Mathematical Modelling of Drying Kinetics of Anonna Muricata L. (Soursop) Seeds Under Different Drying Conditions

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ABSTRACT

The seeds of soursop were dried to preserve the physical and physiological nature of the seeds. The thin layer drying performance of Anonna muricata (Soursop)seeds under three diverse drying techniques; open sun, heat pump and oven drying strategies at temperature of 40oC were assessed so as to foresee the best equation for the drying kinetics from thirteen (13) existing drying Mathematical models. Fresh samples of the seeds were gotten and dried at the same time under these drying strategies and weighed at regular interim until consistent weight was accomplished. The drying data; moisture loss and drying rate were gotten and changed to moisture ratio which was fitted to the thirteen mathematical models. The best fit model to portray the thin layer drying of Anonna muricata (Soursop) leaves was accomplished dependent on the model with the highest correlation coefficient (R^2), and lowest reduced chi square ($\chi 2$) and root mean square error (RMSE). Two term models were the best and most appropriate in predicting drying kinetics of soursop seeds under the different 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 heat pump respectively It is featured that in the drying processes, the lesser the activation energy, the more prominent will be water diffusion inside the product.

Keywords: *Thin layer drying, Soursop seeds, Mathematical model, Drying kinetics, Activation energy, Moisture diffussvity.*

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Highlights of this paper

- Drying soursop seeds at temperature of 40ºC and below using different methods to preserve the physical and physiological nature of the seeds.
- Drying soursop seeds enhance food supply and improve seasonal food choice.
- Mathematical model is necessary to simulate drying kinetics of soursop seed, under different drying methods.
- Mathematical model helps in assessing the performance evaluation of open sun, heat pump and oven drying system used in soursop seed drying.

1. INTRODUCTION

Soursop botanically known as *Annona muricata* is a shrub belonging to the Annonaceae family, and broadly dispersed throughout tropical and subtropical region of the world, including Nigeria [1]. It possesses large amount in the southern part of Nigeria and cultivated primarily in-home gardens. All parts of this plant (leafs, seeds, and pulp) are broadly utilized as traditional medicine against variety of human illness and diseases [2]. The potency of the Soursop seed to solve some medical challenges, especially cancer, cannot be overemphasized. However, the pre-harvest and post-harvest losses due to the perishability of the seed to the actions of various microorganisms had been accounted for as the most challenging preventing the utilization of the seed due to non-availability. Postharvest losses of up to 60% of Soursop have been reported by Pareek, et al. [3]; Moreno-Perez, et al. [4] and pre-harvest losses of soursop by Amusa, et al. [5]. The availability of the fruits that possess a wide range of medicinal and health benefit is scarce because of the fast disintegration of the seed which is accessible for a brief period [6].

It was on historical record that human beings have apprehended the need to store seeds in order to preserve planting stocks and availability during off season [7]. With recent innovation, humans had extended their compass about the demands and strategies for keeping up viable seeds during storage. Essentially, seeds constitute an embryo, food store known as endosperm or cotyledons and an outer protective shell called seed coat or accessory structures. The seeds are influenced more significantly by the seed coat and hilum, which enable moisture to enter or exit the seed. Thus, a suitable drying is essential for seeds in order to maintain its physical and physicochemical constituents. The potential risk during drying is the exposure of very wet materials to high temperatures for significant periods [8]. The quality of drying product can be damaged due to mechanical force and very low relative humidity of the drying air [9]. The availability of the fruits that possess a wide range of medicinal and health benefit is scarce because of the quick disintegration of the seed which is accessible for a brief period [6].

Drying is the most affordable method of preserving, improving shelf life and quality of seeds. Studying drying kinetic model is the rate of reactions that occurred during drying process of soursop seeds. Drying kinetics is carried out 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 or Agricultural material and it is crucial in determination of the drying conditions, which are significant parameters in equipment design and product quality improvement [10]. Deterioration of agricultural produce is a major challenge in agricultural production which is as a result of the amount of moisture contained in the product and could be curbed by drying for future use. It has been estimated that about a quarter of the yearly stored products may be lost due to quality and viability of the stored seeds. Drying is the most affordable method of preserving, improving shelf life and quality of seeds. Studying drying kinetic model is the rate of reactions that occurred during drying process of soursop seeds. Drying kinetics is carried out 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 [10].

Modeling the drying kinetics brings mathematical equations as well as physical knowledge into the procedure;

numerous examinations have been devoted to analyzing the various parts of this phenomenon. The principle of modeling depends on having a set of mathematical equations that can adequately describe the drying framework. Mathematical models are very helpful in the design and analysis of simultaneous heat and moisture transfer processes [11]. 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.

2. MATERIALS AND METHODS

It deals with the experimental setup, methods and strategies followed for sun drying, oven drying and heat pump drying of soursop leaves. The experiment was planned for drying of fresh soursop seeds utilizing three drying methods. The drying information were converted into moisture ratio fitted into various models to realize which best fit each drying method.

