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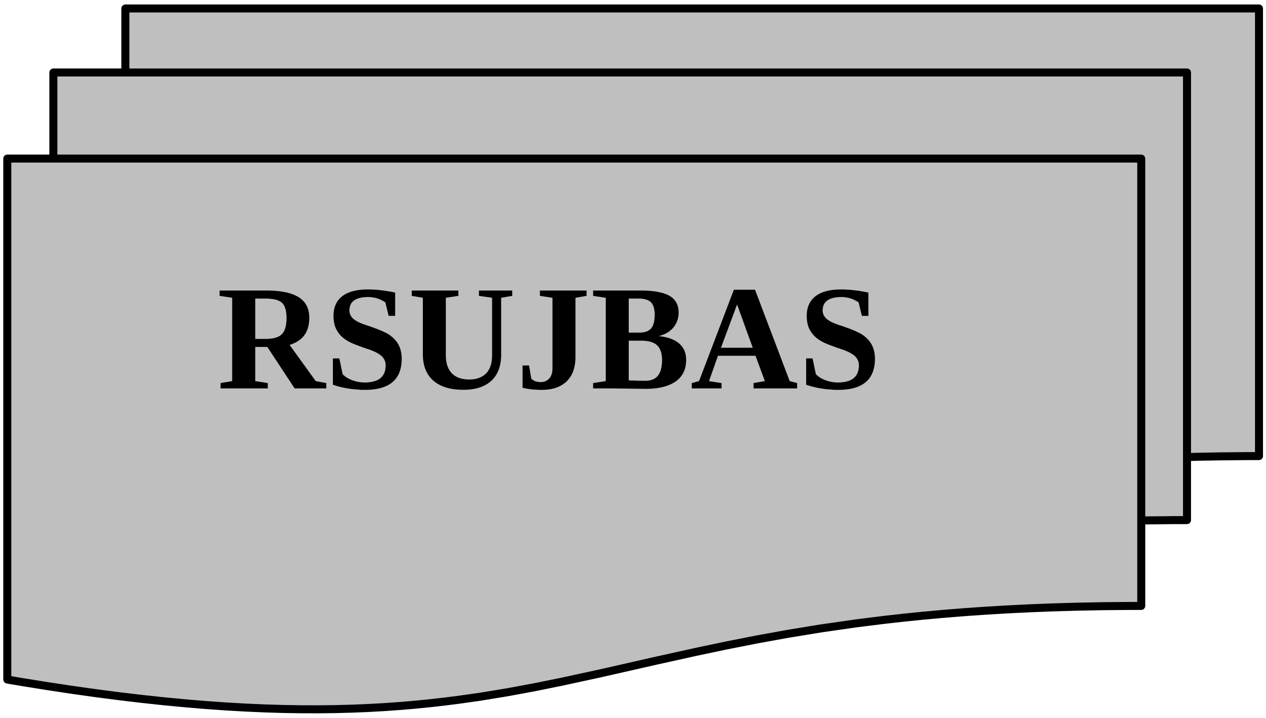

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The acknowledgment of people, grants or funds should be brief.

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# MODELLING THE DRYING CHARACTERISTICS OF TIGER NUT (*CYPERUS ESCULENTUS*)

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## ABSTRACT

*Modelling the drying characteristics of tiger nut During Thin layer drying was studied. Tiger nuts are being consumed either in a fresh, dried or semi-dried state. Microbial deterioration starts easily immediately after harvesting because of its high systemic moisture. Tiger nuts are seasonal agro-products and they are harvested in large quantities during their season of harvest but are scarce and very expensive in the market places during off-season due to post harvest handling. Drying is a process whereby the activities of most decay causing microbes are either deactivated or reduced to safe levels therefore, reducing post-harvest losses. Thus, utilizing a laboratory convection oven drier as a heating source with temperature varying from 60, 80, and 100°C applied variably in multiples of 20°C, this work predicted and analyzed the drying behavior of tiger nuts. The effective moisture diffusivity process and the emanating drying constants and coefficients were assessed utilizing the linearized Fick's second law equation method and non-linear regression statistical approach, respectively. The data from the tests were modeled using three well-known semi-empirical models, including Page, Lewis, and Henderson-Parbis. According to established results from actual experiments, moisture loss from the samples grew quite fast at the beginning of drying but slowed significantly at the end. The results demonstrate that the temperature-dependent effective diffusivity values ranged from 1.21x10-7m2/min to 7.2x10-8m-8/min. For all the temperature ranges employed in this study, the drying profile displayed a declining rate period rather than a clear constant rate period. In order to forecast the drying behavior of tiger nuts, it was discovered that the Henderson-Pabis model was the most accurate. 1.66kJ/mol is the relative activation energy.*

