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Original Article

Investigation into the Drying Kinetics of Salt Water Crab(*Cardisoma Guanhumi*)

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Abstract - *Crab meat degrades rapidly due to microbial decay after death, classifying it as highly perishable seafood (the Crayfish and lobsters alike). As a result, its economic value is affected. Drying is one of the techniques that will provide consumers with ready-to-eat dried Crabmeat to incorporate into everyday meals such as soups and sauces. Thus, the drying behavior of the crab on thin layers was investigated in this study. As the heating source, a laboratory convective oven dryer was used, with temperatures (ranging from 60 to 100°C) applied in multiples of 10°C. Similar to high moisture sea foods, the drying profile showed a typical falling rate period without a clear constant rate for all temperature levels used in this study. The layer thickness was approximately 45 mm. The experiments' data on moisture loss (diffusion) fit the three widely used semi-empirical thin-layer models of Lewis, Henderson-Pabis, and Page. Their applicability was confirmed using statistical variables like Root Mean Square (R^2), X^2, and RSME. This was done to select a thin-layer model that would suitably describe the samples' drying kinetics over the temperature range selected for this study. Therefore, it was assumed that the Henderson-Pabis and Lewis models had correctly predicted the samples drying behavior at the chosen temperature ranges.*

Keywords - *Saltwater crabs, Thin-layer drying, Drying kinetics, Effective diffusivity, Activation energy.*

1. Introduction

Crabs are crustaceans that belong to the infra order Brachyuran and have thick exoskeletons (shells), and a single pair of pincers' hidden tails under the thorax is another subtle feature. Their habitats include the world's oceans, freshwater, and land. They are commercially crucial to the well-being of humans as a local food item because they have a high average meat yield and, when fresh, a substantial meat-to-shell ratio [1]. Humans are the primary predators of crab meat because most aquatic or terrestrial creatures find them highly toxic and shelled. They are primarily marketed alive in the ocean belts of the Niger Delta region in Nigeria. Seafood is widely recognized for its nutritional value. Crabmeat contains essential proteins and minerals, particularly calcium, iron, phosphorus, and potassium [2,3].

According to [3,4,5], Crabmeat has a high protein and mineral content (14 to 22.6%). Crabmeat contains less than 2% lipids [6], the majority of which contains polyunsaturated fatty acids (PUFAs), accounting for 32 to 52 percent of the total fatty acid content, compared to 20 to 28 percent of the total fatty acid content [4,5,7]. Investigation shows several fish species to a crab species (P. pelagicus). Their study revealed that PUFAs and monounsaturated fatty acids (MUFAs) were significantly higher in Crabmeat than in fish flesh. In comparison, saturated fatty acids (SFAs) were lower in crabmeat [2]. Because of the large number of crabs on the southern coast of Nigeria and the high nutritional value of Crabmeat, this decapod should be valorized and preserved using various techniques to establish new food products with high nutritional consumer value.

2. Review of Related Work

One of these methods is drying, which provides customers with ready-to-eat dried Crabmeat to add to regular meals like soups and sauces. Traditional and innovative drying processes, regardless of mode, such as microwave, convective, infrared, and so on, frequently result in product overheating, which causes significant organoleptic degradation, nutrient denaturation, and crack formation. Heat treatments harm the proximate composition of seafood and alter its sensory properties.

Crab meat, on the other hand, degrades rapidly due to microbial decay after death, classifying it as highly perishable seafood. As a result, its economic value suffers. The result is that during processing, endogenous enzymes and chemical processes like Millard browning and oxidative discoloration significantly affect the color of crab meat [8]. Browning also occurs during the cooking process. Nutrients may be lost in processes like canning which involves the storage of animal-muscled biomaterial in wet form, hence the need to prolong the shelf life of this product while retaining its physiochemical and qualitative characteristics; harvested quantities above immediate consumption will necessitate proper and prompt post-harvest handling, preservation, and storage [9].

