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Effect of Pretreatment and Drying Method on Drying Kinetics of Ackee *(Blighia sapida)* Arils

[1]Ojo J. A., [2]Ogunlakin G. O. and [3]Olajire A. S.

[1,2,3]*Department of Food Engineering, Ladoke Akintola University of Technology, P.M.B 4000, Ogbomoso, Oyo State, Nigeria.*

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Corresponding Author:
ajokeojo91@gmail.com

ABSTRACT

The research investigated the effect of different pretreatments and different drying methods on the drying kinetics of ackee arils (AA). Freshly harvested AA were portioned and subjected to pretreatments, including blanching at 85 °C for 3 min, dipping in salt (NaCl) solutions of 1, 2, and 3% w/v for 5 min, and untreated samples served as the control. The aril samples were dried at different temperatures (50, 60, and 70 °C) and monitored at intervals until a constant weight was achieved. They were subsequently analyzed for drying kinetics, effective moisture diffusivity (D_{eff}), and activation energy (Ea), using standard methods. The moisture content reduced from 62.9 to 3% and was in a falling rate period. The moisture loss occurred at a faster rate in AA dried at 70 °C compared to 60 °C and 50 °C. The D_{eff} increased with an increase in drying temperature from 50 to 70 °C. The overall highest D_{eff} was 2.07 ×10^{-4} m^2/s at an oven drying temperature of 60 °C, with 1% salt solution pretreatment, while the lowest was 4.23 × 10^{-6} m^2/s at an oven drying temperature of 70 °C, 3% salt solution pretreatment. The Ea obtained falls within the range of (106.10 – 125.29 $kJmol^{-1}$), which indicates that the AA processed is highly sensitive to temperature. The obtained drying data were fitted into five different thin-layer drying mathematical models using the coefficient of determination (R^2), least values of Chi-Square (χ2), Root Mean Square Error (RMSE) and Mean Biased Error (MBE). Pretreatment had a significant effect ($p \leq 0.05$) on the drying of AA. The Midilli and Kucuk model described the drying behaviour of AA pretreated with 1% salt (NaCl) solution and oven-dried at 70 °C satisfactorily with the R^2 values of 0.999.

INTRODUCTION

Ackee *(Blighia sapida)* is a tropical fruit known for its nutritional content and health benefits, but its perishable nature limits its shelf life. The ackee is a medium-sized tree in the Sapindaceae family native to West Africa. The leaves are fifteen centimeters long, oval in shape, ending in a point; dark green in colour and shiny at the upper base (Oloyede *et al.*, 2023). The fruits, the size of a small pear, are pink to red in colour, oval in shape, marked by three protruding ribs five to six centimeters long, sometimes longer. The black seed has a detestable taste. The different parts of the tree are used for several purposes: consumption, manufacture of soaps, and pharmacopoeia (Kakpo *et al.,* 2020). AA, also known as the vegetable brain, is cream-coloured, nutty-flavored, and edible, and is the major component of the Jamaican national dish, ackee and salt fish (Ekue *et al.,* 2010), with the fruit either eaten fresh or processed. Postharvest losses have been a harm to food security; the losses not only affect product output but also reduce farmers' income, and about 20-40% of fruits and vegetables produced get spoiled (Yadav *et al.*, 2014). The nature of the AA's maturity on the tree before harvesting has been observed to lead to significant losses, as it drops off when not harvested in due time, making it poorly utilized as food. Therefore, the commercial potential of AA is yet to be fully exploited. The preservation of fruits and vegetables, which includes drying, canning, freezing, and others, is essential for extending the shelf life and quality of the product. Among these, drying is especially suited for developing countries due to inadequate facilities, as it offers a highly effective and practical means of preservation, which reduces post-harvest losses and offsets shortages in supply (Oke *et al.,* 2019). Therefore, pretreatment and drying methods using an oven (50, 60, and 70 °C), solar energy, and sunlight are adopted as primary means of storage to reduce postharvest losses of AA by processing them into a dried form with reduced moisture content, thereby better understanding its food uses. In order to study the effects of different components of AA and make predictions about its behaviour, a mathematical model is employed (Darvishi *et al*., 2012).

Several research studies have been conducted on the effect of drying temperatures on fruits and vegetables (Falloon *et al*., 2014; Ampofo-Asiama *et al*., 2020; Olabinjo, 2023). However, no studies have been reported on the pretreatment of AA before drying. Therefore, this study was conducted to determine the effect of different pretreatments and different drying methods on AA and provide a comprehensive knowledge on the mathematical model that can satisfactorily describe AA drying data from five models [Newton (El-Beltagy *et al.,* 2007), Page (Akoy, 2014), Handerson and Pabis (Rosa *et al.*, 2015), Wang and Smith (Omolola *et al.,* 2014) and Midilli-Kucuk (Ayadi *et al*., 2014)].

METHODOLOGY

Sample Preparation

Fresh, disease-free, and mature AA (Plate 1) were obtained from a tree located at the Ladoke Akintola University Teaching and Research Farm, Ogbomoso, Nigeria. The ripe AA were sorted and washed with clean water to remove sand. The harvested AA were grouped into 5 groups, each with an average weight of 55 g, and pretreated with blanching (BL), 1% salt (NaCl) solution (SLT1), 2% salt (NaCl) solution (SLT2), and 3% salt (NaCl) solution (SLT3). AA dried at 50, 60, 70 °C, solar and sun were named A1, A2, A3, A4 and A5.