2.1. Material

Fresh healthy and matured soursop fruit were gotten from Ilado a village via Akure, Ondo State, Nigeria. The samples (seeds) were manually removed and cleaned, broken or juvenile seeds just as foreign materials are sorted. The research was carried out in the Crop processing laboratory of the Department of Agricultural and Environmental Engineering, Federal University of Technology, Akure (FUTA). Ondo State, Nigeria.

2.2. Drying Experiment

Drying Experiment, the fresh healthy, developed seeds of soursop seeds (Annona muricata L.) secured from Ilado village via Akure, Ondo State. The drying experiments were done utilizing open sun drying, heat pump dryer, laboratory oven (TT-9083; Gallenkamp Devices, UK). The samples were weighed using an electronic digital weighing balance (MP 1001) with an accuracy of 0.01 g throughout the drying process. The seeds were dried not fewer than three different methods; open sun drying, oven drying at 40^{0}C with constant air velocity of 1.4m/s^2 and heat pump drying at 40± 2^{0}C. The samples were dried consecutively under these three drying methods and the experiment was performed in triplicates. The weights of the samples were taken at an interim of 30 minutes until a consistent weight was acquired.

2.3. Determination of Moisture Content

The mean value for the initial moisture content was determined dependent on wet basis (w.b). 60g of every one of the samples was put in an oven and heated at 105± 3^{0}C and allowed to dry to a steady weight for 24 hours [12]. The moisture content of the seeds was determined by gravimetric method which determines the mass loss from the sample by drying at constant weight [13]. The moisture content (MC) was calculated by Equation 1.

$$MC_{wb} = \frac{M_w - M_d}{M_d} \qquad 1$$

Where M_t is the moisture content (g water/ g dry matter), m_w the wet mass of sample at a time (g), and m_d is the corresponding dry mass of the sample (g).

2.4. Mathematical Modeling of the Drying Process

The experimental data gotten from the open sun, oven and heat pump drying were stated in terms moisture ratio, drying time and drying rate. The moisture ratio (MR) and the drying rate (DR) of the seeds were determined utilizing the Equations 2 and 3 [14]:

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

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

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

The equation can be solved using the analytical solution for spherical geometry, as followed using Equation 4, based on conjecture that uniform initial moisture appropriation, negligible external factors, temperature gradients, shrinkage during drying and constant diffusion coefficient are insignificant.

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

For the calculation of the effective moisture diffusivity at the different temperature conditions, the slope (k_o) was calculated by plotting ln(MR) versus time according to Equation 5;

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

2.6. Evaluating the Activation Energy

The activation energy for diffusion was estimated using simple Arrhenius equation as given by Kaleemullah and Kailappan [15] using Equation 6

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

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

Where, D_o 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 behavior of the dried samples was appraised 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 procedure. The calculations of the data were done utilizing the software package, Excel 2016 (Microsoft Inc.). The models' parameters were evaluated 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.

Table-1. Mathematical models applied to the oven drying curves of Soursop seeds.

S/N	Model	Equation	References
1	Newton	$MR = \exp^{-kt} j$	[16]
2	Henderson and pabis	$MR = aexp^{-kt}$	[17]
3	Page	$MR = exp\,(-kt^n)$	[18]
4	Logarithmic	$MR = aexp^{-kt} + c$	[19]
5	Two term	$MR = aexp^{-kt} + cexp^{-gt}$	[7]
6	Weibull	$MR = \alpha - bexp(-k_0 t^n)$	[20]
7	Diffusion approach	$MR = aexp^{-kt} + (1-a)\exp^{-kgt}$	[21]
8	Midili kucuk	$MR = aexp^{-kt^n} + bt$	[22, 23]
9	Wang and singh	$MR = 1 + at + bt^2$	[24]
10	Hii et al.	$MR = aexp^{-k_1 t^n} + c\exp^{-gt^n}$	[25]
11	Modified Henderson Pabis	$MR = aexp^{-kt} + b\exp^{-gt} + cexp^{-ht}$	[26]
12	Modified Page I	$MR = \exp^{-kt^n} j$	[27]
13	Modified Page II	$MR = \exp^{-k\left(\frac{t}{l^2}\right)^n} j$	[28]

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

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

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

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

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 Alara, et al. [29]. In spite of the fact that the coefficient of determination (R^2) was one of the primary criterions for choosing the best model to describe thin-layer drying curves of seeds, the statistical test methods such as the reduced chi- square (X^2), root mean square error (RMSE) described by Equation 7 to 9 were additionally used to assess the goodness of fit of the models. The lower chi- square (x^2) and RMSE values and the higher R^2 values were chosen as the basis for goodness of fit.

3. RESULT AND DISCUSSION

Results and discussion of the experiment carried out on the drying of *Annona muricata* seeds.

3.1. Moisture Content

The initial moisture content of the fresh sample of the seed was determined by oven drying method [13]. The moisture content in wet basis was calculated and its results tabulated in Table 2.

Table-2. The initial moisture content of soursop seeds in triplicate.

Mass	A	B	C
Initial mass	6.00	6.06	5.96
Final mass	3.46	3.50	3.32
MC_{wb}	42.33	42.44	44.29

The Moisture content of the seed was observed to range from 42% to 45% wet basis.