In contrast, wet storage methods like freezing, salting, chilling, cooked-canning, and frying are useful. Dry preservation and storage is a tried-and-true technique for extending the shelf life of animal muscle biomaterial. Drying affects the products' physiochemical and quality properties while retaining the essential flavor, color, and nutritional value.

This research aims to increase crab meat's longevity while retaining its flavor, color, and nutritional value. If widely implemented, this study will propose increased demand for crab meat, as it is one of the most consumed and valued meats on the market today. It may be considered the king of seafood due to its exceptional taste and flavors. Drying will also aid in better packaging, serving as a marketing tool. Dried food is always more intensely flavored and highly palatable and, most of the time can be consumed solo. Hence crab meat in the dried form will be a form of delicacy on its own and an absolute delight when added to other meals as a side serve or in the recipe.

As a result, the drying behavior of the saltwater crab was examined on thin layers in this study, and the resulting experimental data were fitted to the chosen thin-layer drying models to characterize the crab drying kinetics. Additionally, this would lead to improved drying process equipment design or a good database.

3. Materials and Methods

3.1. Materials

Fresh crab comes from a local market in Bayelsa State, Nigeria, the yenagoa local government. The crabs were transported to the food processing lab, Department of Agricultural and Environmental Engineering at Niger Delta University in Bayelsa State, to investigate the drying kinetics. The basic measurements of the crab meat (plate 1), which would be utilized in the drying tests, were measured using a 0.001-cm precision veneer calliper. The crab meat was then stratified into groups of different but equal thickness and length, re-stabilized, and stored in refrigerator cabinets without further treatment. The samples were weighed using a digital balance to achieve a uniform weight of 32-g in five (5) different locations.

Plate 1. Saltwater crab

3.2. Description of The Oven Dryer

The goal of the oven dryer is to quickly drain the oven chamber of moisture so that the samples can be dried. The drying oven process forces warm, moist air out of the chamber while bringing in fresh air, allowing the samples to dry quickly. The drying and heating capacities of the oven dryer are high. The samples must dry for a predetermined time at a constant temperature. The sample's moisture content is determined by weighing it before and after drying. Plate 2

Plate 2. Electric oven dryer

3.3. Method

The summary of the experimental data used in this study is represented in Equations 2-4. Three Models were used, Lewis, Henderson, and Page.

3.4. Drying Procedure

Thin layer experiments were carried out at six (6) different temperatures (60°C -110°C). The samples were placed in the oven drier. The digital balance with 0.01-g precision was used to measure the initial and all subsequent moisture content values. The weight loss for each sample was monitored at specific time intervals (of about 10min) to the point of equilibrium and in the manner described in the works of [10] on Spiced Okpokuru (*Orycles rhinoceros*) and catfish [11].

3.5. Data Collection

As was previously mentioned, drying is a phenomenon that gradually reduces moisture levels over time, continuing until a particular level is reached. The initial and final weights of the samples and their initial and final moisture contents in % db were included in the study data. A laboratory-top digital balance with a precision resolution of 0.01 g was used for all weight measurements. The ASAE standard oven method was used to calculate the initial and all subsequent moisture content values [12] (S368 41 2000). Each drying test was conducted three times at each temperature setting, with the average results recorded. The final moisture content for each interval was calculated dryly using the weight differences before and after drying [13].

$$M = \frac{w_i - w_f}{w_f} \quad (1)$$

3.6. Thin Layer Mathematical Drying Models

In technical literature, mathematical models are commonly used to predict the behavior of agricultural and other biomaterials during drying. Several of these thin-layer drying models (the Lewis, Page, and Henderson-

Pabis models, respectively) are chosen for validation in this work on crab meat.

3.6.1. Lewis Model

$$MR_{Predicted} = e^{-kt} \quad (2)$$

3.6.2. Henderson-Pabis Model

$$MR_{predicted} = Ae^{-kt} \quad (3)$$

3.6.3. Page Model

$$MR_{predicted} = e^{-kt^n} \quad (4)$$

Taking the natural logarithm of both sides, deduced equation 8

$$In(MR) = In(k) - kt \quad (5)$$

b and n are model constants, and k is the kinetic (drying) rate constant.