Plate 1: Ackee Arils

Drying of AA

A total of 52 quarry product samples of three different sizes: Stone-Dust (< 2 mm), 3/4-Down (≃ 10 mm) and 3/4-Up (≥ 15 mm) were collected from quarries in Osun and Oyo States, Southwestern Nigeria. The samples were air-dried at room temperature until a constant weight was achieved. The dried samples were then crushed into powder. The powdered samples of the same size from the same source were each packed into a plastic container that matches the geometry of the detector and tightly sealed with the aid of polyvinyl chloride (PVC) tape. All samples were weighed and kept for a period of 28 days before measurement in order to attain radioactive secular equilibrium (Gbenu *et al*., 2016).

Samples Coding

Drying was done using an oven dryer (DHG 9240A) with the selected temperatures of 50, 60 and 70 °C, solar and sun. It was pre-set at each selected temperature for one hour to allow the dryer to equilibrate before placing the ackee aril samples. The sample (55 g) was measured using a digital balance with ± 0.01 g accuracy, spread on perforated drying trays and placed in the oven at a temperature of 50 °C. The weight of the samples was taken at an interval of 1 h until a constant weight was obtained at three consecutive measurements. This procedure was repeated for samples dried at 60,70 °C, solar and sun, respectively. After each day of drying, the samples were placed inside a desiccator to prevent rehydration until the next day.

Determination of Moisture Content

The moisture content of the AA was determined using the standard method of AOAC (2005) and the weight of the AA was converted to moisture content using Equation 1

$$MC = \frac{w_i - w_d}{w_i} \times 100 \quad (1)$$

where MC is the moisture content, w_i is the initial mass of the sample and w_d is the mass of the sample at time t.

Drying Kinetics of AA

The data obtained was used to determine the drying kinetics of AA and as such the variation in the moisture content of AA with drying time, drying rate, effective moisture diffusivity and activation energy were derived. With the use of Equation 2, the drying rate of AA was calculated and the moisture content was then converted into a moisture ratio using Equation 3

$$DR = \frac{m_t - m_{t-1}}{t} \quad (2)$$

$$MR = \frac{M}{Mi} \quad (3)$$

where DR is the drying rate, mt is the moisture content of the product at each time interval, t is the time at regular intervals, MR is the dimensionless moisture ratio, M and Mi are the moisture content at any time t and the initial moisture content, respectively.

Determination of Effective Moisture Diffusivity and Activation Energy

The effective moisture diffusivity (D_{eff}) was calculated using Fick's second equation of diffusion as presented in Equation 4 (Aremu *et al.,* 2013; Komolafe *et al.,* 2018). The activation energy was obtained from the slope of the In D_{eff} against $-\frac{1}{Rg(T+273.15)}$

$$In\ D_{eff} = \left[-\frac{1}{Rg(T+273.15)}\right] E_a + In\ D_o \quad (4)$$

where D_o is the diffusion coefficient (m^2s^{-1}), E_a is the activation energy ($kJmol^{-1}$), T is the temperature (°C) and Rg is the universal gas constant (kJ/molK).

Mathematical Modeling of the Drying Kinetics of AA

The thin-layer drying model describes the drying behaviour of food materials when they are exposed to heated air in a thin layer and has been used by many researchers (Sabat *et al.,* 2018). The moisture content data of the dried ackee arils were converted into a moisture ratio, and the converted data were fitted into five selected thin-layer drying models, as presented in Table 1.

Table 1: Thin-layer drying models used for the drying of AA

S/N	Models	Equations	Reference
1.	Newton	$MR = exp(-kt)$	El-Beltagy *et al.* (2007)
2.	Page	$MR = exp(-kt^n)$	Akoy (2014)
3.	Handerson and Pabis	$MR = a\ exp(-kt)$	Rosa *et al.* (2015)
4.	Wang and Smith	$MR = 1 + at + bt^2$	Omolola *et al.* (2014)
5.	Midilli-Kucuk	$MR = a\ \exp(-kt) + bt$	Ayadi *et al.* (2014)

Statistical Analysis

The experimental data were analyzed using one-way Analysis of Variance (ANOVA) to determine whether there would be any significant variation of the means ($p \leq 0.05$) and the non-linear regression tools of Microsoft Excel. Statistical parameters were used as the primary criteria to select the best model to account for variation in the drying curves of the dried AA. These parameters are Coefficient of Determination (R^2), Root Mean Square Error (RMSE), the Mean Biased Error (MBE), and Chi-square (x^2) (Sabat *et al.,* 2018; Olabinjo, 2022). The statistical parameter was calculated using Equations 5-7.

$$x^2 = \frac{\sum_{i=1}^{N}(MR_i - MR_{predi})^2}{N-Z} \quad (5)$$

$$RMSE = \left[\frac{1}{n}\sum_{i=1}^{N}(MR_{predi} - MR_{expi})^2\right]^{1/2} \quad (6)$$

$$MBE = \frac{1}{n}\sum_{i=1}^{N}(MR_{Predi} - MR_{expi}) \quad (7)$$

where, MR_{expi} is the experimental moisture ratio, MR_{predi} is the predicted moisture ratio, N is the number of observations, and n is the number of constants in the equation.

RESULTS AND DISCUSSION

Drying rate of AA

The plot of moisture content against time yielded the drying curves. Figure 1 shows the drying curves for AA with each pretreatment across the drying methods. It was observed from these curves that there was a gradual decrease in moisture content with an increase in drying time, as the drying curve exhibits a gentle downward trend. The moisture content of the AA before drying was found to be 62.9% wet basis and at the end of the drying experiment, it reduced to less than 3% in the dried samples (Olabinjo and Sama, 2023). The highest loss of moisture was in the early period of drying. At the same time, there was a gradual reduction in moisture content at the latter period of drying, which was a result of the evaporation of free water in the AA samples, leaving the bound water (Olajire *et al.,* 2018).