## INTRODUCTON

The tiger nut is also referred to as earth almond, chufa, ground almond, nutsedge etc. Its scientific name is *Cyperus eculentus* and it is a member of the "sedge family." It is a versatile perennial crop that some regions of the world consider weeds due to its rapid growth. However, it is widely grown in the northern portion of Nigeria, Asia, East Africa, Europe, particularly Spain, and the Arabian Peninsula. It thrives in well-drained loamy or sandy soil that ranges in pH from 5.0 to 7.5 and is approximately 20°C in temperature (Abdelkaer *et al.,* 2017). Tiger nut has been found very useful nourishment-wise and industrially. It has been used in the production of juice, yogurt or milk, beer, chocolate, edible oil, flour soap etc (Achoribo and Ong, 2017). Tiger nut is endowed with minerals namely, potassium, calcium, phosphorus, magnesium, and iron. It is rich in vitamin B1, Vitamin E and C (Maduka and Ire, 2018). It has been confirmed useful in treatment and stabilization of the nervous system as well as enable the body get use to stress (David, 2005).

If not treated, tiger nuts degrade over time, just like many other biomaterials do when moisture is present. Food processing techniques that are widely used and available to practically every social group in society include drying. Drying reduces transportation and packing costs, maintains product availability outside of the harvest season, enhances product appearance, maintains nutritional value and flavor (Saeed *et al.*, 2008; Bijaya, 2018; Deng *et al.*, 2018).

To develop scientific information for the preservation and industrial processing of food products, researchers have contributed a number of contributions. The outcomes of this investigation will offer us with information on the drying behavior of tiger nuts in convective ovens at various temperatures, and as a result, equipment designers will have knowledge they can utilize to create processing equipment that is better and more effective.

## 2.0 MATERIALS AND METHODS

### 2.1. Sample Collection

For the investigation, samples of tiger nut (*Cyperus esculentus*) were bought from the Swali ultramodern market in the Yenagoa LGA Bayelsa State, Nigeria. The samples were delivered to the food processing laboratory, Department of Agricultural and Environmental Engineering at Niger Delta University in Bayelsa State, Nigeria. Compliance with ASAE Standards (S368.4 of 2000 as reviewed) a uniform weight of 5g in five duplicates were obtained, they were first rinsed and cleansed to remove unwanted particles like stones and dust.

### 2.2. Experimentation

After making any necessary preparations, the samples were placed inside a WTC Binder Electric oven (model WTCB) with initial weights of 5g for each of the five temperatures (60°C, 80°C, 100°C) utilized in the experiment. Thrice were used to complete the operation for each temperature, and the average value was noted. According to Mohsenin (1986) and Kongdej Limpaiboon (2011), the final moisture content for each interval was calculated using the weight difference between the beginning and end of drying.

Equation (1) (Sahay and Singh, 2005):

$$\mathrm{MR} = \frac{\mathrm{M-Me}}{\mathrm{M0-Me}} \qquad 1$$

$$\mathrm{MR} = \frac{\mathrm{M}}{\mathrm{Mo}} \qquad 2$$

$$D_R = \frac{Change\ in\ mass}{Change\ in\ Time} \qquad 3$$

### 2.3. Evaluation of thin-layer models

i). the **Lewis model**

$$\mathrm{MR} = \mathrm{e}^{-\mathrm{kt}} \quad \ldots \quad 4$$

ii). the **Henderson-Parbis model**

$$\mathrm{MR} = \mathrm{Ae}^{-\mathrm{kt}} \quad \ldots \quad 5$$

And when n > 1, equation 2 simplifies to

iii). the **Page model**

$$\mathrm{MR} = \mathrm{e}^{-\mathrm{k}t^{n}} \quad \ldots \quad 6$$

A further solution of the Lewis model (6) in logarithmic form can give

$$\ln(\mathrm{MR}) = \ln(\mathrm{k}) - \mathrm{kt} \quad \ldots \quad 7$$

or

$$\ln\left(\frac{M}{M_o}\right) = \ln(\mathrm{k}) - \mathrm{kt} \quad \ldots \quad 8$$