3.7. Obtaining Drying Curves

To properly describe thin-layer drying, drying rates must be controlled. Increasing the drying rate at various drying temperatures can shorten the drying process. High temperatures (say, above 80°C) and various drying conditions may harm the final quality of materials with a high body moisture content [14,15]. For a given split and drying temperature, the reduction of moisture during the drying process may be related to the drying time in the cubic polynomial form in the direction Y[16]

$$y = C_0 + C_1 t + C_2 t^2 + C_3 t^3 + C_4 t^4 \quad (6)$$

Care for the inherent drying process factors where the Cs are constant. The drying rate will be as follows when Equation 6 is differentiated concerning time:

$$\frac{dy}{dt} = -(c_1 + 2c_2 t + 3c_3 t^2 + 4c_4 t^3 \ldots) \quad (7)$$

As drying time passes, the drying rate will slow down, as indicated by the negative sign. Equation 7 can be simplified by considering the higher powers of t as insignificant.

$$\text{Drying rate}\left(\frac{dy}{dt}\right) = -(c_1 + 2c_2 t + 3c_3 t^2 \ldots) \quad (8)$$

Equation (8), with a semi-parabolic shape, generates drying curves for the various drying temperatures used in this study on a graph of drying rate vs. drying time.

3.8. Drying Kinetics

Drying kinetics show good information about the drying process of crab meat.

$$\frac{dM}{dt} = D_e\left(\frac{d^2M}{dr^2}\right) \quad (9)$$

$$MR = \frac{M - M_e}{M_0 - M_e} \quad (10)$$

The drying rate was calculated using 10 [17]

$$D.R. = \frac{\Delta M}{\Delta T} \quad (11)$$

Where; ΔM = Change in moisture content at the wet base

ΔT = Change in time

3.9. Statistical Fitting of Experimented Data

Statistical measures like the R^2, the X^2, and the RMSE are frequently used to evaluate and compare the quality of fit of thin-layer drying models (RMSE). When X^2 and RMSE values are low, R^2 is high. Generally, a given model has been described with acceptable goodness of fit. The three most popular thin-layer drying models were used in this study to fit the experimental drying data of the samples obtained at various temperatures. The mathematical models' accuracy in simulating experimental data was assessed using the criteria. The indicators and statistical parameters were computed following the guidelines.

$$R^2 = 1 - \left[\sum_{i=1}^{n}(MR_{pre,i} - MR_{exp,i})^2\right] \quad (12)$$

$$X^2 = \frac{\sum_{i=1}^{n}(MR_{pre,i} - MR_{exp,i})^2}{n-k} \quad (13)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(MR_{pre,i} - MR_{exp,i})^2}{n}} \quad (14)$$

4. Results and Discussion

4.1. Characterizing Drying Kinetics

It was required to convert the drying data from the experiments (M.R.) to obtain dimensionless moisture ratios. The crab M.R. values were then plotted as a drying time (figure 1) at the chosen temperature while the humidity ratios varied. These variations were given logarithmic and were drawn under the drying system. All moisture ratios are provided during the drying process because it is well-known that activation energy promotes the molecular transport phenomenon (diffusion). It can be seen that the plots in Figure 2 generally followed the drying curves' reported trends for many biomaterials. The curves showed a stronger initial slope, a sign of an initial rise, and a rapid moisture loss during drying. This could be because the samples have more water activity due to faster moisture migration to the surface due to evaporation and evacuation, which hastens the drying process. However, as the temperature rises and less and less water is available for evaporation on the samples' surfaces, the drying process becomes slower (curves flatten) at later stages.

4.2. Fitting Experimental Data into Thing-Layer Drying Models

For all the drying temperatures selected in this study, the transformed dimensionless moisture ratios were used to fit the empirical models of Lewis, Henderson, and Page, respectively. For each of the drying conditions, the parameters were statistically analyzed (see Table 1).

