Modeling of thin-layer solar drying kinetics of cassava noodles (tapioca)

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Abstract: This work aimed at modeling thin-layer solar drying of cassava noodles (tapioca). The selection of good drying models for dryers helps to improve their efficiency. Drying data of tapioca was obtained using a forced convection solar dryer. The treatment combinations of the experiment comprise of air flow velocities (V) of 1.5, 2.5, and 3.5 m s^{-1}; drying layer thicknesses (B) of 0.48 and 0.72 cm; and initial moisture contents (M_i) of 297%, 186%, and 122% (dry basis). Eleven thin-layer drying models from literature, in addition to a new model developed in this work were all fitted to the solar drying data of tapioca. Least square regression analysis was carried out and comparison between drying models was made using goodness of fit statistical parameters. Drying kinetics of the tapioca was determined. Effective moisture diffusivity and activation energy of the tapioca were also determined. The results obtained from the analysis show that the new model (Modified Aghbashlo model) was the best fitted to the drying data of tapioca. The determined effective moisture diffusivity of the tapioca samples varied from 4.93×10^{-11} to 8.82×10^{-11} m^2 s^{-1}. Also, the activation energy of the tapioca samples was determined as 28 kJ mol^{-1}.

Keywords: Cassava noodles, drying models, statistical parameters, effective moisture diffusivity, activation energy, Nigeria

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1 Introduction

The main purpose of drying agricultural materials is to provide longer periods of storage, minimize packaging requirements and reduce transportation weights and costs. Majority of crop drying processes are done using expensive and nonrenewable energy sources, such as fossil fuel, electricity, and biomass fuel. Therefore, cheaper and renewable energy sources for dryers such as solar energy are now being considered. Also, the selection of good drying models for dryers helps to improve their efficiency. Models are often used to study the variables involved in a process, predict drying kinetics of the product and optimize the operating parameters and circumstances (Karathanos and Belessiotis, 1999). Cassava (*Manihotesculentacrantz*) is the fourth most important staple food in the world after rice, wheat and maize (IFAD/FAO, 2000). Nigeria produces over 40 million metric tonnes of cassava annually, which should be processed quickly into storable forms so as to avoid deterioration (FAO, 2012). These storable forms are the by-products of cassava, one of which is cassava noodle (tapioca). Cassava noodle (tapioca) is a cassava-by product, that is popular and relished by the Eastern and Southern Nigerians. Dried tapioca is usually soaked in water and eaten with or without coconut or peanuts as snack (Ihekoronye and Ngoddy, 1985). The softened tapioca, also known locally as a bacha, when cooked with vegetable, palm oil, fish and other food seasoners is known as local (African) salad.

Adequate and efficient drying systems for timely drying of tapioca are not yet fully developed and

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operational. Undesirable biochemical changes and subsequent contamination and spoilage of the tapioca can only be prevented if the drying process is fast enough, and the final product dried to the required moisture content. Several researches on selection of drying models for thin-layer drying of some cassava by-products and other agricultural materials are reported in the literature. However, no research work on selection of thin-layer drying models for cassava noodles (tapioca) is contained in the literature.

Therefore, the objectives of this work are to: (i) study the thin-layer drying kinetics of tapioca using the solar dryer, (ii) fit the drying data of tapioca to twelve thin-layer models from literature, and (iii) determine the effective moisture diffusivity and activation energy of tapioca.

2 Materials and method

2.1 Description of the equipment used

The solar dryer that was used for the experiment is a forced convection integral type solar collector. The solar collector chamber consists of a wooden box of rectangular cross-section of length of 1.15 m and width of 0.75 m, giving a cross sectional area of 0.86 m^2. The face of the collector chamber was titled at an angle of 5°29′ which is the latitude of Owerri. The top of this section was covered with a plain glass. The base of the dryer was lined with layer of dark painted pebbles, which act as a thermal storage unit. A galvanized steel plate having the same dimensions as the collector area and painted dull black was used as an absorber plate. This absorber plate overlay the thermal storage unit. Also, a square hole of dimensions 8 cm × 8 cm, drilled at the exit point, serves as the exit for exhaust air. It also has two access doors used to control the operations. The drying chamber consists of two racks, each containing two trays of dimensions 0.44 m length × 0.44 m width and depth of 0.04 m. The interior sides of the dryer were lined with aluminum foil, so as to enhance reflectivity of heat inside the dryer chamber. Axial flow fan used in the solar dryer was equipped with a speed regulator. The fan was powered by a 20 watts capacity solar panel that was connected to 12 volts, 5 Amps, D.C battery for power storage.