### 2.4. Effective Moisture Diffusivity.

Literature supports the idea that the drying of the majority of biomaterials occurs during the period of falling rate. Fick's second rule of diffusion is observed in the diffusion of moisture via a sequence of thin layer surfaces (Bird *et al.*, 2005), (Zibokere and Egbe, 2020).

$$Deff = \frac{Gradient\ of\ plot * L^2}{-2.4694} \qquad 9$$

### 2.5. Derivation of Activation Energy

The energy band or threshold that must be crossed in order to start the movement of water molecules through a sample is known as the activation energy (Ea). According to the suggestions of (Akgun and Doymaz, 2005; Midilli and Kucuk, 2003) the relationship between effective diffusivity and temperature can be described as an Arrhenius kind of relationship as follows:

$$Deff = Do\exp\left(-\frac{E_a}{R*T}\right) \quad 9$$

$E_a$ =Gradient of plot * R 12

## 2.6 Determination of goodness of fit of thin layer models Applied

For each model, $R^2$, $X^2$, and RMSE were assessed in order to determine its suitability for describing the drying behavior of a given agricultural produce (Sankat and Mujaffar, 1986;; Egbe and Jonathan, 2022). A model was deemed to be appropriate were the $X^2$ and RMSE values found to be low whereas $R^2$ values are high.

$$R^2 = 1-\left[\sum_{i=1}^{n}(MRpre\ i - MRexp\ i)^2\right] \quad 13$$

$$X^2 = \frac{\sum_{i=1}^{n}(MRpre\ i - MRexp\ i)^2}{n-k} \quad 14$$

$$RMSE = \sqrt{\sum_{i}^{n}\frac{(MRpre\ i - MRexp\ i)^2}{n}} \quad 15$$

## 3.0 Results and Discussions

### 3.1 Dehydration Kinetics

Figure 2 shows the moisture ratio of the samples versus drying time at the chosen temperature levels, whereas Figure 3 shows the moisture ratio computed in logarithmic form [n(MR)] against drying time. The moisture ratios are always computed on a dry basis (db). The plots demonstrate an initial increase in moisture loss during drying because of the free water's quick diffusion and evaporation. However, as the drying period wore on, the rate of drying reduced despite an increase in temperature. The steep reduction of the drying curves (shown in Figure 1) suggests that moisture loss from the materials decreases with increasing time (Jain and Pathare, 2007). This indicates a decreasing rate drying process without case-hardening even at high temperatures as the amount of water that can evaporate from the samples' surfaces decreases over time. This is in line with reports about yoghurt being dried in a thin layer pumpkin seeds (Jittanit, 2011), (Burubai and Bratua, 2015); (Hayaloglu *et al.,* 2007), clam (Burubai, 2015), red pepper (Akpinar *et al.,* 2003), fresh tilapia fish (Zhiqiang *et al.,* 2013), plantain (Satimehin and Alabi, 2005), salted (Ehiem and Simonyan, 2011), bananas (Ganesapillai *et al.,* 2011),

