ISBN : 978-93-87793-43-9

DRYING KINETICS OF FERMENTED CASSAVA PEELS FOR CITRIC ACID PRODUCTION

[1]*Ajala, A.S., [1]*Adeoye, A.O., [1]*Olaniyan, S.A.,

[1]*Department of Food Science and Engineering, LadokeAkintola University of Technology, Ogbomoso, Oyo State.*

ABSTRACT

In this study, cassava peels cassava peels were fermented for three days under environmental conditions of 27 ^{o}C and 70 % relative humidity. The peels were cut into slabs with dimensions 0.03, 0.01 and 0.004 m for length, breadth and thickness, respectively. The samples were dried in a tunnel dryer built in the Department of Food Science and Engineering, LadokeAkintola University of technology. The temperatures of drying were 50, 55, 60, 65 and 70 ^{o}C. Moisture loss was determined by manual removal of the sample from the dryer and weighing at every 1 hr interval. Drying was stopped when three consecutive weight of the samples remained constant. The data were subjected into 6 models namely Henderson and Pabis, Logarithms, Newton, Page, Two-Terms and Midilli. The moisture diffusivity ranged from 4.54E-10 – 1.30E-9 m^2/s and the activation energy was 41.616 kJ/mol. Page model gave the best fit with the values of R^2 of 0.998.

Keywords:*cassava-peels, drying, modeling, diffusivity, activation-energy*

1. INTRODUCTION

Nigeria is the highest producer of cassava peels in the world with an estimate of 45 million ton [1]. The ratio of cassava peel from a root of cassava range from 20 to 25%; therefore, approximately more than 9 million tons of peels are generated as waste. It is better to find alternative use for these peels as they contribute to environmental pollution of the country. One of the ways to reduce the quantities of the generated peel wastes is through proper dryingof the product as semi-raw material for industrial use especially in the production of citric acid. Therefore, considering the enormity of the waste, there is need to develop effective drying equipment through models for the product. These various models should be good enough to predict adequately an effective drying pattern of the product in the dryer. Such drying data would be useful in subsequent dryer development. However, as far as literature is concerned, modelling of this product is scarce or not available. This could have been reasons the equipment for the product has not been modelled hitherto. Therefore, this paper focuses on the mathematical modelling and drying kinetics of fermented cassava peels for citric acid production.

2. MATERIAL AND METHODS

2.1 Drying of fermented cassava peels

Cassava peels were fermented for three days under atmospheric conditions. The peels were cut into slab with dimensions 0.03, 0.01 and 0.0025 m for length, breadth and thickness respectively. The samples were dried in a tunnel dryer built in the Department of Food Science and Engineering, LadokeAkintola University of technology. The temperatures of drying were 50, 55, 60, 65 and 70 ^{o}C. Moisture loss was determined by manual removal of the sample from the dryer and weighing at every 1 hr interval. Drying was stopped when three consecutive weight of the samples remained constant[2].

2.2 Mathematical models

To understand the suitable model for the drying characteristics of the samples, the experimental data were fitted in six models described in Table 1

Table 1: Mathematical drying models

Models	Equation	References
Henderson and Pabis	MR=aexp(-kt)	[3]
Logarithms	MR=aexp(-kt) +c	[4
Newton	MR=exp(-kt)	[5]
Page	MR=exp(-kt^n)	[6]
Two term	MR=a exp(kt) + b exp(jt)	[7]
Midilli et al.,	MR=aexp(-kt^n) +bt	[8]

