k = 0.0275, g = -0.0007, a = 5.6962, c = -4.6508, n = 0.3707	0.9530	0.0292	0.0010
	Modified Henderson and Pabis	k = -14.4079, a = 0.0465, g = 7.6862, b = 0.0616, h = 7.7277, c = 0.0329	0.9959	0.0086	0.0001
	Modified Page I	k = 0.0159, n = 0.5186	0.9623	0.0265	0.0007
	Modified Page II	k = 1.0388, a = 0.0022, n = 0.4821, L = 0.0002	0.9649	0.0252	0.0007

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