According to the statistical analysis and fitting results, all models had high R^2 values, ranging from 0.743547 to 0.999421. This implies that each empirical model could adequately describe how the samples dried. When further tuned with the other statistical parameters for the temperature range studied, the Henderson and Pabis model expression, followed by that of Page, had the highest R^2 and the lowest X^2 and RMSE values. This demonstrated how well these models fit the bill for explaining the drying kinetics. So, using the Henderson-Pabis model to forecast how the saltwater crab would dry out under the drying conditions used in this study was a good decision.

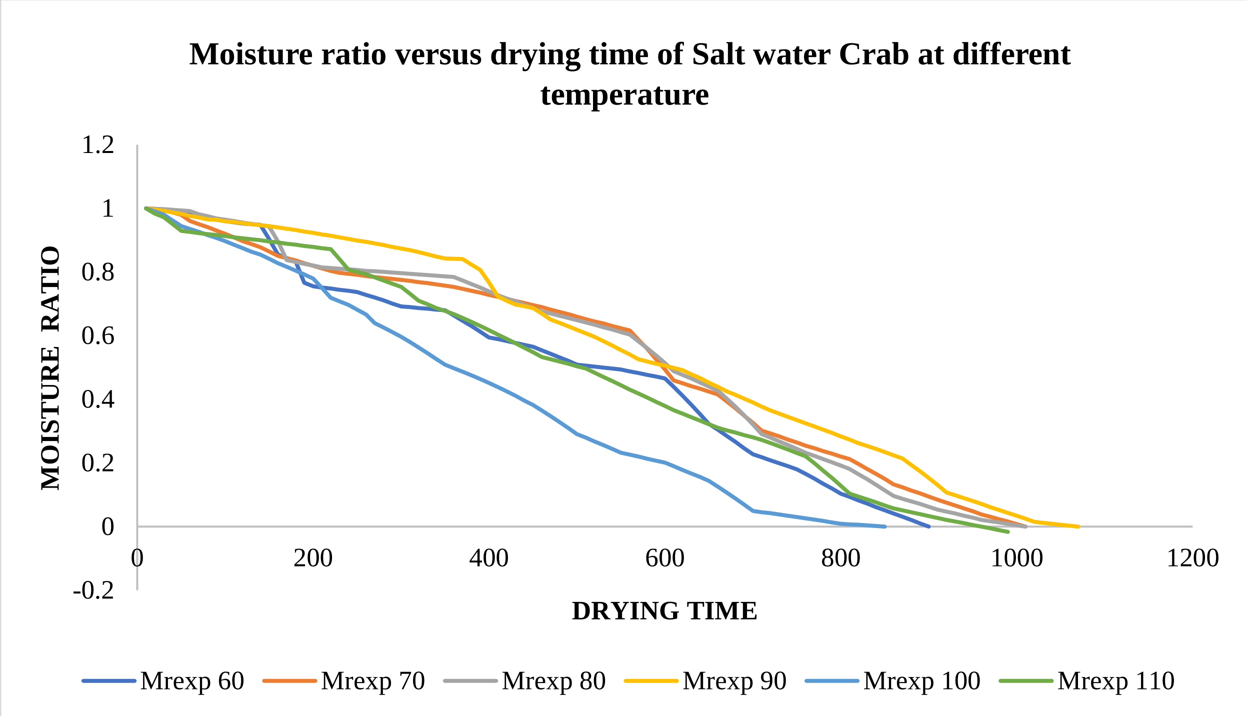

Fig. 1 Moisture ratio versus drying time of salt water crab at different temperatures