3.2. Drying Curves

The drying curves for thin layer drying curves of moisture content against time and drying rate against moisture content of soursop seeds under three drying methods as shown in Figures 1-6. As indicated by the figure, it is clear from the curves that the moisture content diminished continuously with increasing drying time. Figures 1, 3 and 5 indicated moisture content diminishes with expanding drying time. As noticed in different methods of drying, no consistent rate drying period was observed in these curves and all drying tasks are believed to occur in the falling rate period. These outcomes are in agreement with the earlier observations [30, 31]. Figures 2, 4, and 6 shows that the drying rate decreases continuously with decreasing moisture content at increasing drying time. These results are in agreement with the observations of earlier researchers based on thin layer drying of amaranth grains [32].

At 40^{0}C Oven drying method, the moisture content of the seed is reduced from 42.56% (w.b) to 11.78% (w.b). The Soursop seeds were dried in open sun for 25 hours at a temperature of about 40±3^{0}C of average initial moisture content of around 42. 56% (w.b) to the final moisture content of about 14.61% (w.b.) until no further changes in their mass were observed. For the sun drying method which dries from 42.56% (w.b) to 14.6% (w.b), is also good, yet the temperature at different time interim is unsteady so this render it unadvisable as it will cause sudden unexpected weakening or deterioration of the seed. Soursop seeds with initial moisture content in the range of 42.56% (wet basis) were dried to a final moisture content of 17.9% (wet basis). It took approximately 24 hours to dry the seeds to the final moisture content inside the heat pump.

According to Kumar, et al. [33] which acclimates with the data provided earlier, at higher water content, the expansion in temperature of heat pump and oven dryer has more extensive effect on the drying rates than at lower water content, which is almost negligible at the end. Dissimilar to sun drying, heat pump drying and oven drying at 40 degrees Celsius display a consistent rate of drying, however sun drying tends to vacillate at unspecific intervals which may be because of the change in ambient temperature and relative humidity of the environment. As observed by Olabinjo, et al. [34] sun drying shows an unsteady drying rate which affects final moisture content level.

