EFFECTS OF PROCESSING CONDITION ON THE DRYING AND QUALITY CHARACTERISTICS OF OKRA

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ABSTRACT
The study investigated okra drying and quality characteristics at different drying temperatures (50ºC, 60ºC, 70ºC, and 80ºC) and thicknesses (5 mm and 10 mm). The drying was done in a hot air oven. The data obtained were fitted into four existing mathematical drying models to predict drying patterns in okra. The logarithmic model was the best mathematical model that described the drying characteristics of okra slices within the temperature range studied. The moisture content obtained ranged from 8 to 13% wet basis. The effective moisture diffusivity increased as temperature increased while the activation energy for 5 and 10 mm thicknesses was 45.7 kJ/mol and 34.2 kJ/mol, respectively. The ANOVA showed that the different temperatures and thicknesses significantly affected the quality and nutritional content of the dried okra slices at a 5% significance level. The shortest drying time was achieved at 80ºC and 5 mm thickness. However, drying at a temperature of 50ºC and 5 mm thickness yielded the best okra quality.

Keywords: Okra preservation, drying time, temperature, nutritional quality, rehydration

1. INTRODUCTION
Okra is a warm-seasonal vegetable used as food worldwide. There are five species of okra in Africa; three indigenous and two introduced from Asia in the distant past. These species include; *Abelmoschus caillei, Abelmoschus esculentus, Abelmoschus ficulneus, Abelmoschus moschatus,* and *Abelmoschus manihot* (Yuan *et al*., 2018; Awolola and Olorunfemi, 2008). Okra plant is a vegetable fruit that could grow to about 1.83 m (Owolarafe and Shotonde, 2004). It has heart-shaped leaves with edible fruits. It is a tropical plant, which grows best in warm climates. It is an annual crop with peak season only during the rainy season. The fruits are about 10.2 cm long and are ready for harvest in 4 to 5 days after flowering.

Okra has a wide range of applications as it can be steamed for consumption or serve as additive ingredients to prepare stews, salads, and soups. Okra is a food supplement consumed because it behaves like elastic when cooked into soup or stew. It also provides some vitamins, energy, and minerals (Yuan *et al.,* 2018). Its leaf buds and flowers are edible and contain large quantities of carbohydrates, proteins, and vitamin C (Li *et al*., 2019: Liu *et al*., 2018). The nutritional compositions of okra are comparable to soya beans. Therefore, it is essential in the human diet. However, a challenge with the conservation of okra is that it is sensitive to the storage environment, but it could be preserved by drying into a more stable product.

Okra is produced chiefly during the abundance of rain and in some minor areas where the irrigation system is practiced, accounting for its availability in the peak season. The reverse occurs during the lean season as it is produced in low quantity. Consequentially, it is expensive to purchase in the lean season (Bamire and Oke, 2003). Conversely, to create a balance in okra production annually, proper preservation is necessary to retard the deterioration of the product at the peak season. It involves selecting appropriate procedures and technology such as adequate drying procedures to curb wastage and produce products of high market value. The safe moisture content of okra for storage is 10% wet basis (Shivhare *et al.* (2000); Germain *et al.* (2017)).

In other research conducted on the drying kinetics of okra (Olajire *et al.*, 2018; Doymaz, 2005), the findings were limited to the effect of the processing condition on the effective moisture diffusivity and activation energy. Germain *et al.* (2017) studied the physical and chemical properties of okra using a solar dryer. They discovered that the diffusion coefficient of okra varies from 6.16 x 10^{-10} to 47.8 x 10^{-10} m^2s^{-1} depending on the size of the okra slice. Pendre et al. (2012) studied the effect of drying temperature on okra slice sizes 1, 2, 3, 4 cm and discovered that the sizes have significant effects on the drying characteristics of okra. Similarly, Famurewa and Olumofin (2015) investigated the drying kinetics and effect of drying a 2 mm diced okra on the chemical characteristics of dehydrated okra and found that okra retained its nutritional value at 40ºC. For a thin slice of okra (2 mm), Famurewa and Olumofin (2015) found the Modified page model suitable for describing its drying pattern. Doymaz (2005) found the Page model suitable for describing single layer okra drying. This study investigated the effects of the processing condition on the physicochemical properties, rehydration, and nutritional composition of okra. The parameters such as the drying temperature and size of okra, which must preserve okra under storage for long periods, are established in this research.