The reduction in moisture content reduced the water content, thereby minimizing microbial spoilage and deterioration reaction during storage (Olabinjo, 2020). The drying time for the sample oven-dried at 50 °C was longer than that of all other drying methods. This is because the drying temperature is the lowest among the selected oven drying temperatures (Sobowale *et al.,* 2020). The moisture loss occurred at a faster rate in AA dried at 70 °C compared to 60 and 50 °C, which could be attributed to an increase in the energy of water molecules with increased temperature, resulting in the quick evaporation of water from the sample (Sanika *et al*., 2021). The drying rate, a function of drying time and moisture content, was a fundamental parameter computed from the drying data by estimating the geometric derivation occurring in each consecutive time interval, and was expressed as grams of water per gram of material.

Figure 2 depicts the variation of drying rate with moisture content in the AA under the five drying conditions. The drying method had a strong influence on the drying rate curve. A falling rate drying signified that the drying process was controlled by the inner water diffusion (Schoessler *et al*., 2012; Wang *et al*., 2019). Previous researchers have reported similar results (Limpaiboon, 2011; Olajire *et al*., 2018; Sahari and Driscoll, 2013), that drying rate increases with an increase in drying temperature because higher temperatures result in greater diffusion of water, which increases the rate at which water is evaporated from the surface of the AA samples, so that the water level decreases rapidly.

Effective Moisture Diffusivity and Activation Energy of the Drying of AA

The D_{eff} and *Ea* are as shown in Table 2. It was observed that D_{eff} increased with an increase in drying temperature from 50 to 70 °C. This was in line with the report of Aremu *et al*. (2013) that D_{eff} increased with increase in drying temperature from 60 to 80 °C during the drying of mango which was as a result of the fact that water diffusion mainly due to mass transport mechanism from the first phase of drying increases with an increase in drying temperature as stated by Ojediran and Raji (2011).

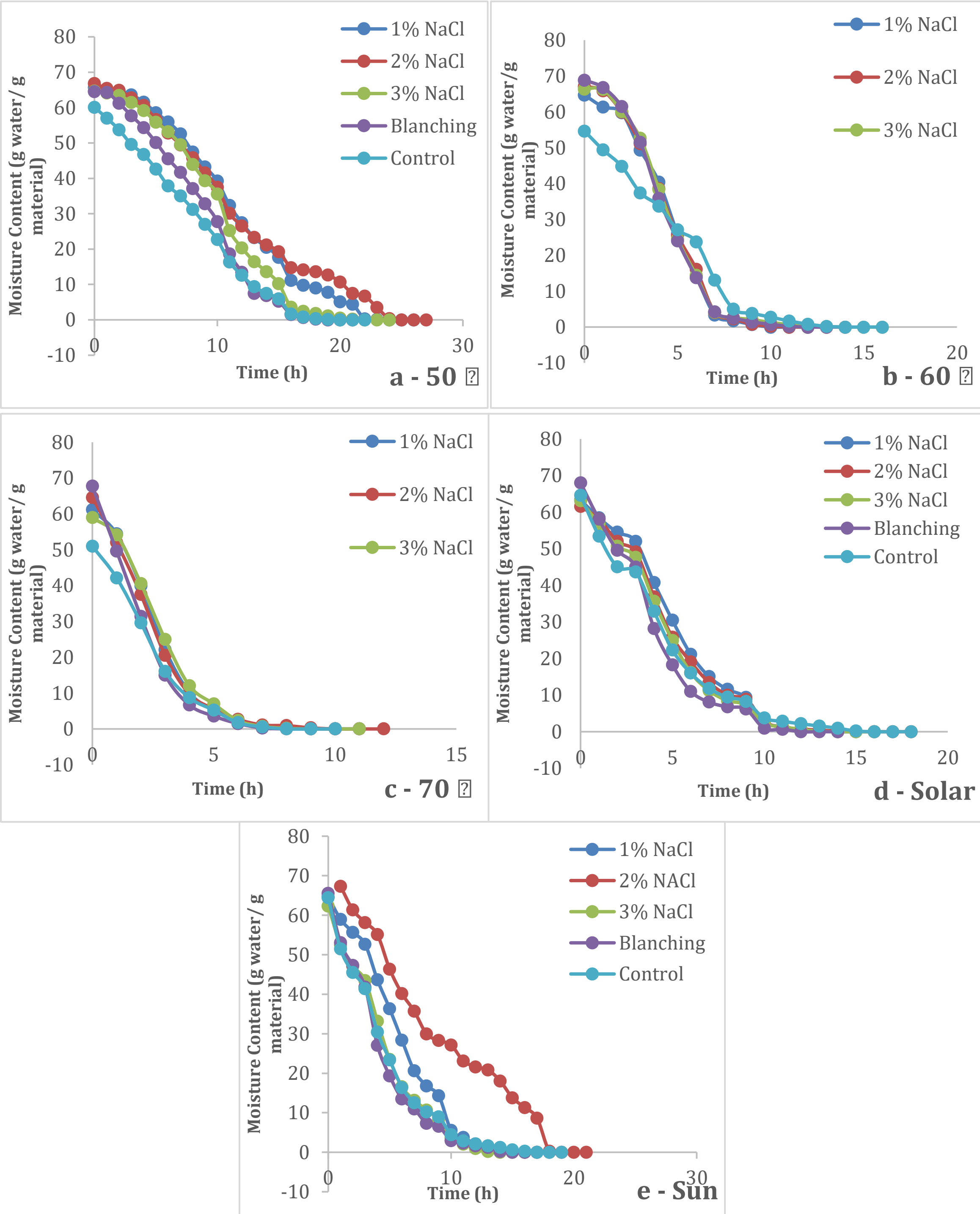

Figure 1: Moisture content against time for salt (NaCl) solution pretreated AA, blanching and control oven dried at 50 (a), 60 (b), 70 °C (c), solar (d) and sun (e).