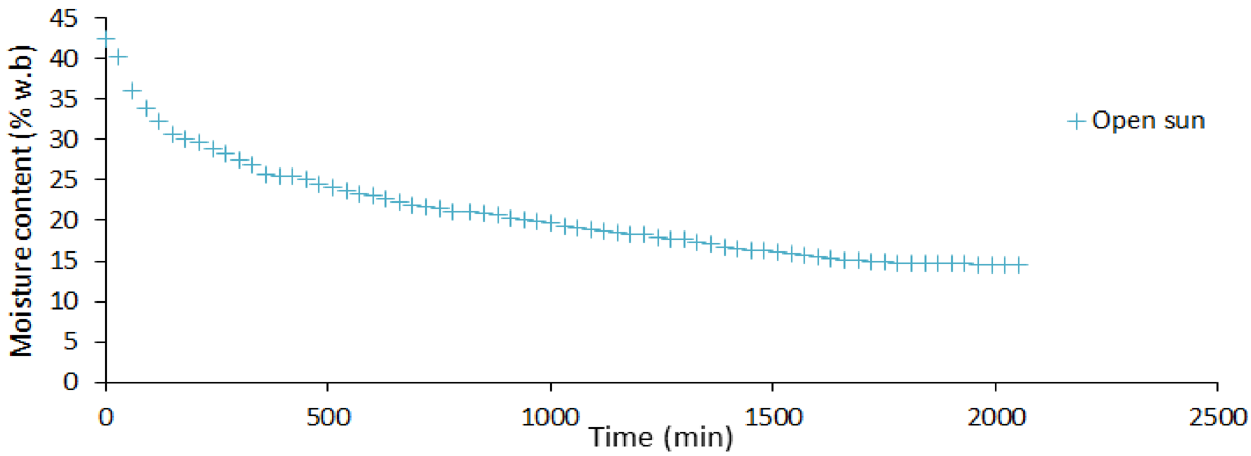

Figure-1. Graph of moisture content against time for open sun drying

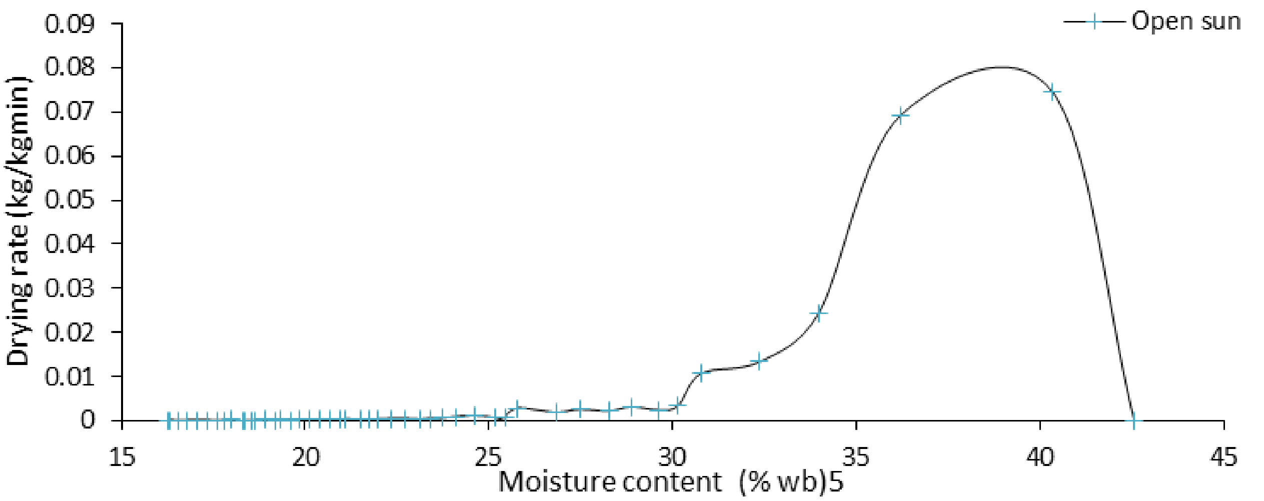

Figure-2. Graph of drying rate against moisture content for open sun drying.

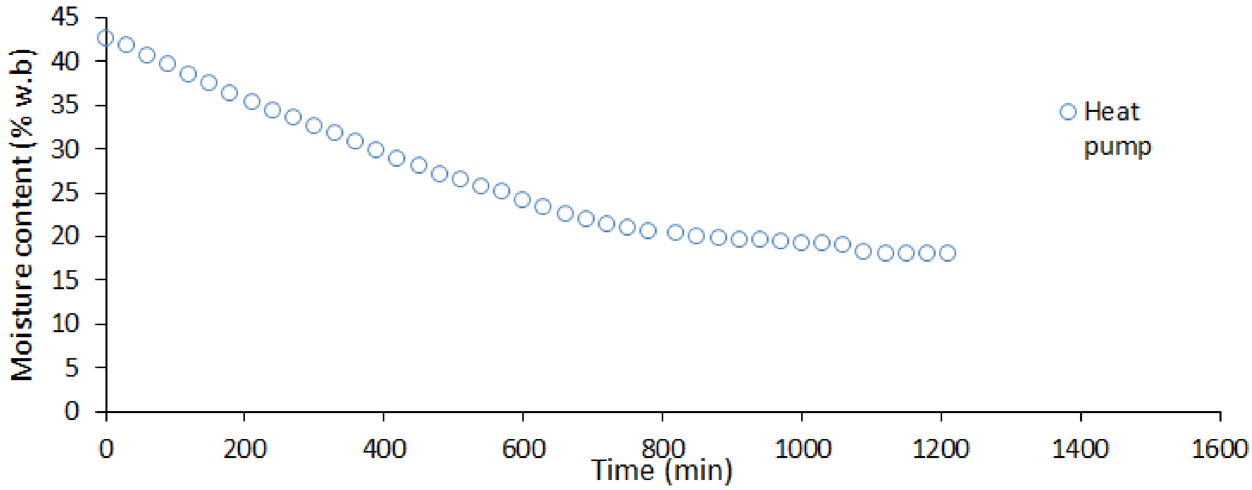

Figure-3. Graph of moisture content against time for heat pump drying at 40 °C.

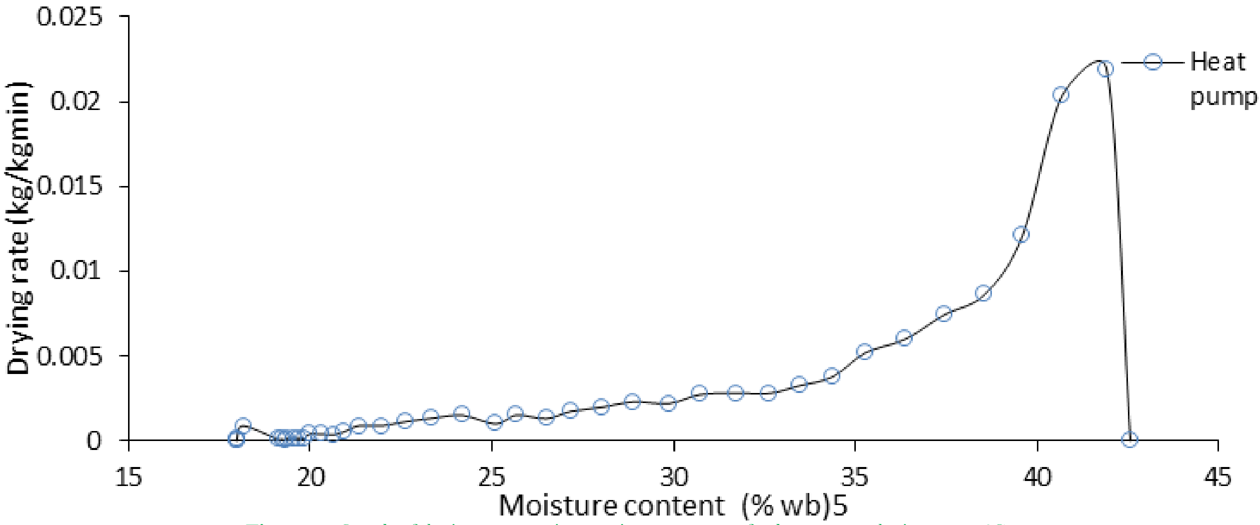

Figure-4. Graph of drying rate against moisture content for heat pump drying at 40 °C.