2. MATERIALS AND METHOD

2.1 Sample Preparation

Freshly harvested okra fruits were obtained from the Teaching and Research Farm, Obafemi Awolowo University (OAU), Ile-Ife, Nigeria. The samples were cut into cylindrical shapes of thickness 5 mm and 10 mm, and the study was carried out in the Department of Agricultural and Environmental Engineering crop processing laboratory, OAU. Ile-Ife, Nigeria.

2.2 Drying Test of Okra Slices

The initial moisture content was determined following the ASABE standard using an oven drying method (ASABE, 2014). About 10 g of sliced okra was measured in a cylindrical container with known weight and placed in the oven (SM 9023 Surgifriend Uniscope, England) at a temperature of 70℃ for 24 h. The weight loss on drying to a constant weight was recorded. The initial weight (W_i) and final weight (W_f) were taken using an electronic weighing balance. The procedure was replicated three times. The moisture content was calculated following Equation (1)

$$\text{MC } (\%)_{wb} = \frac{W_i - W_f}{W_i} \times 100 \qquad (1)$$

About 300 g of okra slices of 5 and 10 mm thickness were dried following a thin layer drying method. The samples were placed in the oven (SM 9023 Surgifriend Uniscope, England) at four different temperatures (50, 60, 70, and 80℃). Moisture loss at every hour was taken using the electronic weighing balance, and the weight reduction was monitored until a constant weight was attained. The procedure was replicated thrice for each temperature. The drying curves were fitted with four moisture ratio models: Logarithmic models, Henderson and Pabis model, Two-term model, and the Lewis model. These models have rarely been found in the literature to describe the drying characteristics of okra. The statistical and graphical analysis was performed using the Python and MATLAB computer program. After fitting the models into experimental data, the goodness of fit of the tested mathematical models to the experimental data was evaluated from the coefficient of determination (R^2) and the standard error of estimate (SEE) between the predicted and experimental values of the moisture ratio.

2.3 Effective Moisture Diffusivity and Activation Energy

The effective moisture diffusivity defines the rate of moisture movement. It was determined using Fick's second equation of diffusion as described by Olajire *et al.* (2018); Touil *et al.* (2014); Aremu *et al.* (2013). The moisture ratio was computed using Equations (2) and (3)

$$MR = \frac{M - M_e}{M_i - M_e} \quad (2)$$

$$MR = \frac{4}{\varepsilon^2} exp\left[-\frac{\varepsilon^2 D_{eff}}{r^2} t\right] \quad (3)$$

Where; M is the moisture content at any time t, M_e is the equilibrium moisture content, M_i is the initial moisture content, ε is the root of Bessel function, D_{eff} is the effective moisture diffusivity ($m^2 s^{-1}$), r is the sample thickness (m), and t is the drying time (s). The effective moisture diffusivity was obtained using Arrhenius expression as in Equation (4)

$$D_{eff} = D_o exp\left[-\frac{E_a}{RT}\right] \quad (4)$$

The activation energy E_a (kJ/mol) was determined from the plot of ln (D_{eff}) versus 1/(K^{-1}). The slope of the line is (E_a/R), and the intercept equals ln (D_o). T is the temperature of air (K), and R is the gas constant (kJ/mol K).

2.4 Properties of Dried Okra

The qualities determined include true density, bulk density, elasticity, viscosity, colour, and rehydration properties of the okra. The true density was determined by the water displacement method. Slices of okra with known weight were wrapped in polythene to prevent them from absorbing water. The sample was immersed in a measuring cylinder containing 10 cm^3 of water such that it did not float. The volume of water displaced was recorded. The procedure was replicated four times. The true density was calculated using Equation (5).

$$\sigma_t = {}^{m}/_{v} \quad (5)$$

Where; σ_t is true density (g/cm^3), m is the mass of fruits in (g), v is the volume of water displaced (cm^3).