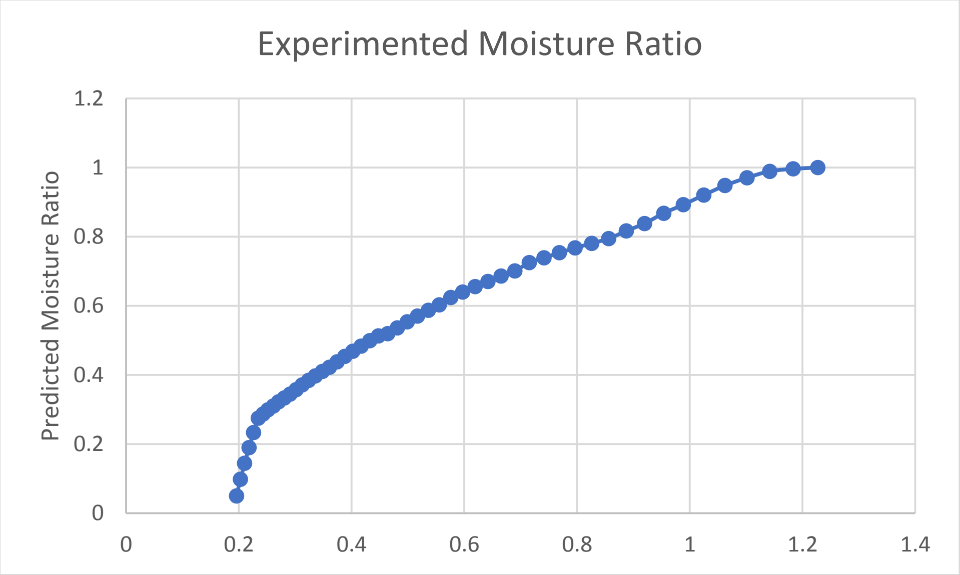

**Figure 1. A graph of Experimented Moisture Ratio versus Predicted Moisture Ratio**

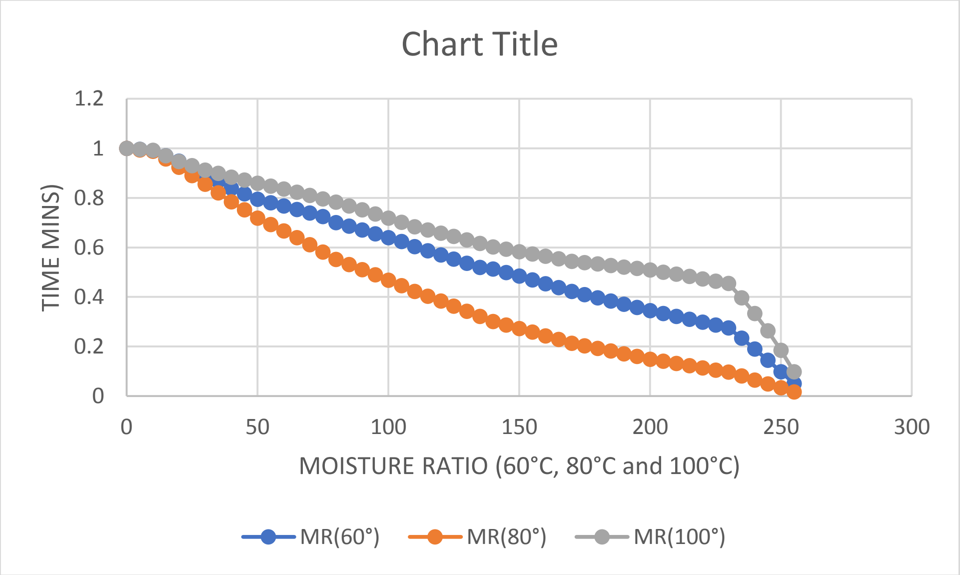

**Fig. 2: Drying curve at different temperature for** Tiger nut (*cyperus esculentus*)

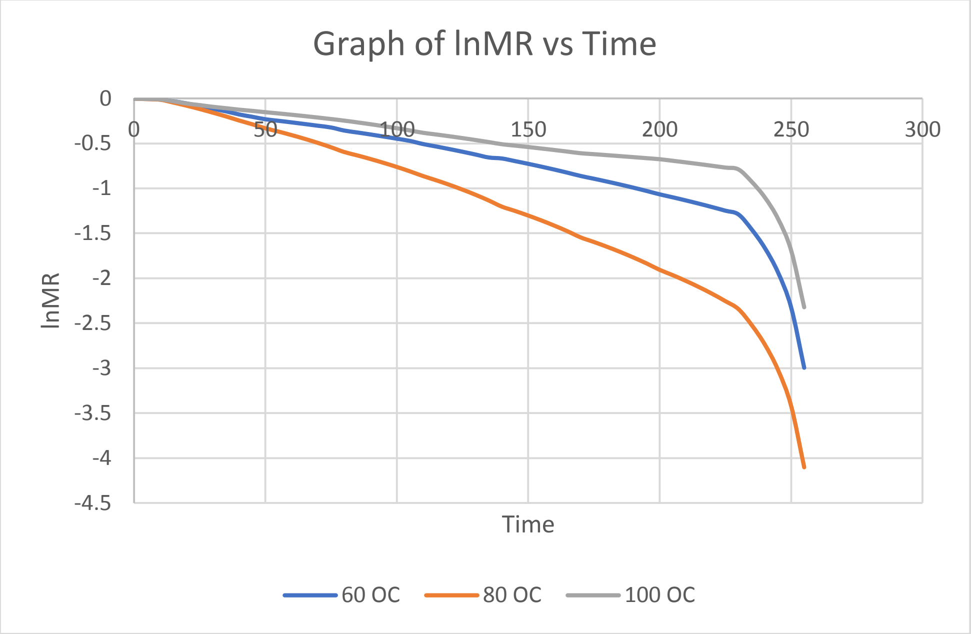

**Fig. 3:** **Drying curve of** Tiger nut (*cyperus esculentus*)

### 3.2. Fitting Experimental Data into Thin-Layer Drying Models Tiger nut (*cyperus esculentus*)

Equations 4, 5, and 6 were utilized to estimate the samples' dry behavior using the thin-layer drying models of Lewis, Henderson-Parbis, and Page. The fitting is carried out to enable the selection of the model that most accurately describes the drying behavior of thin-layer specimens. Tables 1 show $R^2$, RMSE, and chi-square values used as statistical criteria during the fitting process. Using experimental data fitted into Fick's diffusion equation using a non-linear least square statistical analysis (SPSS, 1996), the fitting constants "a," "k," "n," and "c" were first determined. $R^2$ values for the range of drying temperatures used in this study were the primary criterion for choosing an appropriate thin-layer drying model that could be used to characterize the drying data for the specimens. Table 1 shows that the Lewis model's $R^2$ values ranged from 0.990569 to 0.99432, the Page model's $R^2$ values ranged from 0.869204 to 0.969274, and the Henderson model's $R^2$ values ranged from 0.9999 to 0.9999. Next, the RMSE values ranged from 0.0000595 to 0.002125. The Henderson-Pabis model, followed closely by the Page model, seems significantly representative (-level = 0.05), with values banded or clustered along the straight line of the plot (Figure 1). This is a reasonable indication that the Henderson model provided a better goodness of fit than the others. The Page model and the Lewis model came in second and third and were therefore regarded as suitable for estimating the drying characteristics of the tiger nuts.

**Table 1: Statistical Parameters of Tiger nut *(cyperus esculentus)* on the Three Thin-layer Drying Models**

| LEWIS MODEL | | | | | | |
|---|---|---|---|---|---|---|
| Temp. °C | $R^2$ | $X^2$ | RMSE | k | A | n |
| 60 | 0.990569 | $1.8136x10^{-4}$ | 0.013339343 | 0.0072 | - | - |
| 80 | 0.98938 | 0.000204 | 0.014155 | 0.012 | | |
| 100 | 0.994321224 | 0.000109207 | 0.01035117 | -0.0049 | - | - |
| **HANDERSON MODEL** | | | | | | |