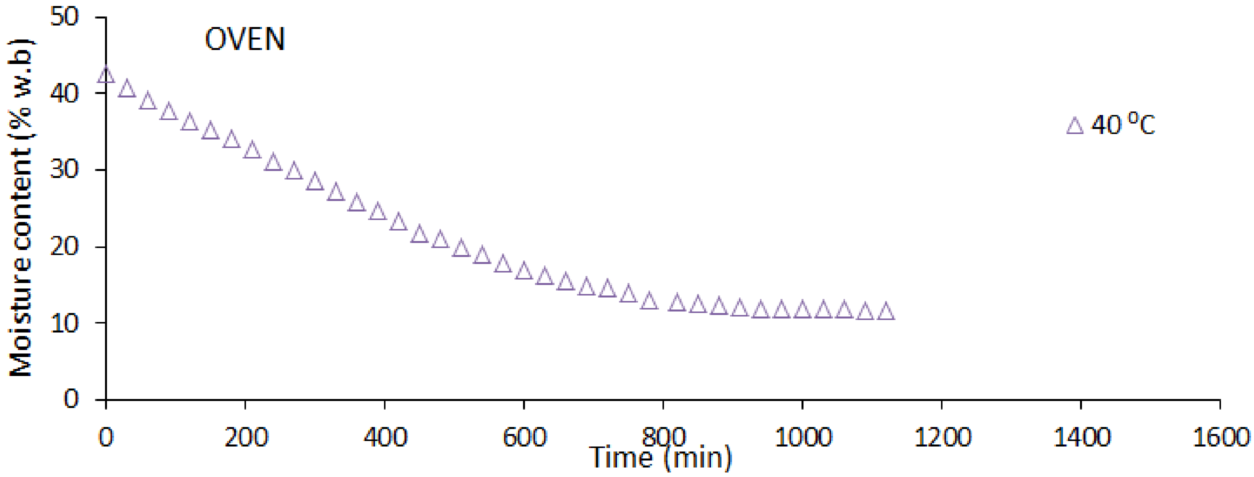

Figure-5. Graph of moisture content against time for oven drying at 40 °C.

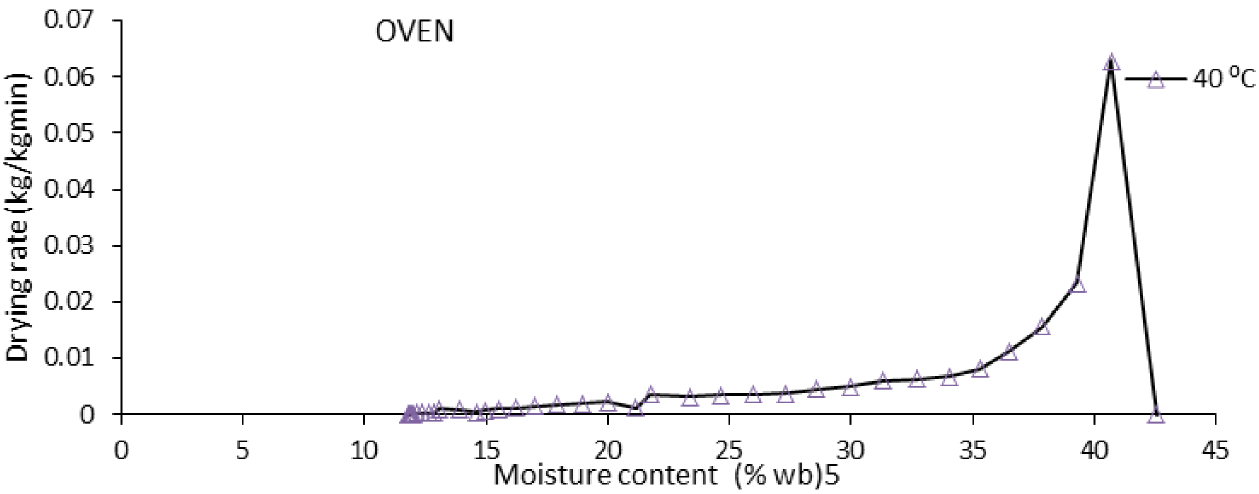

Figure-6. Graph of drying rate against moisture content for oven drying at 40 °C.

3.3. Effective Moisture Diffusivity

The viable moisture diffusivity was calculated using Fick's diffusion equation for particles with slab geometry was utilized for estimation of effective diffusivity by method of slopes expressed in equation 5 and is shown in Figure 7. The effective diffusivity value of Soursop seeds for oven, open sun and heat pump drying were; 1.6801231 E-10, 6.34205 E-11 and 1.02978E-10 respectively as shown in Table 2. This demonstrates that as the moisture content diminishes, the permeability to vapour expanded, provided the pore structure remains open. Sharma and Prasad [35] likewise stated a comparable trend in the variation in the moisture diffusivity with moisture content and as a result, it leads to fast drying. The acquired estimation of D_{eff} from this study exist in general range 1.1217E-11 to 6.713E-11 for drying of seeds as reported by Rizvi, [36].