To determine the bulk density of the dried okra slices, samples were packed in a can of known volume. It was densely packed by tapping the can softly and several times to allow the okra to occupy voids Audu et al. (2015). Then the weight of the sample was determined with a digital weighing balance (JADEVER NWTH, 6 kg, Made in China). This experiment was replicated four times, and the bulk density was estimated following Equation (6)

$$\sigma_b = {}^{w_m}/_{v_m} \quad (6)$$

Where; σ_b is bulk density (g/cm^3), w_m is the weight of the material (g), v_m is the volume of the container (cm^3)

The elasticity was determined by suspending 5g of ground sample in 10 ml of distilled water. The mixture was homogenized by manual agitation and left for 5 min. The elasticity was evaluated by measuring the height of cuts of the mixture when scooped by a spoon. Similarly, the viscosity of the okra was determined by suspending 5g of ground okra in 10 ml of distilled water, mixed, and left for 5 min. The mixture was placed on a digital viscometer with a spindle speed rate of 30 rpm, and the readings were taken. The colour of the okra samples was determined using the Munsell system. It consists of sets of a disk with different colours and a scale. The disks are arranged so that each colour occupies a specific proportion and then placed on the colourimeter, which now spines the disks producing one particular colour read off on the scale. The values usually obtained in percentage were relevant for the determination of the colour notations. The colour notations were expressed as Munsell hue (H), Munsell chroma (C), and Munsell value (V). The samples were subjected to daylight reflectance (Y) and chromaticity coordinates (x,y) regarding the Munsell colour system scales. The value of V, equivalent to Y, was obtained from a standard table while the figures were used to obtain the hue H and chroma C (Munsell, 1905).

2.5 Rehydration Experiment

Exactly 10 g of the dried okra slices soaked in 100 ml of distilled water for 2 hours were used to determine the dehydration capacity. The rate of water absorption was recorded at 15 min intervals. At the end of the stated period, the okra was cleaned to remove the excess surface moisture and then placed in the oven at 70 ℃ for 24 h, and the moisture content was determined.

2.6 Nutritional Content of Dried Okra

The mineral content (calcium, magnesium, and iron) was determined by first digesting the okra. It was achieved by weighing 0.5 g of the sample into a platinum crucible. A mixture of HCL and HNO_3 was added and left in the muffle furnace for 10 min. It was removed and allowed to cool, then a little quantity of distilled water was added to the mixture and filtered into a 50 ml distilled water in a volumetric flask, vigorously shaken to enhance homogenization. Each mineral (Ca, Mg, and Fe) was read with the Atomic absorption spectrophotometer (AAS). Also, the vitamin C content of the okra samples was determined as described by Elgailani *et al*. (2017).

3. RESULTS AND DISCUSSION

3.1 Effects of Drying Conditions on the Drying Rate of Okra

The initial moisture content of the okra sample was 87.9% (wb), while the final moisture content of the dried okra sample at the various temperatures (50, 60, 70, and 80 ℃) and thicknesses (5 and 10 mm) ranged from 8 to 13%. The drying rate of okra slices was studied at different temperatures (50, 60, 70, and 80℃) and thicknesses (5 and 10 mm). The drying rate decreased continuously throughout the drying time. There was no constant rate period such that all the drying processes of the samples took place in the falling rate period like some similar vegetables reported by Doymaz and Pala (2002a); Akpinar *et al.* (2003); Senadeera *et al.* (2003). The moisture content of 10% wet basis was achieved at drying times of 1200 min at 50℃, 780 min at 60℃, 600 min at 70℃, and 360 min at 80℃ for 5 mm thick okra slice. The corresponding values for 10 mm thick okra slice was 1860 min at 50℃, 1140 min at 60℃, 780 min at 70℃, and 480 min at 80℃. The results further showed that okra slices of 5 mm thickness dried faster than okra slices of 10 mm at the same drying conditions.

Figures 1 and 2 represent the variations of moisture ratio. The experimental results showed that drying air temperature is paramount to drying okra slices. As the air temperature increased, moisture removal increased, thus resulting in a substantial decrease in drying time. The moisture ratio as a dependent variable emanated as a function of drying time and drying temperature. The values indicated by the exponential curves were higher at 50°C and dropped at 80°C. The increase in the drying temperature subjected the samples to a drastic decrease in the moisture ratio. However, the findings are similar to the report of Ertekin and Yaldiz (2004); Kashaninejad and Tabil (2004); Doymaz and Pala (2002a) on various vegetables. An increase in the thickness of the okra slices led to a decrease in the drying rate, which invariably led to increased drying time due to an increase in the moisture travel distance.