2.2 Procedure for the experimental test

The experiment was designed to be a 3×2×3 factorial in completely randomized design in three replications with factors: initial moisture content of tapioca (297%, 186%, and 122%); layer thickness of tapioca (0.48 and 0.72 cm); and air flow velocity (1.5, 2.5, and 3.5 m s^{-1}). The layer thicknesses of 0.48 and 0.72 cm were achieved by using two layers (0.48 cm) and three layers (0.72 cm) of the tapioca samples respectively. According to ASAE, (1999), a thin-layer is a layer that is fully exposed to drying air and should not exceed three layers of particles (materials) for forced convection drying, at air velocity not less than 0.3 m s^{-1}.

Large quantities of freshly prepared tapioca were purchased from the Owerri main market, Imo state, Nigeria. These tapioca samples, which were processed from the same variety of cassava tubers (NR 8082) were conditioned to three initial moisture contents of 297%, 186%, and 122% (dry basis).At the beginning of the experiment, the solar dryer was positioned in an open place, away from tall trees and buildings, so as to minimize the effect of shading. The solar dryer was aligned in the North-South axis and positioned to face South as recommended in literature (Duffie and Beckman, 2006; Tiwari, 2012). The dryer was allowed to run for 30 minutes under no load, before the commencement of drying tests. This enabled the dryer to attain equilibrium conditions. A given mass of the tapioca samples was weighed using the digital weighing balance (OHAUS) of capacity 4.1 kg and sensitivity of 0.01g, and then placed inside the dryer cabinet. During the drying test, the mass of the tapioca samples was determined at hourly intervals. Also, the dry bulb temperature and relative humidity of the dryer; as well as the wet and dry bulb temperatures of the ambient air were determined at hourly intervals using a digital hygrometer and a wet and dry bulb thermometer respectively. A hand-held pyranometer (model: 4890.20; Frederiksen) was used to measure the insolation falling on the surface of the solar dryer at hourly intervals. The drying process continued until equilibrium moisture content of the tapioca at the given drying conditions was reached. This point was characterized by a constant mass recorded for two consecutive measurements of mass during the drying process. At the end of the drying experiment, the tapioca samples were oven dried at a temperature of 100°C for 8 hours to obtain the oven dried mass, as recommended in literature (Kajuna et al., 2001). The moisture ratio for each experiment was determined using Equation (1).

$$MR = \frac{M_t - M_e}{M_i - M_e} \tag{1}$$

where, M_t = moisture content of the material at a given time (g H_2O 100 g^{-1} dry matter); M_e = equilibrium moisture content (g H_2O 100 g^{-1} dry matter); M_i = initial moisture content (g H_2O 100 g^{-1} dry matter); k = drying constant.

Equation (1) applies to drying under uniform temperature and relative humidity. However, during solar drying of crops, the samples were not exposed to uniform relative humidity and temperature. Therefore, the moisture ratio was simplified as reported by Midilli et al. (2002), Kingsley and Singh (2007) and expressed as

$$MR = \frac{M_t}{M_i} \tag{2}$$

2.3 The new model

The new model is a modified form of Aghbashlo model. It was developed by adding a constant (c) to the Aghbashlo model. The added constant (c) is assumed to be a factor of incident solar radiation received on the surface of the solar dryer. The mathematical expression for the modified Aghbashlo model is given in Equation (3).

$$MR = \exp{-\left(\frac{k_1 t}{1 + k_0 t}\right)} \tag{3}$$

2.4 Fitting of thin-layer drying models to experimental data

A total of twelve thin-layer drying models as shown in Table 1 were fitted to the drying data of tapioca, using the nonlinear regression analysis programme, based on least squares Levenberg-Marquardt algorithm. The criteria for the selection of the best fitted model was based on goodness of fit statistical parameters, which include coefficient of determination (R^2), adjusted coefficient of determination (AR^2), root mean squared error (RMSE), and standard error of estimate (SEE). The statistical parameters are mathematically expressed in Table 2.