3.4. Activation Energy

The value of the activation energy *Ea* was determined by exploiting the Arrhenius equation. Indeed, the curve which connects the experimental points of Ln (*Deff*) and the inverse of the absolute temperature 1/T Figure 7 is almost linear. As indicated by Zogzas, et al. [37] the activation energy for farm products ranges from 12.7 to110 kJ mol-1, which is within the range (23.38 kj/mol to 27.95 kj/mol) of the activation energy got in Table 2. It is featured that in the drying processes, the lesser the activation energy, the more will be water diffusion within the product [38]. The activation energy is a hindrance that ought to be broken with the goal that the diffusion procedure is able to be release in the product [38].

Table-2. The effective diffusivities of drying soursop seed under open sun and heat pump.

Drying systems	Heat pump (40±4° C)	Open sun (40±3° C)	Oven drying (40±4° C)
Thickness(mm)	4	3	1.6413358
D_{eff} (10^{-10})	1.02978	0.634205	1.6801231
E_a (kj/mol)	27.95	24.00	24.53

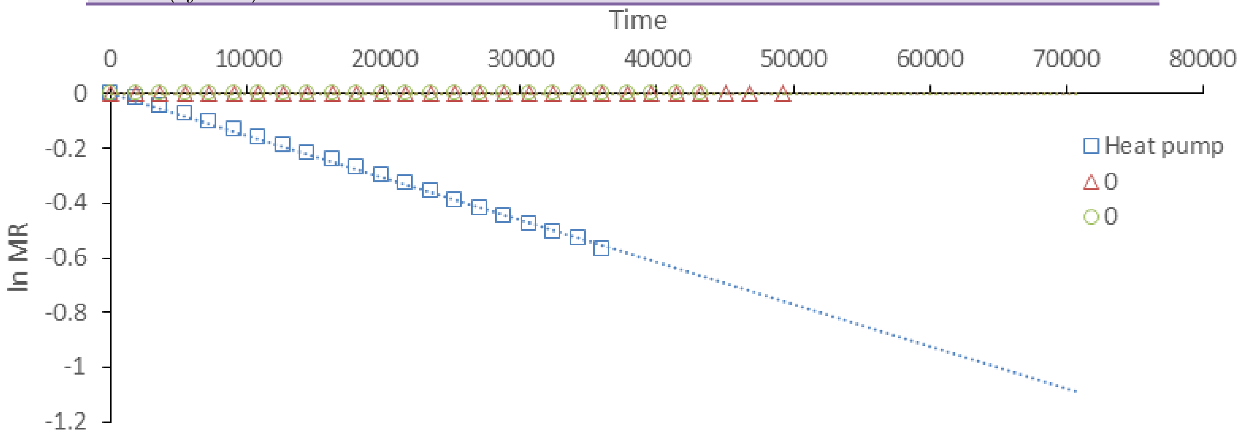

Figure-7. Relation between D_{eff} and $1/T$.

3.5. Modeling

Moisture content data were converted to moisture ratio, then fitted into the thirteen (13) thin layer drying models listed in Table 1 and that are often times utilized in the drying of agricultural produce [29]. Table 3 shows the results of linear regression analysis of fitting the thirteen mathematical drying models to experimental data for Soursop seeds used to evaluate goodness of fit such as R^2, χ^2, and RMSE. The model that best portray the thin layer drying characteristics is the one that gives the highest value of R^2, and the lowest value of RMSE provides information on the long-term performance of the correlations, helping for the comparisons of the real deviation amid experimental and predicted values. It was observed that two term model as bolded in the table is the best and most appropriate in predicting drying kinetics of soursop seeds under the varying drying methods of study. It's 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 heat pump respectively as shown in Table 3.

Table-4. Values of drying constants and coefficients of mathematical models of non-regression model for the drying of soursop seeds under open sun, heat pump and oven.

Drying system	Model	Model constants	R^2	RMSE	X^2	SEE
Oven	Newton	k = 0.1121	0.9813	0.0268	0.0273	0.0007
	Henderson and pabis	k = 2.1305, a = 0.1395	0.9801	0.0233	0.0242	0.0006
	Page	k = 0.1286, n = 0.9412	0.9883	0.018	0.0187	0.0003
	Logarithmic	k = 0.1386, a = 1.0011, c = 0.0545	0.9907	0.0158	0.0168	0.0003
	Two term model	k = 0.1614, g = 0.0403, a = 0.8671, c = 0.1982	0.991	0.0157	0.0169	0.0003
	Verma et al	k = 0.0237, g = 0.1344, a = 0.0974	0.9891	0.0172	0.0182	0.0003
	Diffusion approach	k = 0.1121, g = 1, a = 3.0345	0.9909	0.0157	0.0167	0.0003
	Midili kucuk	k = 0.1266, b = 0.0016, a = 1.0457, n = 1.0047	0.9887	0.0175	0.0189	0.0004
	Wang and	a = -0.0776, b = 0.0015	0.9909	0.0157	0.0163	0.0003