These models show relationship between moisture ratio and drying time. Moisture ratio (MR) during the thin layer drying was obtained using equation 1

$$\text{MR}=\frac{M_i - M_e}{M_O - M_e} \quad (1)$$

Where MR= dimensionless moisture ratio, M_i = instantaneous moisture content (g water/g solid), M_e =equilibrium moisture content (g water/ g solid), M_o = initial moisture content (g water/ g solid). However, due to continuous fluctuation of relative humidity of the drying air in the dryer, Equation 1 is simplified in equation 2 according to [9]

$$\text{MR}=\frac{M_i}{M_O} \quad (2)$$

2.3 Statistical Analysis

The drying model constants were estimated using a non-linear regression analysis. The analysis was performed using Statistical Package for Social Scientist (SPSS 16.0 versions) software. The reliability of the models was verified using statistical criteria such as coefficient of determination (R^2), reduced chi-square (χ^2), root mean square error (RMSE) and mean bias error (MBE). A good fit is said to occur between experimental and predicted values of a model when R^2 is high and χ^2,RMSE and MBE are lower [10]. The comparison criteria method can be determined as follows:

$$\chi^2= \frac{\sum_{i-1}^{n}(MR_{(\exp,i)} - MR_{(pred,i)})^2}{N - z} \quad (3)$$

ISBN : 978-93-87793-43-9

MBE= $\frac{1}{N}\sum_{i=1}^{n}(MR_{(pred,i)} - MR_{(\exp,i)})$ (4)

RMSE = $\left[\frac{1}{N}\sum_{i=1}^{n}(MR_{(pred,i)} - MR_{(\exp,i)})^2\right]^{1/2}$ (5)

2.4 Determination of Moisture Diffusivity

Fick's equation was simplified to describe the drying characteristics of cassava peels samples. The simplified equation was used to determine the effective moisture diffusivity from the samples during drying. The equation according to [11] is represented thus:

$$MR= \frac{M - M_0}{M_0 - M_e} = \frac{8}{\pi^2}\sum_{n=0}^{n=1} \frac{1}{(2n-1)^2} \exp \frac{-(2n-1)^2 \pi^2 D_{eff} t}{4l^2} \quad (6)$$

Where D_{eff} is the moisture diffusivity (m^2/s), t is the drying time (s), *l* is the half of the slab thickness (m)

The effective moisture diffusivity (D_{eff}) was calculated from the slope of plot of ln MR against drying time (t) according to [12] and is represented in equation 7

$$\boldsymbol{k}= \frac{D_{eff} t}{4l^2} \quad (7)$$

Where *k* is the slope.

3. RESULTS AND DISCUSSION

3.1 Drying pattern of moisture content

The pattern of moisture content against time is as shown in Fig. 1. The figure shows that higher the temperature of drying, the shorter the drying time. The drying curve exhibited falling rate pattern common to all agricultural products [10]. The same trend was found in Fig. 2 where moisture ratio against time declined over time.[11] reported reason for higher moisture removal in the early stage of falling rate as to be higher moisture percentage in the sample available for drying at the initial stage.