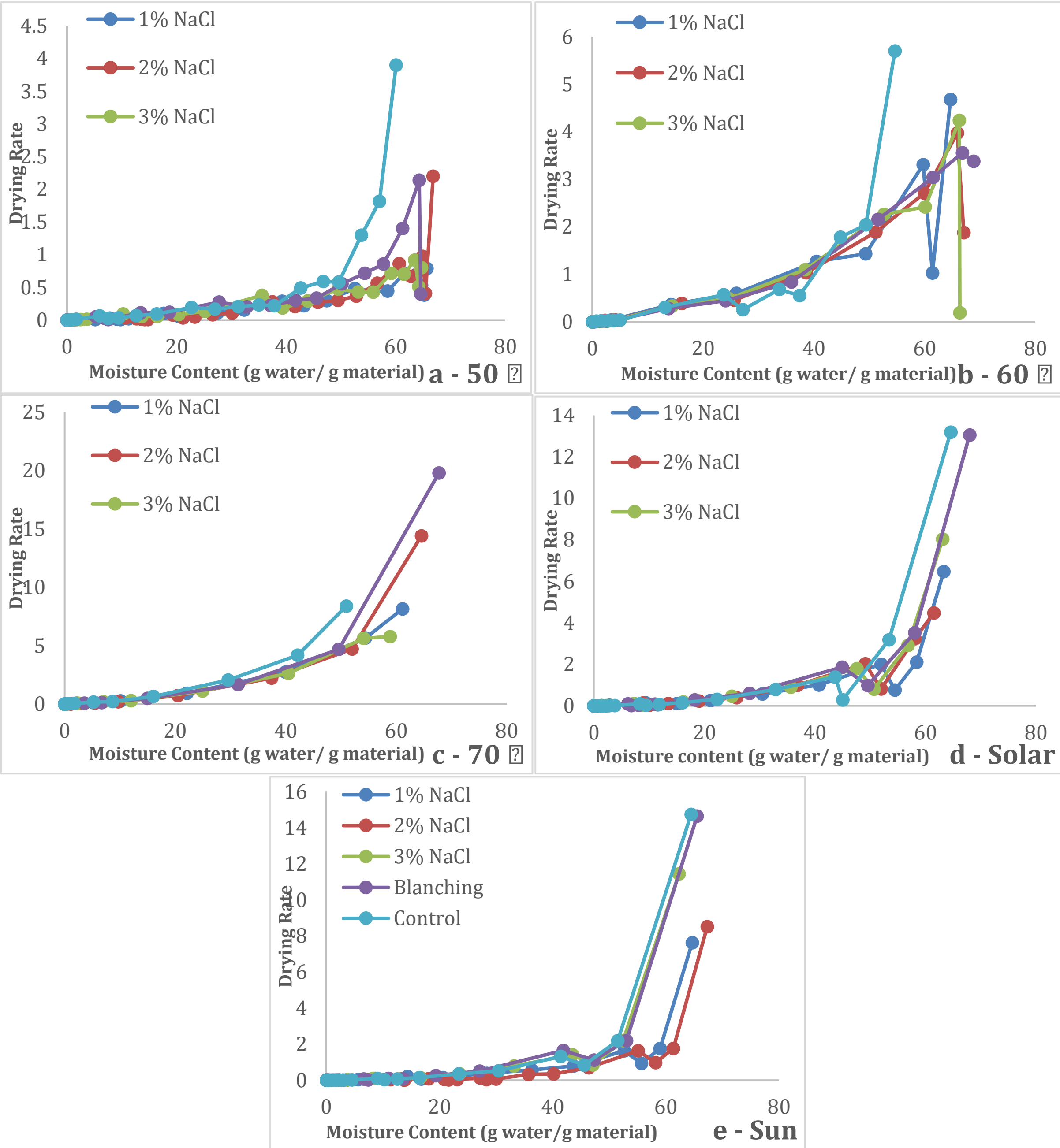

Figure 2: Drying rate curve for salt (NaCl) solution pretreated AA, blanching and control oven dried at 50 (a), 60 (b), 70 °C (c), solar (d) and sun (e).

From the results presented in Table 2, it was observed that the calculated values of D_{eff} ranged from 10^{-4} to 10^{-6} m^2/s. These values are relatively higher than the typical range of 10^{-9} to 10^{-12} commonly reported for most agricultural products (Alara *et al*., 2019). This deviation can be attributed to the unique composition of AA, particularly their high lipid content and porous cellular structure, pretreatments employed (salt and blanching), reducing bound water, enhancing free water mobility, disrupting cell membranes, softening tissues and increasing porosity, thereby accelerating moisture migration (Doymaz, 2010). Similar deviations in D_{eff} have been reported for other high oil content food materials, such as oilseeds and fruit pulps, where composition and matrix structure significantly influence moisture migration (Kaya and Aydin, 2009).