	smith					
	Hii et al.	k = 0.0575, g = 0.0046, a = 0.6804, c = 0.3086, n = 1.723	0.991	0.0156	0.0172	0.0003
	Modified Henderson pabis	k = 0.05, a = 0.0015, g = 0.05, b = 0.0015, h = 0.05, c = 0.1	0.991	0.0157	0.0177	0.0003
	Modified Page I	k = 0.0593, n = 1	0.9883	0.018	0.0187	0.0003
	Modified Page II	k = 1, a = 0.8, n = 0.9, L = 0.7	0.9887	0.0175	0.0189	0.0004
Heat pump	Newton	k = 0.0448	0.9359	0.0911	0.0918	0.0084
	Henderson and Pabis	k = 0.0303, a = 0.7895	0.9116	0.0448	0.0454	0.0001
	Page	k = 0.1906, n = 0.5032	0.9944	0.0113	0.0114	0.0068
	Logarithmic	k = 0.1025, a = 0.5617, c = 0.3365	0.975	0.0237	0.0242	0.0083
	Two term model	k = 0.0219, g = 0.4407, a = 0.667, c = 0.3295	0.9961	0.0093	0.0096	0.0085
	Verma *et al*	k = 0.022, g = 0.4484, a = 0.668	0.9961	0.0093	0.0095	0.0087
	Diffusion approach	k = 0.4484, g = 0.049, a = 0.332	0.9961	0.0093	0.0095	0.0087
	Midili Kucuk	k = 0.1968, b = 0.001, a = 1.0185, n = 0.52	0.9953	0.0102	0.0105	0.0088
	Wang and Smith	a = -0.052, b = 0.001	0.9302	0.0658	0.0668	0.0084
	Hii *et al*	k = 0.2263, g = -0.001, a = 0.8802, c = 0.1371, n = 0.5383	0.9955	0.0101	0.0105	0.0052
	Modified Handerson and Pebis	k = 0.3335, a = 0.0219, g = 0.3335, b = 0.0219, h = 0.3295, c = 0.4406	0.9961	0.0093	0.0098	0.0089
	Modified Page I	k = 0.0371, n = 0.5032	0.9944	0.0113	0.0114	0.0085
	Modified Page II	k = 1.0258, a = 0.5647, n = 0.4817, L = 7.8376	0.9949	0.0107	0.011	0.0085
Open sun	Newton	k = 0.1121	0.9714	0.0432	0.0435	0.0019
	Henderson and Pebis	k = 2.1305, a = 0.1395	0.9652	0.0338	0.0342	0.0012
	Page	k = 0.1286, n = 0.9412	0.9867	0.0209	0.0212	0.0005
	Logarithmic	k = 0.1386, a = 1.0011, c = 0.0545	0.9977	0.0086	0.0088	0.0001
	Two term model	k = 0.1614, g = 0.0403, a = 0.8671, c = 0.1982	0.9993	0.0047	0.0048	0
	Verma *et al*	k = 0.0237, g = 0.1344, a = 0.0974	0.9714	0.0432	0.0441	0.0019
	Diffusion approach	k = 0.1121, g = 1, a = 3.0345	0.9714	0.0432	0.0441	0.0019
	Midili Kucuk	k = 0.1266, b = 0.0016, a = 1.0457, n = 1.0047	0.9992	0.0052	0.0054	0
	Wang and Smith	a = -0.0776, b = 0.0015	0.998	0.0105	0.0106	0.0001
	Hii *et al*	k = 0.0575, g = 0.0046, a = 0.6804, c = 0.3086, n = 1.723	0.9993	0.0049	0.0051	0
	Modified Handerson and Pebis	k = 0.05, a = 0.0015, g = 0.05, b = 0.0015, h = 0.05, c = 0.1	0.9977	0.0086	0.009	0.0001
	Modified Page I	k = 0.0308, n = 1	0.9867	0.0209	0.0212	0.0005
	Modified Page II	k = 1, a = 0.8, n = 0.9, L = 0.7	0.9886	0.0191	0.0197	0.0004

3.6. Validation of Model Used

Figures 8-10 demonstrates the correlation of the predicted and experimented values for the oven, heat pump drying, and open sun drying techniques correspondingly. The model utilized is validated to check the suitability of the model in forecasting 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 utilized to predict the drying curve. The graphs of predicted moisture ratio and experimented moisture ratios for various samples under the varying conditions, R^2 ranges from 0.9961 to 1 shows the validation satisfy thin layer model.