A model was selected based on the model with the highest values of R^2 and AR^2 and lowest values of RMSE and SEE.

Table 1 Thin-layer drying models used for the research

S/N	Model name	Equation
1	Newton (Lewis)	$MR = \exp(-kt)$
2	Page	$MR = \exp(-kt^n)$
3	Henderson and Pabis	$MR = a\exp(-kt)$
4	Logarithmic	$MR = a\exp(-kt) + c$
5	Two-term	$MR = a\exp(-k_0t) + b\exp(-k_1t)$
6	Two-term exponential	$MR = a\exp(-kt) + (1-a)\exp(-kat)$
7	Verma et al.	$MR = a\exp(-kt) + (1-a)\exp(-gt)$
8	Diffusion approach	$MR = a\exp(-kt) + (1-a)\exp(-kbt)$
9	Wang and Singh	$MR = 1 + at + bt^2$
10	Aghabashlo	$MR = \exp-\{(k_1t)/(1+k_0t)\}$
11	Weibull	$MR = \exp(-(t/a)^b)$
12	Modified Aghbashlo	$MR = \exp-\{(k_1t)/(1+k_0t)\} + ct$

Table 2 Mathematicalexpressions for the statistical parameters used in the research

Parameters	Formula
Coefficient of determination	$R^2 = \frac{SSR}{SST} = 1 - \frac{SSE}{SST}$
The adjusted R^2	$AR^2 = 1 - \frac{SSE / df_{error}}{SST / df_{total}}$
The standard error of estimate (SEE)	$SEE = \sqrt{\frac{\sum_{i=1}^{N}(MR_{exp,i} - MR_{cal,i})^2}{N - np}}$
Root mean square error	$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(MR_{exp,i} - MR_{cal,i})^2}{N}}$

Note: SSR is regression sum of squares; SST is total sum of squares; SSE is error sum of squares; df_{error} is error degrees of freedom; df_{total} is total degrees of freedom; MR_{exp} is experimental moisture ratio; MR_{cal} is calculated moisture ratio; N is number of data points; n is empirical constant and; p is parameter.

2.5 Determination of effective moisture diffusivity of tapioca

The tapioca slices were considered to be approximately of slab geometry, of average thickness of 0.24 cm. The effective moisture diffusivity was determined according to Maskan et al. (2002) as represented in Equation (4). Effective moisture diffusivity was calculated by plotting values of natural logarithm of moisture ratio (lnMR) versus drying time (seconds). The effective moisture diffusivity was calculated using method of slopes (Maskan et al., 2002; Doymaz, 2004) and expressed in Equation (5).

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

$$Slope(S) = \frac{D_{eff}\pi^2}{4L^2} \tag{5}$$

where, D_{eff} is effective moisture diffusivity, m^2 s^{-1}; t is drying time, s, and L is half of slab thickness, m.

2.6 Determination of the activation energy of tapioca

The activation energy was calculated using an Arrhenius type equation (Lopez et al., 2000; Akpinar et al., 2003) as given in Equation (6).

$$D_{eff} = D_o \exp\left(-\frac{E_a}{RT_a}\right) \tag{6}$$

where, E_a is the activation energy, kJ mol^{-1}; R is universal gas constant (8.3143 kJ mol^{-1} K^{-1}); T_a is absolute air temperature, K, and D_0 is the pre-exponential factor of the Arrhenius equation, m^2 s^{-1}. Finding the natural logarithm of each component in Equation (6) gives

$$\ln D_{eff} = \ln D_o - \frac{E_a}{RT_a} \tag{7}$$

A plot of $\ln D_{eff}$ versus $1/T_a$ in Equation (7) gives a straight line graph whose slope (S_A) is given as

$$S_A = \frac{E_a}{R} \tag{8}$$

3 Results and discussion

3.1 Fitting of drying data of tapioca to thin-layer drying models

The tapioca samples were dried from varying initial moisture contents of 297%, 186%, and 122% (average of 202%, expressed in dry basis) to final moisture content of 9.8% (dry basis). The values of moisture ratios obtained with drying time of tapioca are summarized in Appendix (1). The results of fitting the twelve thin-layer drying models to the experimental drying data for tapioca are summarized in Table 3. The values of the drying constants obtained from fitting the twelve thin-layer models to the drying data are given in Table 4.