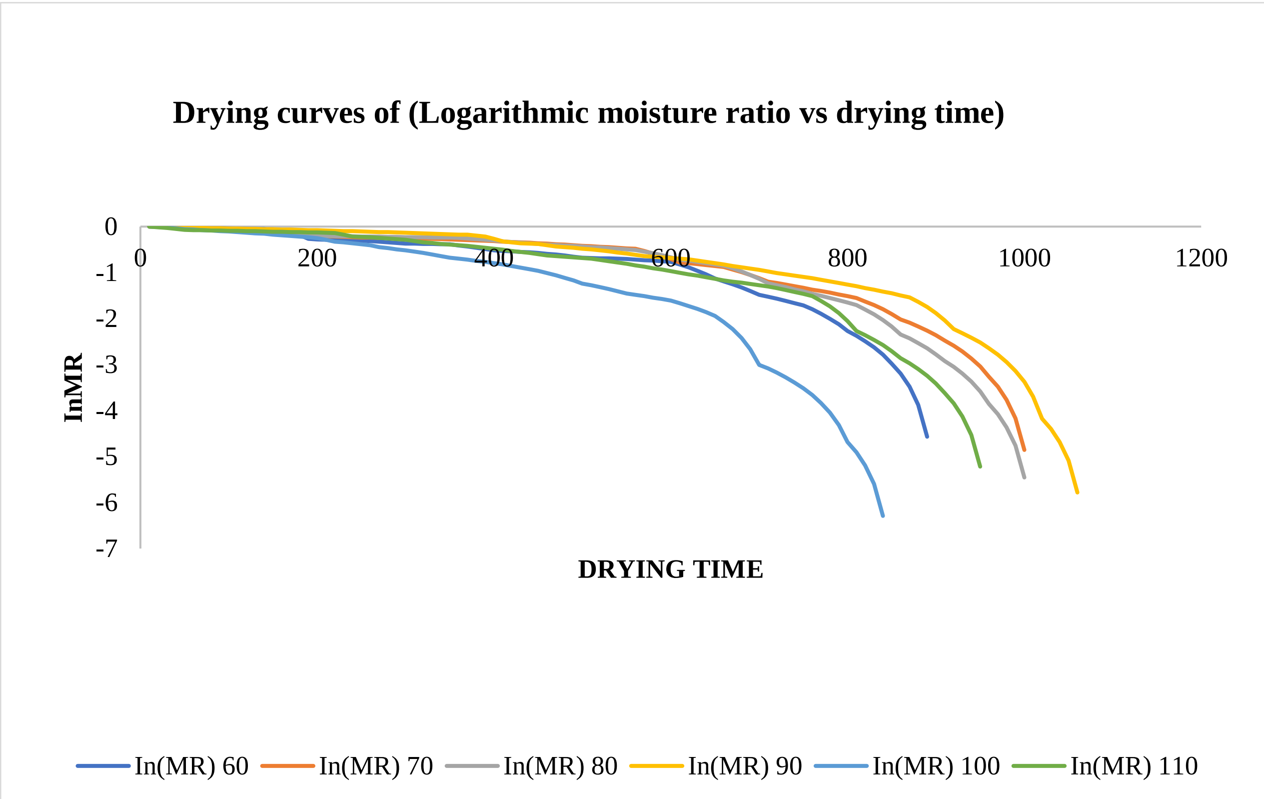

Fig. 2 Drying curves of (Logarithmic moisture ratio vs. drying time)