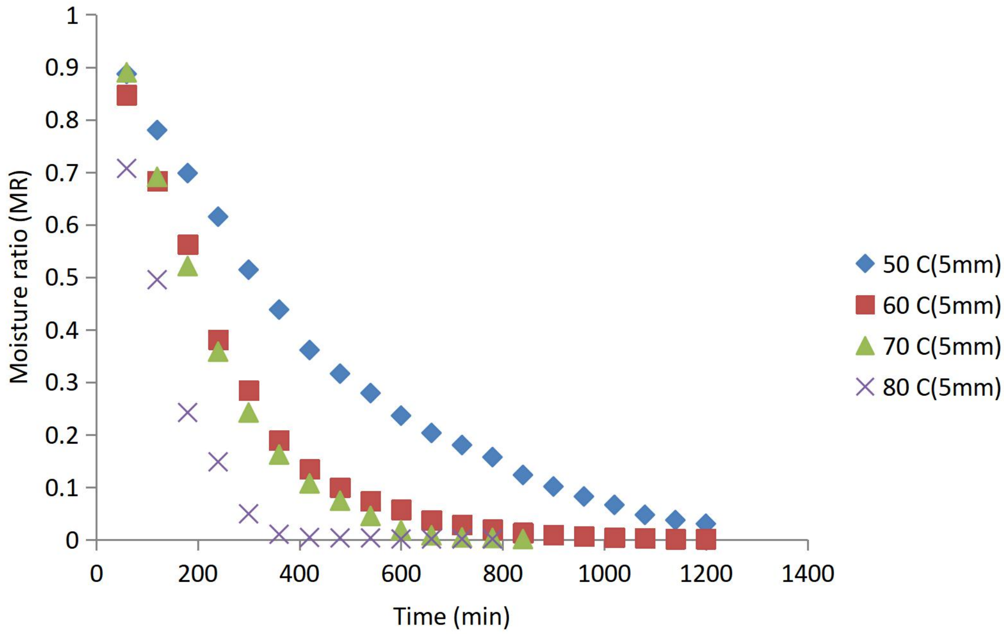

Figure 1: The responses of moisture ratio to drying time at 5 mm slice thickness

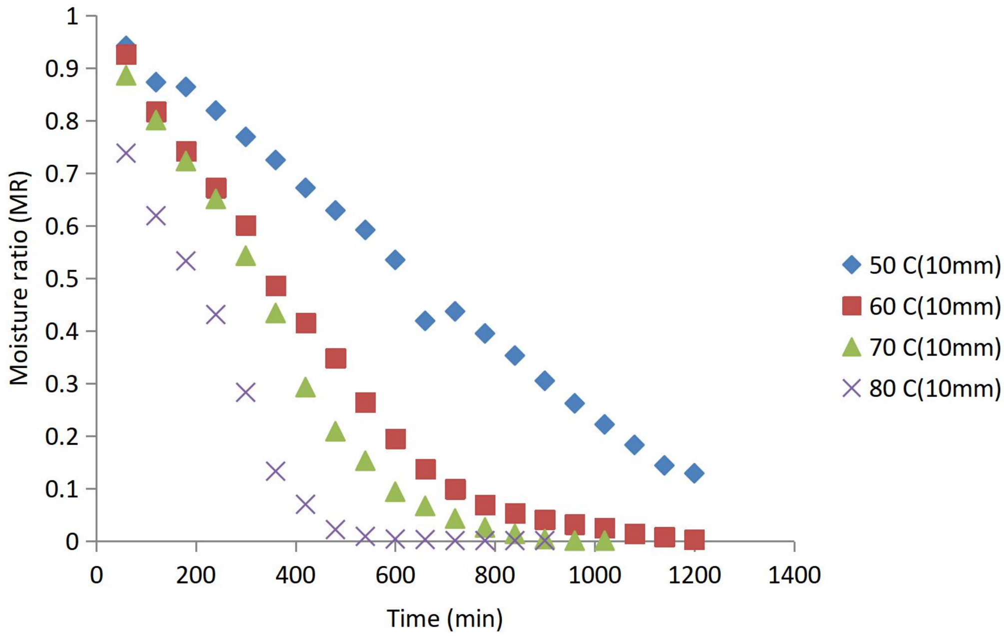

Figure 2: The responses of moisture ratio to drying time at 10 mm slice thickness

3.2 Drying Models for Okra

The values of coefficient of determination and standard error of estimate with estimated parameters for the four models are presented in Tables 1 and 2. Moisture ratio models were compared according to their coefficient of determination (R^2) and standard error of estimate (SEE), which varied between 0.9986 and 0.9245, 0.0865, and 0.0106, respectively.