From the results in Table 3, it was observed that all the models showed high values of R^2 (0.98284-0.9964) and AR^2 (0.97879-0.9953). Also all the models showed low values of RMSE and SEE. However, the new model (modified Aghbashlo model) with the highest R^2 and AR^2 values of 0.9964 and 0.9953 respectively; and lowest RMSE and SEE values of 0.00055 and 0.02259 respectively, best fitted the thin-layer solar drying data of tapioca. This implied that the new model could be used to predict to a high degree of accuracy, the drying kinetics of tapioca within the range of applied drying conditions. By substituting the values of the constants k_0, k_1, and c in Table 4 into Equation (3), gave the specific form of the new model for thin-layer solar drying of tapioca as

$$MR = \exp-\left(\frac{0.3241t}{1+0.0208t}\right) - 0.0035t \tag{9}$$

Table 3 Average values of statistical parameters obtained from fitting the models to drying data

S/N	Model name	R^2	AR^2	RMSE	SEE
1	Newton	0.98284	0.98284	0.02088	0.04232
2	Page	0.99238	0.99147	0.00101	0.03022
3	Henderson &Pabis	0.98528	0.98357	0.002002	0.0414
4	Logarithmic	0.99349	0.99157	0.001012	0.03067
5	Two term	0.98638	0.98004	0.00246	0.04498
6	Two term exponential	0.99106	0.99	0.001204	0.03255
7	Verma et al	0.99276	0.99084	0.001102	0.030697
8	Diffusion	0.98284	0.97879	0.00264	0.068022
9	Wang & Singh	0.98763	0.98619	0.00153	0.03475
10	Aghabashlo	0.99371	0.99293	0.00082	0.02754
11	Weibull	0.99238	0.99147	0.00102	0.03022
12	New model	0.9964	0.9953	0.00055	0.02259

Table 4 Average values of drying constants obtained from fitting drying data of tapioca to the different thin-layer models

Model name	a	b	c	g	k	k_o	k_1	n
Newton					0.3435			
Page					0.3058			1.13898
Henderson &Pabis	1.0129				0.347			
Logarithmic	1.2107		–0.21696		0.2873			
Two term	0.3165	0.7024				3.244	0.3397	
Two term exponential	1.3202				0.6617			
Verma et al	81.1845			3.3375	0.4015			
Diffusion	1	1			0.3435			
Wang and Singh	–0.2589	0.019						
Aghbashlo						–0.0317	0.3046	
Weibull	3.157	1.139						
New model			–0.0035			0.0208	0.3241	