ISBN : 978-93-87793-43-9

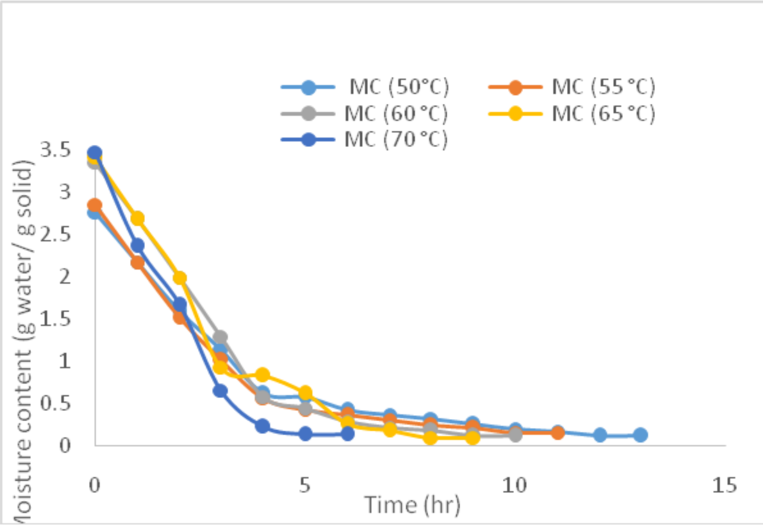

Figure1: Moisture content against time

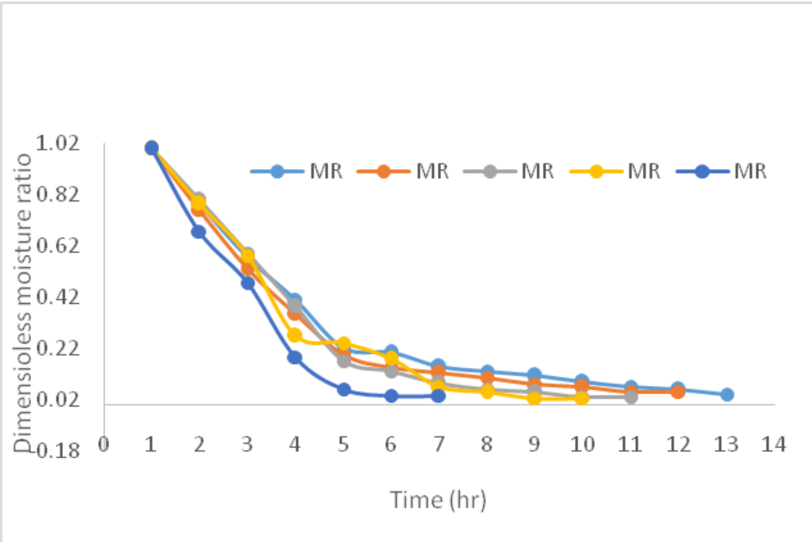

Figure2: Moisture ratio against time

3.2 Results of statistical criteria and constants of the models

The statistical criteria to test the reliability of the models are as shown in Table 2. A good fit occur in a model when the values of coefficient of determination (R^2) is high and values of reduced chi square and others are low. By this, page model had the highest R^2 value of 0.998. The values of constants in the models are as shown in Table 3. These constants sustained the models and were derived from regression analysis of various variables in the models.

ISBN : 978-93-87793-43-9

Table 2: Values of statistical parameters

Model	Temp	R^2	χ^2	MBE	RMSE
Henderson	50	0.990	0.0005	0.0055	0.0208
and Pabis	55	0.991	0.0001	0.0031	0.0118
	60	0.980	0.0009	-0.0073	0.0275
	65	0.980	0.0002	-0.0116	0.0436
	70	0.973	0.0001	-0.0104	0.0390
Logarithms	50	0.990	0.0005	0.0055	0.0208
	55	0.991	0.0001	0.0031	0.0118
	60	0.980	0.0009	-0.0073	0.0275
	65	0.980	0.0024	-0.0116	0.0436
	70	0.973	0.0019	-0.0104	0.0390
Newton	50	0.990	0.0007	0.0070	0.0262
	55	0.990	0.0002	0.0038	0.0145
	60	0.976	0.0002	-0.0038	0.0142
	65	0.977	0.0004	-0.0052	0.0196
	70	0.971	0.0014	-0.0097	0.0363
Page	50	0.990	0.0008	0.0070	0.0262
	55	0.991	0.0006	0.0060	0.0225
	60	0.998	0.0006	0.0061	0.0231
	65	0.989	3.6E-6	0.0004	0.0017
	70	0.991	0.0001	-0.0025	0.0096
Two terms	50	0.992	3.3E-7	-0.0001	0.0004
	55	0.993	0.0027	-0.0118	0.0442
	60	0.980	0.0011	-0.0073	0.0275
	65	0.980	0.0027	-0.0116	0.0436
	70	0.985	0.0188	0.0310	0.1160
Midilli	50	0.990	0.1037	0.0727	0.2721
	55	0.738	0.1753	0.0945	0.3539
	60	0.769	0.3300	0.1297	0.4855
	65	0.819	0.5320	0.1647	0.6164
	70	0.847	2.8559	0.3817	1.4282