Table 1: Statistical result of the drying models for 5mm thickness

Model	Temperature ℃	Coefficient				R^2	SEE
Lewis	50	k=0.0024				0.9921	0.0235
	60	k=0.0041				0.9778	0.0376
	70	k=0.0044				0.9569	0.0596
	80	k=0.0074				0.9641	0.0429
Henderson and Pabis	50	a=1.067	k=0.0025			0.9963	0.0162
	60	a=1.1844	k=0.0048			0.9932	0.0208
	70	a=1.2926	k=0.0056			0.9935	0.0231
	80	a=1.2695	k=0.0091			0.9854	0.0274
Logarithmic	50	a=1.0848	k=0.0022	c= -0.0509		0.9986	0.0106
	60	a=1.1785	k=0.0046	c=-0.0136		0.9942	0.0203
	70	a=1.2790	k=0.0049	c=-0.0369		0.9972	0.0165
	80	a=1.2499	k=0.0085	c=-0.0154		0.9876	0.0276
Two-term	50	a=1.5087	ko=0.0029	b=-0.5239	k1=0.0056	0.9986	0.0107
	60	a=3.8518	ko=0.0035	b=-2.7078	k1=0.0032	0.9953	0.0189
	70	a=1.6837	ko=0.0042	b=-0.4601	k1=0.0024	0.9980	0.0145
	80	a=3.4758	ko=0.0062	b=-2.2865	k1=0.0053	0.9907	0.0253

Table 2: Statistical result for the drying models for 10mm thickness

Model	Temperature (℃)	Coefficient				R^2	SEE
Lewis	50	k=0.0012				0.9401	0.0235
	60	k=0.0024				0.9446	0.0724
	70	k=0.0029				0.9245	0.0865
	80	k=0.0046				0.9451	0.0613
Henderson and pabis	50	a=1.1059	k=0.0014			0.9597	0.0162
	60	a=1.1962	k=0.0028			0.9706	0.0527
	70	a=1.2205	k=0.0034			0.9546	0.0671
	80	a=1.1017	k=0.0051			0.9508	0.0581
Logarithmic	50	a=6.7195	k=0.00012	c=-5.7235		0.9981	0.0122
	60	a=1.2624	k=0.0020	c=-0.1512		0.9881	0.0355
	70	a=1.3002	k=0.0023	c=-0.1798		0.9785	0.0494
	80	a=1.1039	k=0.0041	c=-0.0698		0.9654	0.0526
Two- term	50	a=7.1939	ko=0.0026	b=-6.3052	k1=0.0030	0.9931	0.0239
	60	a=8.2458	ko=0.0049	b=-7.4039	k1=0.0057	0.9943	0.0253
	70	a=11.1799	ko=0.0063	b=-10.5082	k1=0.0072	0.9924	0.0305
	80	a=5.0749	ko=0.0027	b=-4.0547	k1=0.0024	0.9697	0.0514

R – Correlation Coefficient, SEE – Standard Error of the Estimate
The Logarithmic model gave the best fit for drying okra slices as the experimental and predicted moisture ratios almost banded at a 45° straight line. Therefore, it represents the drying behaviour of okra with an R^2 of 0.9986 and SEE of 0.0106. Similar findings were reported by Madamba *et al.* (1996) for garlic slices and by Doymaz and Pala (2002b) for the red pepper.