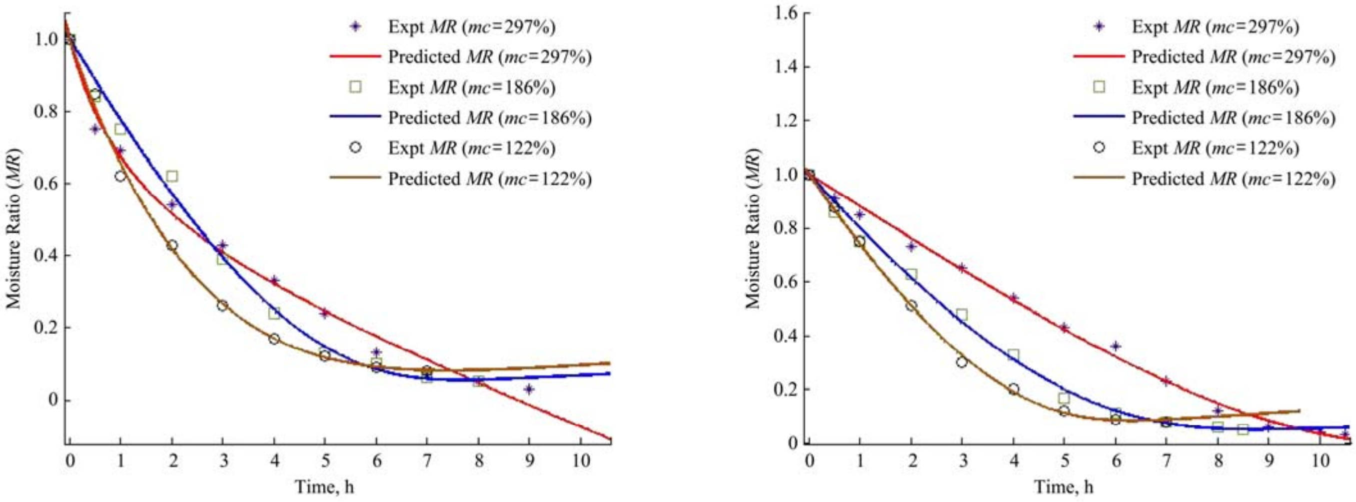
Table 5 gives the statistical parameters and drying constants obtained from fitting the drying data of tapioca to modified Aghbashlo model. It was evident from the table that the Aghbashlo model fitted best to the tapioca samples, dried at initial moisture content of 122% (dry basis), layer thickness of 0.48 cm, and air flow velocity of 2.5 m s^{-1}. This treatment gave the highest R^2 and AR^2 values of 0.9995 and 0.9992 respectively, and lowest RMSE and SEE values of 0.00011 and 0.01053 respectively.

Table 5 Statistical parameters and drying constants for Modified Aghbashlo model

M	*B*	*V*	R^2	AR^2	*RMSE*	*SEE*	k_0	k_1	*c*
297	0.48	1.5	0.9911	0.9889	0.0012	0.03422	0.54755	0.4961	–0.0539
		2.5	0.996	0.9948	5.59E–04	0.0236	0.41081	0.6933	–0.0361
		3.5	0.996	0.9952	0.00047	0.0216	0.36373	0.5266	–0.0298
	0.72	1.5	0.9958	0.9949	0.00062	0.0248	–0.0598	0.1179	–0.0018
		2.5	0.9968	0.996	0.00049	0.02208	–0.0651	0.1215	–0.0062
		3.5	0.9974	0.9969	0.00039	0.01965	–0.0644	0.1333	0.0028
186	0.48	1.5	0.9949	0.9935	0.00083	0.02878	–0.0901	0.2399	0.0067
		2.5	0.9968	0.9957	0.00051	0.02261	0.04904	0.40419	–0.0132
		3.5	0.9965	0.9956	0.00049	0.02231	0.01396	0.23489	–0.0138
	0.72	1.5	0.9947	0.9934	0.00081	0.0285	–0.0789	0.21303	0.0055
		2.5	0.9954	0.9938	0.00082	0.02865	–0.1119	0.21187	0.0062
		3.5	0.9988	0.9985	0.00019	0.01361	–0.0515	0.2799	0.0046
122	0.48	1.5	0.9971	0.9961	0.00047	0.0217	–0.0428	0.41936	0.00943
		2.5	0.9995	0.9992	0.00011	0.01053	–0.1512	0.36097	0.0172
		3.5	0.9965	0.9955	0.00053	0.02302	–0.0673	0.28722	0.0092
	0.72	1.5	0.9989	0.9985	0.00019	0.01373	–0.1041	0.2865	0.0124
		2.5	0.9943	0.9915	0.00113	0.03355	–0.1134	0.40303	0.0128
		3.5	0.9987	0.9983	0.00018	0.01357	–0.0103	0.40459	0.0055
	Average		0.9964	0.9953	0.00055	0.02259	0.0208	0.32412	–0.0035