The overall highest D_{eff} was found to be 2.07 ×10^{-4} m^2/s at an oven drying temperature of 60 °C, with 1% salt solution pretreatment, while the lowest was found to be 4.23 × 10^{-6} m^2/s at an oven drying temperature of 70 °C, 3% salt solution pretreatment. The D_{eff} obtained was found to be higher than the unpretreated ackee apple (7.71 × 10^{-9} m^2/s) oven dried at 70 °C (Olabinjo, 2022); and, was found to be in the same range with those of mango varieties (1.12 × 10^{-6} m^2/s and 1.12 × 10^{-6} m^2/s) oven dried at 75 °C (Jonathan Ampah *et al.,* 2022). The *Ea* obtained falls within the range of (106.10 – 125.29 $kJmol^{-1}$) which indicates that the AA processed is highly sensitive to temperature and was found to be higher than unpretreated AA (18.168 $kJmol^{-1}$) as reported by Olabinjo (2022), for apricots from 24.01 to 25.0 $kJmol^{-1}$ (Mirzaee *et al.,* 2010); some, were found to be within the range of 1.27 $kJmol^{-1}$ – 110 $kJmol^{-1}$ as reported by Alara *et al* (2019) for bio materials.

Table 2: Effective Moisture Diffusivity (m^2/s) and Activation Energy ($kJmol^{-1}$) of the Different Drying Processes of AA

Drying method	Pretreatment	Effective Moisture Diffusivity (m^2/s)	Activation Energy($kJmol^1$)
Oven at 50 °C	1% NaCl	1.01× 10^{-4}	109.46
	2% NaCl	2.11× 10^{-5}	113.67
	3% NaCl	1.20× 10^{-4}	108.99
	Blanching	1.31× 10^{-4}	108.76
	Control	1.37× 10^{-4}	108.64
Oven at 60 °C	1% NaCl	2.07× 10^{-4}	110.86
	2% NaCl	2.65× 10^{-5}	116.56
	3% NaCl	3.83× 10^{-5}	115.54
	Blanching	2.88× 10^{-5}	116.33
	Control	1.83× 10^{-4}	111.19
Oven at 70 °C	1% NaCl	5.67× 10^{-6}	124.46
	2% NaCl	2.06× 10^{-4}	114.21
	3% NaCl	4.23× 10^{-6}	125.29
	Blanching	1.84× 10^{-4}	114.53
	Control	1.83× 10^{-5}	112.10
Solar	1% NaCl	3.31× 10^{-5}	110.34
	2% NaCl	1.29× 10^{-4}	106.76
	3% NaCl	1.65× 10^{-4}	106.11
	Blanching	1.83× 10^{-4}	106.10
	Control	1.51× 10^{-4}	106.34
Sun	1% NaCl	3.83× 10^{-5}	118.89
	2% NaCl	1.13× 10^{-5}	122.38
	3% NaCl	1.65× 10^{-4}	114.74
	Blanching	1.49× 10^{-4}	115.03
	Control	3.09× 10^{-5}	119.51

However, the values are within the range of (110.837 – 130 $kJmol^{-1}$) obtained for beberis fruit (Aghbashlo *et al.,* 2008) and lower than 146.40 to 232.45 $kJmol^{-1}$ obtained for Jerusalem antichoke tubers (Li *et al.,* 2013). This is because water that exists in the form of chemical absorption in food materials requires more energy to extract the water that is present on the surface of food materials (Nwakuba *et al.,* 2021).

Evaluation of the Drying Model of AA

Thin-layer drying models such as the Newton, Page, Henderson and Pabis, Wang and Smith, and Midilli and Kucuk were used to fit the drying of AA experimental data, while the statistical parameters (R^2, x^2, RMSE and MBE) and constants for AA samples used for the comparison of the models for different drying methods were listed in Tables 3, 4, 5, 6 and 7.

Table 3: Statistical Parameters for Selected Thin Layer Model on the Drying of AA at 50 °C

Model	Pretreatment	R^2	x^2	RMSE	MBE	Constants
Newton	1% NaCl	0.857	0.021	0.732	-0.245	k = 0.078
	2% NaCl	0.904	0.012	0.569	-0.173	k = 0.078
	3% NaCl	0.840	0.026	0.775	-0.150	k = 0.090
	Blanching	0.868	0.032	0.800	-1.520	k = 0.105
	Control	0.915	0.011	0.488	0.087	k = 0.113
Page	1% NaCl	0.998	0.000	0.056	0.021	k = 0.030, n = 2.334
	2% NaCl	0.995	0.001	0.092	0.024	k = 0.009, n = 1.852
	3% NaCl	0.997	0.000	0.069	0.074	k = 0.002, n = 2.264
	Blanching	0.994	0.008	0.268	-0.617	k = 0.005, n = 2.284
	Control	0.992	0.001	0.106	0.138	k = 0.017, n = 1.821
Henderson & Pabis	1% NaCl	0.907	0.014	0.417	0.287	a = 1.231, k = 0.095
	2% NaCl	0.940	0.008	0.317	0.225	a = 1.186, k = 0.092
	3% NaCl	0.889	0.019	0.456	0.319	a = 1.239, k = 0.109
	Blanching	0.906	0.026	0.494	-0.470	a = 1.203, k = 0.124
	Control	0.936	0.009	0.298	0.233	a = 1.147, k = 0.128
Midili & Kucuk	1% NaCl	0.958	0.052	0.535	-0.250	a = 1.070, b = -0.047, k = 0.008
	2% NaCl	0.996	0.001	0.061	0.000	a = 1.010, b = -0.001, k = 0.011, n = 1.734
	3% NaCl	0.942	0.061	0.551	-0.250	a = 1.067, b = -0.053, k = 0.010
	Blanching	0.953	0.012	0.224	-0.363	a = 1.017, b = -0.057, n = 1.06E-06
	Control	0.996	0.001	0.053	0.001	a = 0.957, b = -0.002, k = 0.013, n = 1.880
Wangh & Singh	1% NaCl	0.956	0.007	0.286	-0.240	a = -0.047, b = 0.000
	2% NaCl	0.976	0.003	0.200	-0.176	a = -0.051, b = 0.000
	3% NaCl	0.941	0.010	0.334	-0.253	a = -0.055, b = 0.000
	Blanching	0.959	0.014	0.371	-0.901	a = -0.066, b = 0.001
	Control	0.982	0.003	0.159	-0.109	a = -0.077, b = 0.001