3.3 Moisture Diffusivity and Activation Energy

The values of D_{eff} for different temperatures are given in Table 3. The values obtained were within the range of 10^{-11} m²/s to 10^{-8} m²/s required for food products (Li *et al.,* 2019; Xie *et al.,* 2017). The cell wall of the okra was disrupted as the moisture diffused from the inside to the outside. The moisture gradient inside the material resulted in the development of stress, which caused a structural change in the okra. Consequentially, it could be observed that the values of D_{eff} increased with an increase in temperature. Similar results were obtained by Li et al. (2019). The activation energies estimated for the okra thickness of 5 and 10 mm are 34.2 and 45.7 kJ/mol, respectively, obtained from the slopes of the linear plot in Fig. 3. An increase in the slice thickness increased the activation energy required to migrate moisture from the internal structure of the okra. According to Touil *et al.* (2014), the diffusion coefficient is infrequently constant and varied with the temperature, moisture content, and spatial coordinates.

Table 3: Effective moisture diffusivity at different temperatures

Temperature (°C)	D_{eff} (m²/s) (5 mm)	D_{eff} (m²/s) (10 mm)
50	7.36×10^{-9}	1.73×10^{-8}
60	1.51×10^{-8}	4.70×10^{-8}
70	2.19×10^{-8}	7.22×10^{-8}
80	2.65×10^{-8}	9.84×10^{-8}

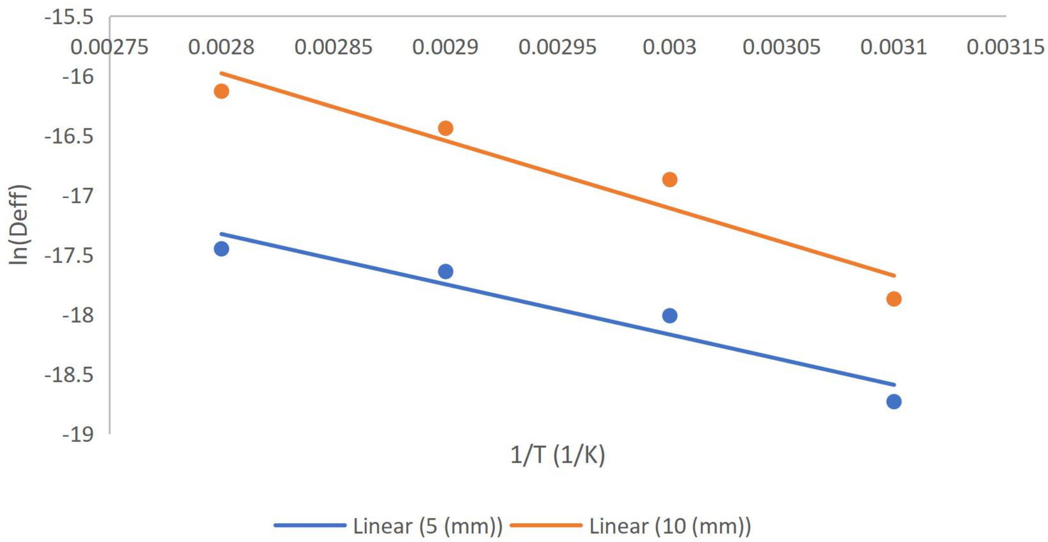

Figure 3: Influence of temperature on effective moisture diffusivity at varying thicknesses.

3.4 Quality Characteristics of Dried Okra Slices

The physical characteristics of dried okra slices at different temperatures are presented in Table 4. The true and bulk density decreased slightly with an increase in temperature and thickness of the okra slices. However, the elasticity and viscosity of the okra slices decreased with an increase in temperature and thickness. As the temperature of okra slices increased, the elasticity and viscosity decreased, which indicates that higher temperature tends to have a destructive effect on the quality of the okra. For a better result, okra slices should preferably be dried at 50°C and 5 mm thickness.

Table 4: Quality characteristics of dried okra

Thickness (mm)	Temperature (°C)	True Density (g/cm³)	Bulk Density (g/cm³)	Elasticity (mm)	Viscosity (mPa/s)
5	50	0.37	0.345	14	190.7
	60	0.36	0.33	12	148.4
	70	0.35	0.313	12	48.5
	80	0.31	0.282	10	38.3
10	50	0.44	0.35	13	181.7
	60	0.39	0.336	11	147.2
	70	0.37	0.326	10	39.8
	80	0.34	0.288	9	36.2

Furthermore, the statistical analysis shown in Table 5 indicated that the two factors interaction model was significant ($p<0.05$). The change in temperature and thickness significantly affected the dried okra's elasticity, true, and bulk density. It implied a variation in the physical properties of the food material when it was subjected to different drying temperatures and sizes. The observation was in agreement with the study on okra seed (Sahoo and Srivastava, 2002), a component of the okra fruit. Therefore, it is evident that higher temperatures during the drying process resulted in swift shrinkage of the food material.