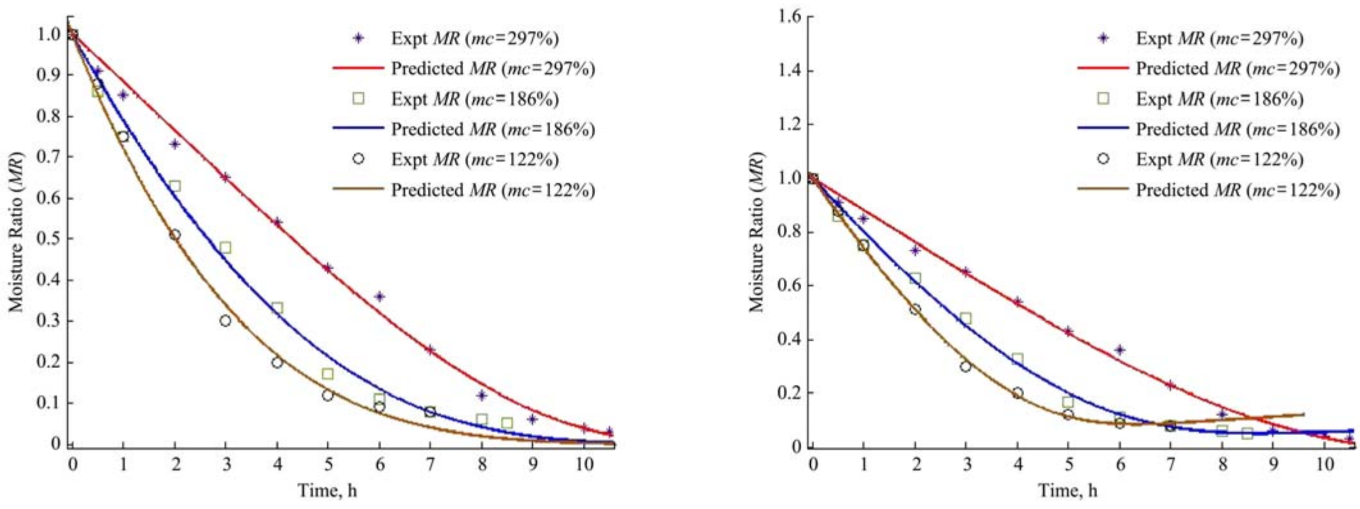
Note: *M* = initial moisture content (% dry basis), *B* = Layer thickness of tapioca (cm), *V*= air flow velocity (m s^{-1}).

The comparison between the predicted and experimental values of moisture ratio for the new model is shown in Figures 1 and 2. The curves show very close correlation between the predicted and the experimental moisture ratios of the tapioca.



a. For layer thickness of 0.48 cm b. For layer thickness of 0.72 cm

Figure 1 Experimental and predicted values of moisture ratio at varying times for the new model at velocity of 1.5 m s^{-1}



a. Aghbashlo Model

b. Modified Aghbashlo Model

Figure 2 Experimental and predicted values of moisture ratio at varying times for velocity of 1.5 m s^{-1} and layer thickness of 0.72 cm

3.2 Results obtained for drying kinetics of tapioca

From the drying curves (Figures 1 and 2), it was observed that the drying of the tapioca samples exhibited the characteristic moisture desorption behavior. An initial high rate of moisture removal was followed by slower rate of moisture removal at the later stages. This characteristic behavior is due to the variations in the tenacity with which water is held in agricultural products. As the drying progressed, the moisture ratio and moisture content values were observed to decrease non- linearly with increase in drying time for all the samples. This characteristic behavior is also reported for other agricultural materials like carrot, cassava chips, pre-treated cassava chips, and mulberry. (Aghbashlo et al., 2009; Ajara et al., 2012; Tunde-Akintunde and Afon, 2010; Doymaz, 2004). Also from Appendix1 and Figures 1 and 2, it was evident that the drying rates of tapioca varied with different values of initial moisture content, air flow velocity, and layer thickness of tapioca.

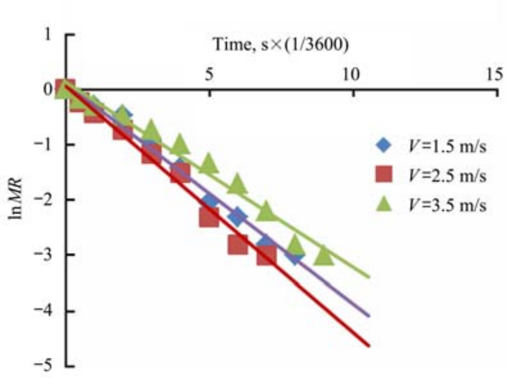
3.3 Results obtained for effective moisture diffusivity and activation energy

The values of the slope (*S*) for each treatment, and the value of *L*, which was determined as half of 0.24 cm = 0.12 cm (0.0012 m) were substituted into Equation (4) to determine the values of effective moisture diffusivity as summarized in Table 6. The graphical plots of ln*MR* versus drying time are summarized in Figure 3.