Table 4: Statistical Parameters for Selected Thin Layer Model on the Drying of AA at 60 °C

Model	Pretreatment	R^2	x^2	RMSE	MBE	Constants
Newton	1% NaCl	0.851	0.028	0.557	0.037	k = 0.211
	2% NaCl	0.873	0.023	0.523	0.048	k = 0.212
	3% NaCl	0.883	0.019	0.540	0.095	k = 0.211
	Blanching	0.888	0.019	0.498	0.084	k = 0.220
	Control	0.923	0.011	0.403	0.151	k = 0.189
Page	1% NaCl	0.997	0.001	0.055	0.061	k = 0.010, n = 2.818
	2% NaCl	0.999	0.000	0.039	0.026	k = 0.016, n = 2.564
	3% NaCl	0.999	0.000	0.035	-0.021	k = 0.013, n = 0.698
	Blanching	0.999	0.000	0.027	0.006	k = 0.020, n = 2.480
	Control	0.988	0.002	0.113	0.087	k = 0.042, n = 1.822
Henderson & Pabis	1% NaCl	0.883	0.024	0.348	0.197	a = 1.192, k = 0.244
	2% NaCl	0.905	0.019	0.320	0.199	a = 1.195, k = 0.246
	3% NaCl	0.914	0.015	0.327	0.226	a = 1.206, k = 0.245
	Blanching	0.959	0.015	0.304	0.203	a = 1.188, k = 0.253
	Control	0.938	0.009	0.256	0.188	a = 1.127, k = 0.210
Midili & Kucuk	1% NaCl	0.998	0.000	0.031	0.000	a = 0.976, b = -0.001, k = 0.008, n = 2.943
	2% NaCl	0.999	0.000	0.026	0.001	a = 0.993, b = -0.001, k = 0.01, n = 2.584
	3% NaCl	0.999	0.000	0.024	-0.002	a = 1.001, b = 0.000, k = 0.013, n = 2.700
	Blanching	0.999	0.000	0.019	-0.001	a = 0.996, b = -7.51E-05, k = 0.019, n = 2.49
	Control	0.991	0.002	0.071	0.001	a = 0.949, b = -0.001, k = 0.028, n = 1.993
Wangh and Singh	1% NaCl	0.931	0.014	0.268	-0.145	a = -0.144, b = 0.004
	2% NaCl	0.941	0.012	0.253	-0.158	a = -0.152, b = 0.005
	3% NaCl	0.940	0.011	0.273	-0.178	a = -0.154, b = 0.006
	Blanching	0.948	0.010	0.240	-0.155	a = -0.160, b = 0.006
	Control	0.976	0.004	0.160	-0.084	a = -0.135, b = 0.004

Table 5: Statistical Parameters for Selected Thin Layer Model on the Drying of AA at 70 °C

Model	Pretreatment	R^2	x^2	RMSE	MBE	Constants
Newton	1% NaCl	0.938	0.010	0.309	0.112	k = 0.356
	2% NaCl	0.967	0.004	0.217	0.128	k = 0.387
	3% NaCl	0.931	0.011	0.332	0.105	k = 0.330
	Blanching	0.978	0.003	0.163	0.109	k = 0.466
	Control	0.965	0.005	0.227	0.131	k = 0.380
Page	1% NaCl	0.999	0.000	0.020	-0.005	k = 0.114, n =1.965
	2% NaCl	0.999	0.000	0.028	0.008	k = 0.195, n = 1.609
	3% NaCl	0.999	0.000	0.022	-0.003	k = 0.095, n = 1.998
	Blanching	0.999	0.000	0.021	0.012	k = 0.295, n = 1.471
	Control	0.999	0.000	0.024	0.009	k = 0.186, n = 1.622