The colour notations obtained for the dried okra slices at different temperatures (50, 60, 70, and 80 ℃) and thicknesses (5 and 10 mm) are presented in Table 6. An increase in temperature tends to increase the colour of the samples slightly, except for those dried at 80°C. A higher value (V) gives a brighter colouration, while a lower value gives a dark colour. The okra slices dried at 80 ℃ had a lower value indicating the darkness of the sample because higher temperature drying usually causes deterioration of the colour (An *et al*., 2016).

3.5 Effects of Varying Drying Condition on the Rehydration Properties of Okra

Table 7 shows the variation of the moisture contents of okra slices at different temperatures (50, 60, 70, and 80 ℃) and thicknesses. Both sample thicknesses followed a similar trend in moisture sorption. Moisture sorption was high at the initial stage, followed by a drastic decrease at the latter stage. The behaviour could be attributed to the fact that the samples were prepared from the same food material and the mass of the samples was not significant. A similar characteristic of moisture sorption behaviour was observed in kiwifruits (Maskan, 2001). The okra slices exhibited typical moisture sorption behaviour as the amount of water absorbed increased to a maximum and progressively decreased with increased temperature. The scenario was evident at the drying temperatures of 70 ℃ (5 mm) and 60 ℃ (10 mm), where a marked decline in the okra moisture content was observed.

Table 5: ANOVA of the physical characteristics of dried okra slices

Source of variation	df	Sum of Squares	Mean Square	F-value	p-value	Description
True Density						
Model	3	0.0218	0.0073	123.66	< 0.0001	significant
A-Temperature	1	0.0146	0.0146	248.32	< 0.0001	
B-Thickness	1	0.0062	0.0062	104.7	< 0.0001	
AB	1	0.0008	0.0008	13.98	0.0039	
Residual	10	0.0006	0.0001			
Bulk Density						
Model	3	0.0093	0.0031	63.68	< 0.0001	significant
A-Temperature	1	0.0087	0.0087	177.86	< 0.0001	
B-Thickness	1	0.0003	0.0003	5.73	0.0377	
AB	1	0.0000	0.0000	0.274	0.6121	
Residual	10	0.0005	0.0000			
Elasticity						
Model	3	39.1	13.03	103.28	< 0.0001	significant
A-Temperature	1	35.46	35.46	281.01	< 0.0001	
B-Thickness	1	4.79	4.79	37.93	0.0001	
AB	1	0.0124	0.0124	0.098	0.7607	
Residual	10	1.26	0.1262			
Viscosity						
Model	3	58964.64	19654.88	41.55	< 0.0001	significant
A-Temperature	1	58590.39	58590.39	123.85	< 0.0001	
B-Thickness	1	478.28	478.28	1.01	0.3384	
AB	1	4.63	4.63	0.0098	0.9231	
Residual	10	4730.85	473.09			

Table 6: Colour notation for different temperature and thickness

Temperature (°C)	**5mm**		**10mm**	
	H	V/C	H	V/C
50	7.5Y	4.80/2.6	1.4GY	4.75/3.3
60	8.2Y	5.16/3.5	1.8GY	4.31/3.4
70	10Y	5.27/3.9	10Y	5.08/3.8
80	8.1Y	4.40/5.3	4.5Y	4.64/3.3

Table 7: Rehydration characteristics of okra slices dried at different temperatures

Time (min)	**Drying Temperature** (℃)							
	50	**60**	**70**	**80**	**50**	**60**	**70**	**80**
	5 mm				**10 mm**			
30	182.99	204.00	192.08	196.79	149.00	127.51	129.37	131.77
60	256.84	342.18	275.32	296.43	224.00	214.75	177.19	184.31
90	314.79	453.84	333.00	352.48	274.59	275.85	215.05	220.77
120	366.50	500.62	369.52	414.32	315.89	316.48	248.08	25245
150	402.94	552.33	401.05	442.62	354.26	346.41	281.16	287.98
180	439.27	577.46	410.36	476.75	376.53	369.29	295.82	321.46
210	451.90	603.53	432.22	499.73	397.95	402.19	315.22	341.46
240	499.10	615.14	461.38	520.36	426.34	418.20	333.33	368.92