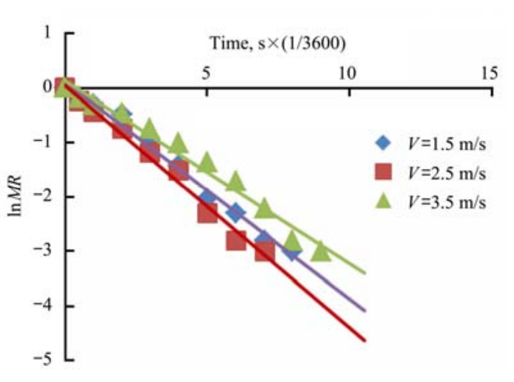
Table 6 Effective moisture diffusivities (D_{eff}) obtained for the drying of tapioca

B	0.48 (cm)			0.72 (cm)		
M/V	1.5	2.5	3.5	1.5	2.5	3.5
	Values of $D_{eff}\times10^{-11}$					
297	6.11	7.37	5.22	5.27	5.72	4.93
186	6.48	7.24	5.45	5.98	7.49	5.72
122	6.21	8.77	5.71	6.41	8.82	5.61
Mean	6.27	7.79	5.46	5.89	7.34	5.42

Note: B = drying layer thickness (cm), V = air flow velocity (m s^{-1}), M = initial moisture content (%).



a. Initial moisture content of 297% (db)



b. Initial moisture content of 186% (db)

Figure 3 Plots of ln MR versus time for layer thickness of 0.48 cm

Graphical plots of natural logarithm of effective moisture diffusivity (lnD_{eff}) versus the reciprocal of the absolute dryer temperature (1/T) were plotted for selected treatments (Figure 4). The slope (S_A) of the straight-line curve gave a value of –3437 K^{-1}, while the intercept of the curve (lnD_0) is –12.99. Thus, by substituting for S_A = –3437 K^{-1} and $R = 8.3143\times10^{-3}$ kJ mol^{-1} into Equation (7) gave the value of the Activation energy (E_a) for the drying of tapioca as 28.576 kJ mol^{-1}.

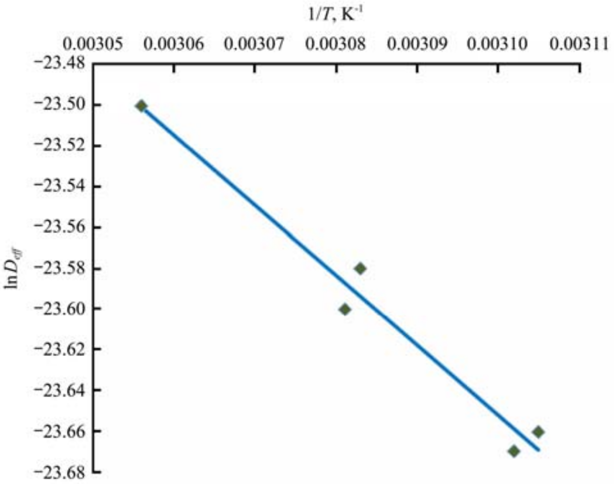


Figure 4 Graphical plots of lnD_{eff} versus 1/T

The range of effective moisture diffusivities obtained for tapioca (4.93×10^{-11} m^2 s^{-1} to 8.82×10^{-11} m^2 s^{-1}) are within the range of values, and slightly higher than the values of 2.43×10^{-11} to 4.52×10^{-11} m^2 s^{-1} reported for cassava chips (Ajala et al., 2012). However, the range of values of effective moisture diffusivities determined for tapioca are lower than the values of 7.31 to 8.06×10^{-7} reported for pre-treated cassava chips (Tunde-Akintunde and Afon, 2010). The difference in values may be attributed to: the different methods of processing the cassava tubers into chips and tapioca, the pretreatment given to the cassava chips, and the type of drying system used. Also, the effective moisture diffusivities of tapioca varied with the different treatments in the experiment. The Activation energy of 28.576 kJ mol^{-1} that was obtained for tapioca, is within the range of values of 16.1 to 44.49 kJ mol^{-1}, reported for stone apple, cassava chips, finger millet, and bell pepper (Rayaguru and Routray, 2012; Ajala et al., 2012; Rhadika et al., 2011; Taheri-Garavand et al., 2011).