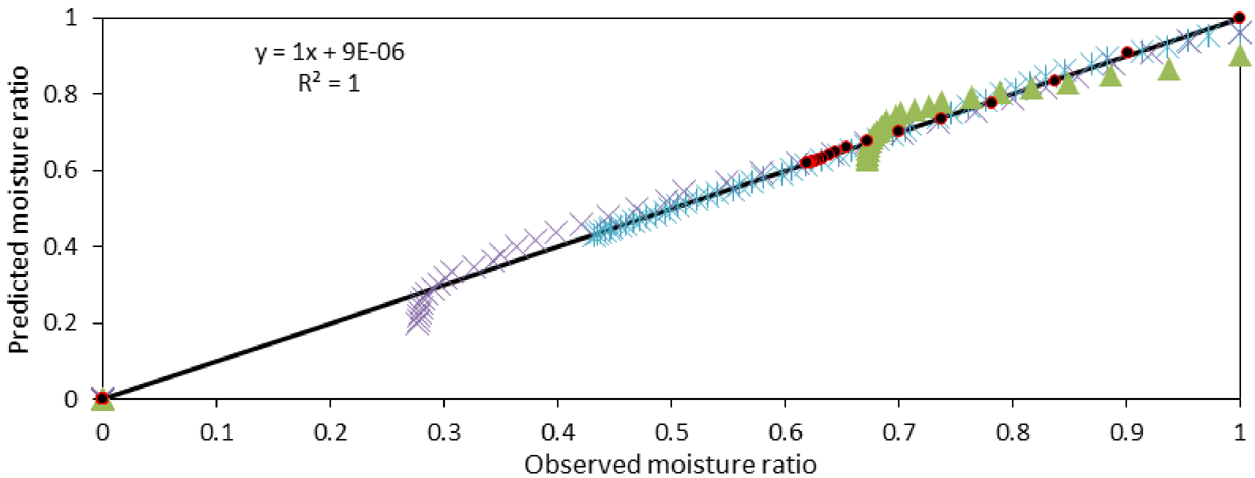

Figure-8. Plot of Experimented MR against Predicted MR for soursop seed in oven.

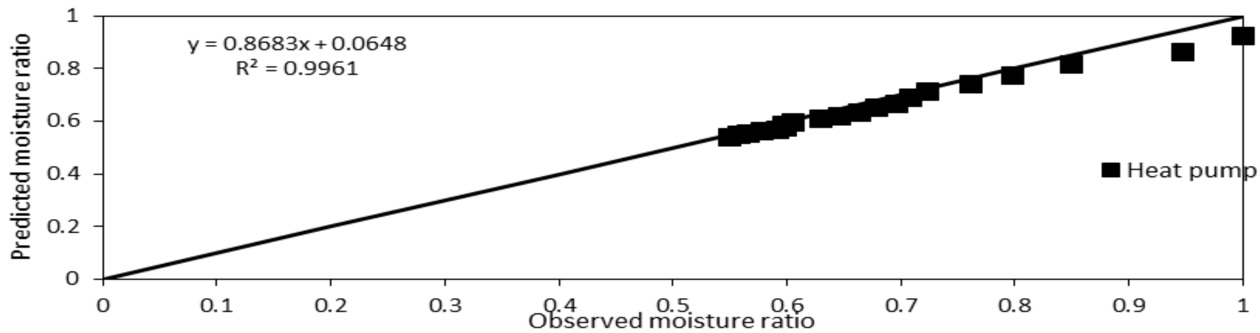

Figure-9. Plot of Experimented MR against Predicted MR for soursop seed in heat pump.

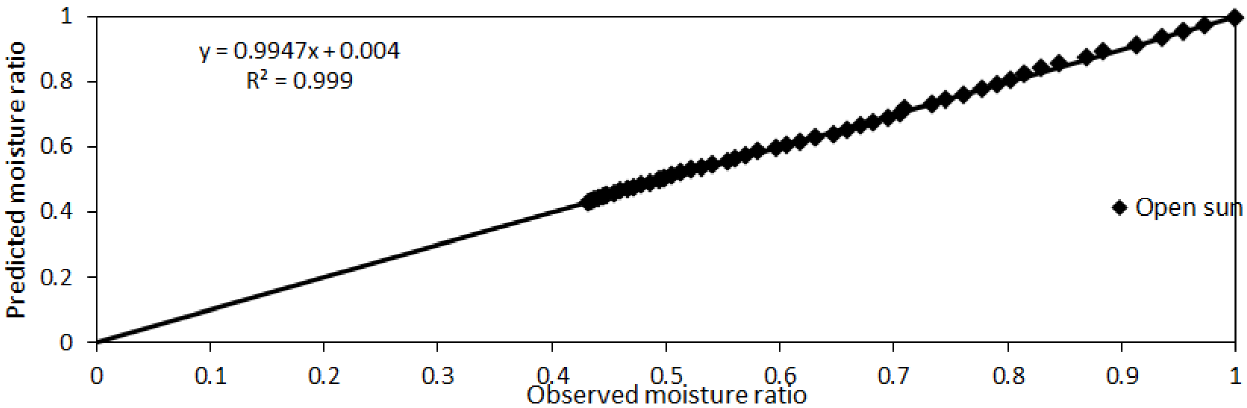

Figure-10. Plot of Experimented MR against Predicted MR for soursop seed under open sun.

4. CONCLUSION

Seed drying is one of the methods that are used to preserve the quality for availability throughout the year, as well as reduce post-harvest loses. In this study, the various drying techniques used were capable to preserve the quality of the seed. The result from the thirteen thin-layer model equations used in testing the drying experiment carried out on the thin-layer drying behavior of soursop seeds at 40ºC. 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 heat pump 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 Soursop seeds for open sun, heat pump 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.

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