3.6 Nutritional Content of Dried Okra

Table 8 shows the nutritional content of okra at different thicknesses (5 and 10 mm) and temperatures (50, 60, 70, and 80℃). The result indicated that the nutritional quality of okra decreased with an increase in temperature. Similarly, the statistical analysis of the nutritional content affected by the two factors (temperature and thickness) investigated are presented in Table 9. The analysis of the mean values showed that the change in the temperature and thicknesses of the okra slices had a significant effect on the amount of vitamin C and Iron retained in the food material. Conversely, the change in the value of the parameters studied does not significantly affect the Calcium present in the material after drying. However, on the other hand, the change in thickness of the okra slices significantly affected the magnesium content retained in the product. The mineral contents of the fruits were retained more in the 5 mm thick okra slice, whereas the mean value for 50℃ was found to be higher than other temperatures.

Table 8: The nutritional content of okra

Nutrients (mg)	**Temperature (ºC)**							
	50	**60**	**70**	**80**	**50**	**60**	**70**	**80**
	5 mm				**10 mm**			
Vitamin C	20.9	19.0	18.2	18.2	17.3	16.4	14.5	15.5
Calcium	0.93	3.34	0.98	0.76	2.19	1.19	0.98	1.03
Magnesium	0.18	0.18	0.17	0.17	0.15	0.17	0.17	0.17
Iron	3.73	1.96	1.26	0.23	0.43	1.04	0.64	0.94

Table 9: ANOVA of vitamin C, calcium, magnesium, and iron contents of dried okra slices

Source of variation	df	Sum of Squares	Mean Square	F-value	p-value	Description
Vitamin C						
Model	3	41.72	13.91	39.37	< 0.0001	significant
A-Temperature	1	13.66	13.66	38.68	< 0.0001	
B-Thickness	1	31.9	31.9	90.3	< 0.0001	
AB	1	0.2732	0.2732	0.7734	0.3998	
Residual	10	3.53	0.3532			
Calcium						
Model	3	2.48	0.826	1.57	0.2576	not significant
A-Temperature	1	1.8	1.8	3.42	0.094	
B-Thickness	1	0.1435	0.1435	0.2725	0.613	
AB	1	0.2344	0.2344	0.4452	0.5197	
Residual	10	5.26	0.5265			
Magnesium						
Model	3	0.0012	0.0004	21.28	0.0001	significant
A-Temperature	1	0.0000	0.0000	2.31	0.1593	
B-Thickness	1	0.0005	0.0005	24.19	0.0006	
AB	1	0.0006	0.0006	30.2	0.0003	
Residual	10	0.0002	0.0000			
Iron						
Model	3	17.03	5.68	118.54	< 0.0001	significant
A-Temperature	1	5.17	5.17	107.99	< 0.0001	
B-Thickness	1	4.38	4.38	91.53	< 0.0001	
AB	1	8.79	8.79	183.65	< 0.0001	
Residual	10	0.4788	0.0479			

4. CONCLUSION

The effects of some drying conditions on the drying rate, effective moisture diffusivity, activation energy, quality characteristics, rehydration, and nutritional composition of okra slices were established. The shortest drying time was 360 mins observed at 80℃ and 5 mm thickness. The logarithmic model gave the best fit with an R^2 of 0.9986 and SEE of 0.0106. Also, the effective moisture diffusivity fruit increased with an increase in temperature and thickness. At the same time, the activation energy of the okra slices was observed to be 34.2 and 45.7 kJ/mol at 5 and 10 mm thickness, respectively.

Similarly, an increase in the drying temperature decreased the elasticity and viscosity of the okra slices. Drying Okra slices at an elevated temperature significantly ($p<0.05$) affected the nutritional quality except for the calcium content. However, okra dried at 50℃, and 5 mm thickness was found to retain the optimal nutritional composition of the food material. The comprehensive analysis established in this study would enhance the quality of okra processing and preservation both locally and industrially.

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