Henderson & Pabis	1% NaCl	0.950	0.009	0.196	0.127	a = 1.115, k = 0.388
	2% NaCl	0.972	0.004	0.141	0.105	a = 1.075, k = 0.411
	3% NaCl	0.946	0.010	0.208	0.136	a = 1.128, k = 0.363
	Blanching	0.981	0.003	0.108	0.082	a = 1.053, k = 0.486
	Control	0.971	0.004	0.145	0.112	a = 1.083, k = 0.405
Midili and Kucuk	**1% NaCl**	**0.999**	**0.000**	**0.014**	**-0.001**	a = 1.001, k = 0.115, n = 1.964
	2% NaCl	0.999	0.000	0.019	-0.001	a = 0.993, b = 0.000, k = 0.190, n = 1.623
	3% NaCl	0.999	0.000	0.015	-0.001	a = 1.006, b = 0.000, k = 0.098, n = 1.975
	Blanching	0.999	0.000	0.014	0.000	a = 0.997, b = -1.00E-03, k = 0.294, n = 1.465
	Control	0.999	0.000	0.016	0.000	a = 1.001, b = 0.000, k = 0.187, n = 1.611
Wangh and Singh	1% NaCl	0.975	0.004	0.139	-0.047	a = -0.245, b = 0.014
	2% NaCl	0.972	0.004	0.140	0.025	a = -0.245, b = 0.014
	3% NaCl	0.974	0.005	0.143	-0.067	a = -0.233, b = 0.013
	Blanching	0.977	0.004	0.119	0.033	a = -0.291, b = 0.020
	Control	0.976	0.003	0.131	0.013	a = -0.243, b = 0.014

Table 6: Statistical Parameters for Selected Thin Layer Model on the Drying of AA using Solar Dryer

Model	Pretreatment	R^2	$\chi 2$	RMSE	MBE	Constants
Newton	1% NaCl	0.913	0.013	0.442	0.101	k = 0.181
	2% NaCl	0.929	0.010	0.410	0.134	k = 0.189
	3% NaCl	0.936	0.009	0.365	0.133	k = 0.202
	Blanching	0.951	0.007	0.292	0.145	k = 0.247
	Control	0.972	0.003	0.229	0.175	k = 0.216
Page	1% NaCl	0.996	0.001	0.070	0.038	k = 0.029, n = 1.987
	2% NaCl	0.996	0.001	0.068	0.007	k = 0.039, n = 1.876
	3% NaCl	0.995	0.001	0.073	0.029	k = 0.051, n = 1.786
	Blanching	0.991	0.001	0.088	0.037	k = 0.095, n = 1.604
	Control	0.991	0.001	0.090	0.049	k = 0.115, n = 1.360
Henderson & Pabis	1% NaCl	0.935	0.010	0.270	0.195	a = 1.156, k = 0.204
	2% NaCl	0.949	0.008	0.246	0.200	a = 1.156, k = 0.213
	3% NaCl	0.951	0.007	0.226	0.171	a = 1.128, k = 0.224
	Blanching	0.959	0.006	0.187	0.139	a = 1.096, k = 0.267
	Control	0.976	0.003	0.150	0.129	a = 1.063, k = 0.228
Midili and Kucuk	1% NaCl	0.996	0.001	0.047	0.000	a = 0.979, b = 0.000, k = 0.025, n = 2.048
	2% NaCl	0.996	0.001	0.048	-0.001	a = 0.995, k = 0.037, n = 1.891
	3% NaCl	0.995	0.001	0.049	-0.001	a = 0.974, k = 0.043, n = 1.872
	Blanching	0.992	0.001	0.060	-0.001	a = 0.975, b = -0.001, k = 0.084, n = 1.652
	Control	0.992	0.001	0.060	0.000	a = 0.967, b = 0.000, k = 0.099, n = 1.416
Wangh and Singh	1% NaCl	0.969	0.005	0.186	-0.120	a = -0.129, b = 0.004
	2% NaCl	0.975	0.004	0.171	-0.112	a = -0.135, b = 0.004

3% NaCl	0.980	0.003	0.144	-0.079	a = -0.145, b = 0.005
Blanching	0.984	0.002	0.117	-0.030	a = -0.173, b = 0.007
Control	0.986	0.002	0.115	0.033	a = -0.146, b = 0.005

Table 7: Statistical Parameters for Selected Thin Layer Model on the Drying of AA using Sun Dryer

Model	Pretreatment	R^2	$\chi2$	RMSE	MBE	Constants
Newton	1% NaCl	0.923	0.011	0.429	0.133	k = 0.184
	2% NaCl	0.953	0.005	0.306	0.052	k = 0.114
	3% NaCl	0.960	0.005	0.272	0.162	k = 0.206
	Blanching	0.974	0.003	0.215	0.153	k = 0.235
	Control	0.981	0.002	0.189	0.191	k = 0.217
Page	1% NaCl	0.996	0.001	0.073	0.070	k = 0.030, n = 1.862
	2% NaCl	0.976	0.003	0.156	0.077	k = 0.056, n = 1.312
	3% NaCl	0.993	0.001	0.083	0.063	k = 0.087, n = 1.482
	Blanching	0.993	0.001	0.080	0.031	k = 0.129, n = 1.361
	Control	0.993	0.001	0.079	0.061	k = 0.134, n = 1.273
Henderson & Pabis	1% NaCl	0.942	0.009	0.263	0.209	a = 1.145, k = 0.138
	2% NaCl	0.960	0.004	0.199	0.108	a = 1.074, k = 0.123
	3% NaCl	0.967	0.004	0.175	0.144	a = 1.083, k = 0.221
	Blanching	0.978	0.003	0.140	0.116	a = 1.063, k = 0.248
	Control	0.983	0.002	0.127	0.125	a = 1.047, k = 0.226
Midili and Kucuk	1% NaCl	0.997	0.001	0.043	0.001	a = 0.967, b = -0.001, k = 0.024, n = 1.949
	2% NaCl	0.988	0.002	0.078	0.000	a = 1.014, b = -0.014, k = 0.085, n = 0.936
	3% NaCl	0.994	0.001	0.052	0.000	a = 0.967, b = -0.001, k = 0.076, n = 1.518
	Blanching	0.993	0.001	0.054	0.000	a = 0.974, b = 0.000, k = 0.116, n = 1.406
	Control	0.995	0.001	0.050	0.001	a = 0.968, b = -0.001, k = 0.120, n = 1.303
Wangh and Singh	1% NaCl	0.978	0.003	0.163	-0.110	a = -0.116, b = 0.003
	2% NaCl	0.986	0.002	0.119	0.017	a = -0.080, b = 0.001
	3% NaCl	0.992	0.001	0.084	-0.018	a = -0.146, b = 0.005
	Blanching	0.983	0.002	0.123	0.036	a = -0.158, b = 0.006
	Control	0.983	0.002	0.125	0.0070	a = -0.143, b = 0.005