| 60 | 0.99996 | $6.92891x10^{7}$ | 0.00082451 | 0.0072 | 1.226911 | - |
| 80 | 0.999761 | 4.69E-06 | 0.002125 | 0.012 | 1.38168 | |
| 100 | 0.9999998 | 3.68222E-09 | 5.95254E-05 | -0.0049 | 1.133715 | - |
| PAGE MODEL | | | | | | |
| 60 | 0.912849 | $1.709x10^{3}$ | 0.040551 | 1.4143 | | 0.000677 |
| 80 | 0.969272 | 0.000603 | 0.024078 | 1.4924 | | 0.000777 |
| 100 | 0.869204 | 0.002565 | 0.049677 | 1.3171 | | 0.000761 |

### 3.3. Effective Diffusivity, $D_e$

Effective diffusivity, or De, is a parameter that describes how well moisture migrates from the solid matrix to the specimen's surface. The method of slopes was used to derive Equation 9-13 which yielded effective diffusivity. For the temperature settings used in this study, the obtained data ranged from $.21x10^{-7}m^2/min$ to $7.2x10^{-8}m^{-8}/min$ based on an average of three replications. It is clear that when the drying temperature increased, moisture diffusivity increased as well. Diffusion is a temperature-dependent mechanism; thus this is in line with pumpkin seeds, grape seeds, and fresh water clam, Jittanik, (2011), Robert *et al.*, (2008), Burubai and Bratua, (2015) all reported similar results.

### 3.4. Activation Energy, $E_a$

Ea denotes the energy kinetics of the moisture transport process and is used to determine the degree of temperature dependency of the specimens' moisture diffusivity (heat sensitivity) during the drying tests. Equation 14 was linearized over the temperature values utilized in this study using the Arrhenius type connection (equation 14-17). The predicted Ea value of 1.66KJ/mol in this study as similar to investigations in various technical literatures (Zogzas *et al.*, 1996)

## 4. Conclusion

To understand the tiger nut thin-layer drying dynamics, this research was done. According to observations in various literature, drying was seen to occur beyond the period of falling rate. The best three thin layer models for forecasting the kinetics of specimen drying were investigated using experimental data matched to them. Henderson-Parbis model and Page model, in that order, were agreed to be reliable predictors of how tiger nuts will behave under the drying temperature ranges used. The effectiveness of moisture diffusivity values increased as the drying temperature progress and the activation energy value which was calculated to be 1.66KJ/mol.

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