3.3 Effective moisture diffusivity of fermented cassava peels

The values of moisture diffusivity of fermented cassava peels are as shown in Table 4. The values ranged from 4.54E-10 - 1.30E-09 m^2/s. It is observed from the table that temperature affects moisture diffusivity because at lower temperature, the value of diffusivity was low while at higher temperature, the value of diffusivity was higher. This shows that moisture diffusivity is temperature dependent as earlier asserted by other researchers

ISBN : 978-93-87793-43-9

such as [13], [14] and[11]. Values of moisture diffusivities of various products are as follows: cassava chips (2.43-4.52 x10^{-11} m^2/s) by [11]; fermented corn grains, (2.78-3.06 x10^{-11} m^2/s) by [15], carrot slices (2.3-4.26x10^{-11} m^2/s) by [13], shrimp (1.27- 2.53 x10^{-11} m^2/s) by [12].

Table 3: Values for model constants

Model	Temp	a	b	c	k	j	n
Henderson	50	1.020			0.304		
and Pabis	55	1.024			0.347		
	60	1.061			0.361		
	65	1.050			0.369		
	70	1.38			0.497		
Logarithms	50	0.546		0.624	0.304		
	55	0.505		0.708	0.347		
	60	0.469		0.816	0.361		
	65	0.483		0.778	0.369		
	70	0.772		0.296	0.497		
Newton	50				2.98		
	55				0.339		
	60				0.343		
	65				0.353		
	70				0.482		
Page	50				0.29		1.02
	55				0.314		1.06
	60				0.217		1.378
	65				0.253		1.277
	70				0.329		1.416
Two terms	50	1.023	0.007		0.322	0.116	
	55	1.030	0.001		0.359	0.347	
	60	0.816	0.245		0.361	-0.361	
	65	0.83	0.220		0.369	-0.369	
	70	29.59	-28.57		0.234	-0.237	
Midilli	50	6.0E-7	0.011		14.13		0.049
	55	0.616	-0.64		-0.043		0.674
	60	0.678	0.027		-0.017		-1.4E-7
	65	0.719	-0.089		-0.036		-1.1E-7
	70	0.784	-0.134		-0.093		-1.0E-7

ISBN : 978-93-87793-43-9

Table 4: Values of effective moisture diffusivities at different temperatures

Drying air temperature (^{0}C)	Effective moisture diffusivity (m^2/s)
50	4.54E-10
55	5.19E-10
60	6.48E-10
65	6.48E-10
70	1.30E-09

3.4 Activation energy of the drying process

Determination of the activation energy of the drying process was obtained by plotting

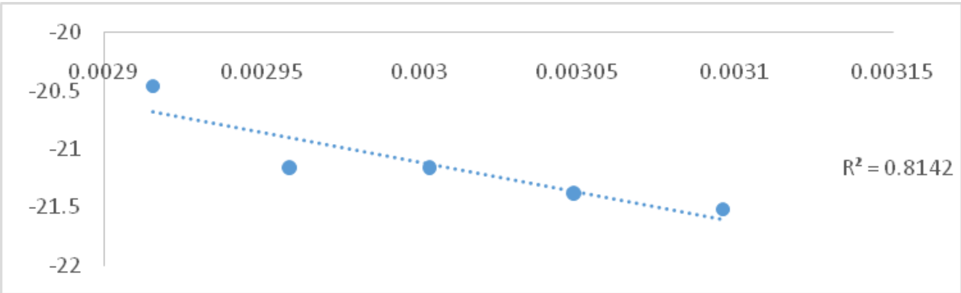

Figure 3: Plot of ln D versus Temperature Inverse

lnD against temperature inverse. The slope of the curve was used to determine the value of activation energy used. The activation energy calculated was 41.616 kJ/moland diffusivity coefficient (D_0) to be 0.0031m^2/s. The value of activation energy in this study compared to other food products are: cassava chips (30.30kJ/mol) by [11];potato (20kJ/mol) by [16]; shrimps (33.851kJ/mol) by [12].