The results showed the relationship between moisture ratio and drying time. The model that best describes the thin-layer drying characteristics of ackee aril with different pretreatments was selected based on having the highest R^2 value above 0.9 and the lowest values of the x^2, RMSE and MBE. Midilli and Kucuk's model was observed to have the goodness of fit with the maximum R^2 value of 0.9999 and minimum x^2 value of 0.000. The values of R^2 for oven-dried samples ranged from 0.840 to 0.998, 0.851 to 0.999, and 0.931 to 0.999 for all pretreatments dried at 50, 60 and 70 ºC, respectively. The values of x^2 for oven-dried samples, the ranges were 0.000 to 0.061, 0.000 to

0.028, and 0.000 to 0.011 for all pretreatments dried at oven temperatures of 50, 60, and 70 °C, respectively. The values of RMSE for oven dried samples ranged from 0.053 to 0.800, 0.019 to 0.557, and 0.014 to 0.332 for all pretreatments dried at oven temperature of 50, 60, and 70 °C, respectively and the values of MBE for oven dried samples ranged from -0.109 to 0.319, -0.001 to 0.226, and -0.001 to 0.136 for all pretreatment dried at oven temperature of 50, 60 and 70 °C, respectively.

For solar-dried samples, values of R^2 ranged from 0.913 to 0.996; x^2 ranged from 0.001 to 0.013; RMSE ranged from 0.047 to 0.442 and MBE ranged from -0.001 to 0.195. while for sun-dried samples, the values of R^2 ranged from 0.923 to 0.997; x^2 ranged from 0.001 to 0.011; RMSE from 0.043 to 0.429; MBE from -0.110 to 0.209 for all pretreatments. The Midilli and Kucuk model described the drying behaviour of AA pretreated with SLT1 and oven-dried at 70 °C satisfactorily, having the R^2 values of 0.999.

Validation of the Established Model

The established model was used to predict the moisture ratio of AA and the validation was done by comparing the predicted moisture ratio with the experimental moisture ratio, as shown in Figure 4. There was good agreement between the experimental and predicted variables and this indicates that the Midilli and Kucuk model could be used to predict the thin layer drying of AA for samples pretreated with SLT1 and oven-dried at 70 °C.

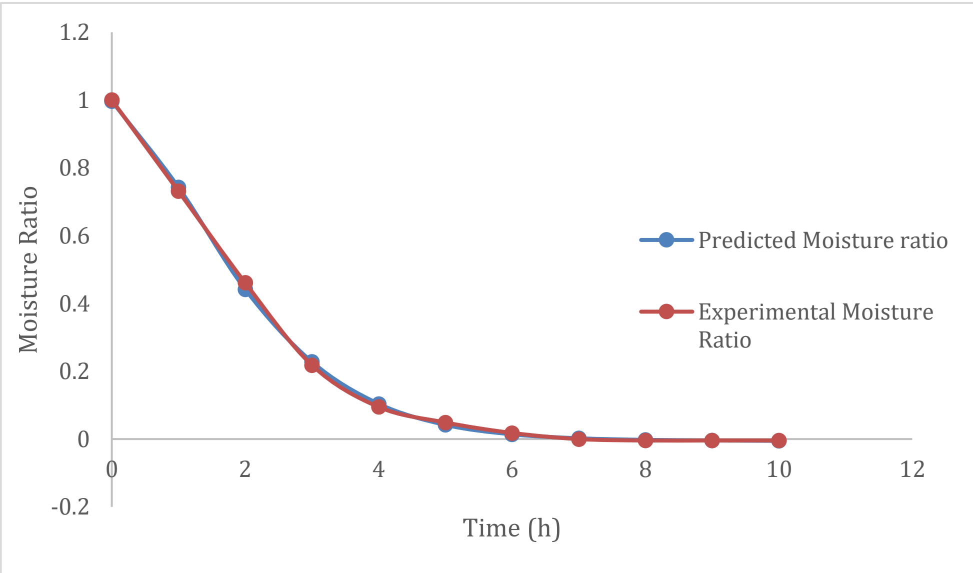

Figure 3: Comparison of experimental and predicted moisture ratio against drying time for AA oven-dried at 70 °C.

CONCLUSION

Based on the results, it can be concluded that the drying methods have a profound effect on the drying kinetics of the dried AA. Drying rate was greatly affected by the drying temperature, which decreased as drying progressed and increased with an increase in drying temperature and an increase in drying temperature led to a decrease in the drying time. The D_{eff} also increased with an increase in drying temperature, while the *Ea* was found to be higher than that of unpretreated AA. Based on the results obtained for the four statistical parameters (R^2, x^2, RMSE and MBE), the model that best described the thin-layer drying characteristic of AA was Midilli and Kucuk for samples pretreated with SLT1 and oven-dried at 70 °C.

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