4 Conclusion

This research showed that a modified form of Aghbashlo model was best fitted to the thin-layer, solar drying kinetics of tapioca. This study also revealed that the values of effective moisture diffusivities, and the value of activation energy obtained for thin-layer, solar drying of tapioca are within the range of values recorded in literature for related agricultural products. However, it is recommended that the new model (modified Aghbashlo model) should be used to further fit drying data of other agricultural materials.

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Appendix 1 Values of moisture contents for different drying times of the experiment

B	V	M	Time, h																
			0	0.5	1	2	3	4	5	6	7	7.5	8	8.5	9	10	10.5	11	11.5
0.48	1.5	297	1	0.75	0.69	0.54	0.43	0.33	0.24	0.13	0.07		0.05		0.03				
	1.5	186	1	0.84	0.75	0.62	0.39	0.24	0.13	0.1	0.06		0.05						
	1.5	122	1	0.85	0.62	0.43	0.26	0.17	0.12	0.09	0.08								
	Mean	202	1	0.81	0.69	0.53	0.36	0.25	0.16	0.11	0.07		0.05		0.03				
0.48	2.5	297	1	0.7	0.6	0.4	0.3	0.21	0.11	0.06	0.04	0.03							
	2.5	186	1	0.8	0.65	0.48	0.31	0.22	0.1	0.06	0.05								
	2.5	122	1	0.84	0.67	0.39	0.18	0.11	0.08										
	Mean	202	1	0.78	0.64	0.42	0.26	0.18	0.1	0.06	0.05	0.03							
0.48	3.5	297	1	0.76	0.65	0.49	0.41	0.32	0.24	0.18	0.12		0.07		0.05	0.04	0.03		
	3.5	186	1	0.85	0.75	0.63	0.48	0.37	0.26	0.18	0.11		0.06		0.05				
	3.5	122	1	0.86	0.73	0.54	0.4	0.2	0.18	0.11	0.09	0.08							
	Mean	202	1	0.82	0.71	0.55	0.43	0.3	0.23	0.16	0.11	0.08	0.07		0.05	0.04	0.03		
0.72	1.5	297	1	0.91	0.85	0.73	0.65	0.54	0.43	0.36	0.23		0.12		0.06	0.04	0.03		
	1.5	186	1	0.86	0.75	0.63	0.48	0.33	0.17	0.11	0.08		0.06	0.05					
	1.5	122	1	0.88	0.75	0.51	0.3	0.2	0.12	0.09	0.08								
	Mean	202	1	0.88	0.78	0.62	0.48	0.36	0.24	0.19	0.13		0.09	0.05	0.06	0.04	0.03		
0.72	2.5	297	1	0.91	0.87	0.72	0.64	0.5	0.37	0.26	0.2	0.11	0.05		0.03				
	2.5	186	1	0.85	0.76	0.61	0.43	0.24	0.1	0.06	0.05								
	2.5	122	1	0.8	0.62	0.43	0.17	0.1	0.08										
	Mean	202	1	0.85	0.79	0.59	0.41	0.28	0.18	0.16	0.13	0.11	0.05		0.03				
0.72	3.5	297	1	0.92	0.83	0.72	0.64	0.53	0.39	0.27	0.2		0.13		0.08	0.06		0.04	0.03
	3.5	186	1	0.9	0.73	0.54	0.39	0.26	0.18	0.11	0.08		0.06		0.05				
	3.5	122	1	0.8	0.66	0.47	0.31	0.2	0.13	0.11	0.09	0.08							
	Mean	202	1	0.87	0.74	0.58	0.45	0.33	0.23	0.16	0.12	0.08	0.1		0.07	0.06		0.04	0.03

Note: B = drying layer thickness (cm), V = air flow velocity (ms^{-1}), M = initial moisture content (%).