4. CONCLUSION

The study shows that drying rate of the samples took a falling rate pattern in which drying at higher temperatures resulted in shorter drying time. Effective moisture diffusivity (D_{eff}) was affected by temperatures directly because the higher the temperature, the higher the D_{eff}. Activation energy of the samples was comparable with other agricultural products.

REFERENCES

[1] FAO, 2008. Corporate Document Repository. [Online]. The impact of HIV/AIDS on the agricultural sector.:://www.fao.org/DOCREP/005/Y4636E/y4636e05.htm

[2] Ajala, A.S, Falade, K.O. and Tunde- Akintunde T.Y. 2011. Effect of osmotic pretreatment on the drying kinetics of okra (*Hibiscus ecsulentus*). Journal of Engineering and Technology, 6 (2): 41- 44

[3] Chinnman 1984. Evaluation of selected mathematical models for describing thin layer drying of in-shell pecans. Transaction of the ASAE, 27: 610-615

[4] Togrul, I.T., Pehlivan, D., 2004. Modeling of thin layer drying of some fruits under open-air sun drying process. Journal of Food Engineering 65, 413–425.

[5]Kingly, R.P., Goyal, R.K., Manikantan, M.R. and Ilyas, S.M. 2007. Effect of pre-treatment and drying air temperature on drying behaviour of peach slice. International Journal of Food Science and Technology, 4:65-69

[6] Karathanos, V.T. and Belessiotis, V. G. 1999. Application of a thin layer equation to drying data of fresh and semidried fruits. Journal of Agricultural Engineering Research, 74, 335-361,

[7] Hodge, B. K. and Taylor, R. P. 1999 Analysis and design of energy systems, 3rd Ed., Prentice Hall Inc., New Jersey,

[8] Midilli, A., Kucuk, H., Yapar, Z., 2002. A new model for single layer drying. Drying Technology 20 (7), 1503–1513.

[9] Goyal, R.K., Kingsley, A.R.P., Manikantan, M.R., and Ilyas, S.M. 2007. Mathematical modeling of thin layer drying kinetics of plum in a tunnel dryer. Journal of Food Engineering 79(1): 176-180

[10] Ajala, A.S. Ajala, F.A. and Tunde-Akintunde, T.Y. 2012a. Study on drying kinetics of fermented corn grains. Food Science and Quality Management Journal, 5: 10-17

[11] Ajala, A.S., Aboiye, A.O, Popoola, J.O., Adeyanju, J.A. (2012). Drying characteristics and mathematical modelling of cassava chips. Chemical and Process Engineering Research, 4: 1-9. New York, USA. ISSN: 2225-0913

[12] Ajala, A.S. and Ajala, F.A. 2014. A study on drying kinetics of shrimps. International Journal of Innovation and Applied Studies 9(4): 1778-1785

[13] Doymaz, I. 2004. Convective air drying characteristics of thin layer carrots. Journal of Food Engineering, 61(3): 359-364.

[14] Guine, R., Lopes, P., Joao, B.M. and Ferreira, D.M.S 2009. Effect of ripening stage on drying kinetics and properties of S. Bartolomeo pears. International Journal of Academic Research, 1(1):3

[15] Ajala, A.S. and Abubakar, M.A. 2018. Study of drying kinetics and quality attributes of fermented corn grains as affected by drying temperatures and velocities. Journal of Nutritional Health & Food Engineering, 8(2):205-212

[16] Bon, J., S. Simal, C. Rossello and A. Mulet, 1997. Drying characteristics of hemispherical solids. Journal of Food Engineering, 34: 109-122