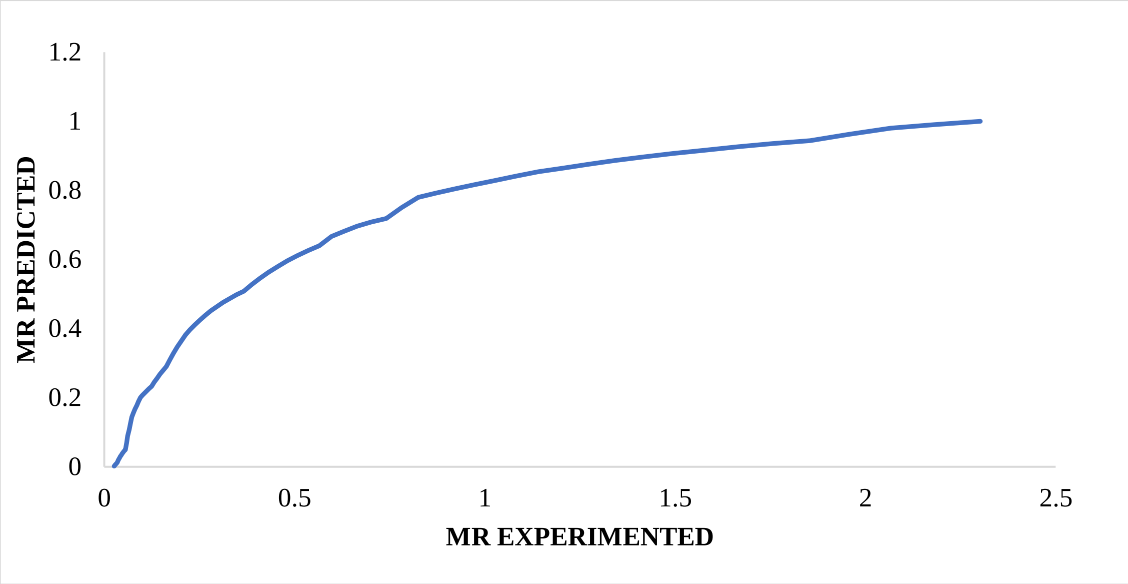

Fig. 3 Relationship between experimented moisture ratio and henderson's model moisture ratio prediction at 100°C

Table 1. Statistical parameters of salt water crab on three selected thin-layer drying models

MODEL NAME	TEMPERATURE (◦C)	R2	X2	RMSE	K	a	N
LEWIS	60	0.743547	0.002881	0.053381	0.031800		
	70	0.941214	0.000588	0.24125	0.003000		
	80	0.923490	0.000765	0.027523	0.003500		
	90	0.919173	0.000763	0.274840	0.003300		
	100	0.949162	0.000061	0.007734	0.005400		
	110	0.777529	0.00227	0.014991	0.035800		
HENDERSON	60	0.765410	0.002636	0.051054	0.031800	1.743509	
	70	0.999452	0.000005	0.002329	0.003000	1.063984	
	80	0.997805	0.000022	0.004662	0.003500	2.188027	
	90	0.998356	0.000016	0.003920	0.003300	2.191311	
	100	0.993914	0.000007	0.002676	0.005400	2.429778	
	110	0.791713	0.002125	0.014505	0.034400	2.018188	
PAGE	60	0.812852	0.002103	0.045601	0.031800		0.000019
	70	0.902831	0.000972	0.031017	1.425700		0.000099
	80	0.858765	0.001412	0.037395	1.754000		0.000012
	90	0.869739	0.001229	0.034891	1.629100		0.000023
	100	0.957394	0.000051	0.007080	1.462600		0.00016
	110	0.938203	0.000631	0.007901	1.3536		0.000172

5. Conclusion and Recommendation

This study investigated the kinetic behavior and its effect on a selected specimen, which is the saltwater crab. According to the observed drying process, the falling rate period was followed. The experiment data were modeled using the three-thin layer theory to choose the model that would most accurately predict the drying kinetics of the sample. The Henderson-Pabis model and Lewis models were closely related and provided accurate predictions of the saltwater crab drying behavior under the applied drying temperatures. The research could be beneficial in designing and developing drying apparatus to preserve saltwater crabs. Three different thin-layer drying models were the only ones available in the study. The selection base could potentially be increased beyond the threshold used in this work to obtain greater accuracy in the drying data for a better drying system design.

References

[1] Aysun Maskan, Sevim Kaya, and Medeni Maskan, "Hot Air and Sun Drying of Grape Leather PESTIL," *Journal of Food Engineering*, vol. 54, no. 1, pp. 81-88, 2002. [CrossRef] [Google Scholar] [Publisher Link]

[2] A.D. Premarathna et al., "Nutritional Analysis of Some Selected Fish and Crab Meats and Fatty Acid Analysis of Oil Extracted from Portunus Pelagicus," *International Journal of Scientific and Technology Research*, vol. 4, no. 7, pp. 197–201, 2015. [Google Scholar] [Publisher Link]

[3] Maurizio Zotti et al., "Comparative Analysis of the Proximate and Elemental Composition of the Blue Crab Callinectes Sapidus, The Warty Crab Eriphiaverrucosa, and the Edible Crab Cancer Pagurus," *Heliyon*, vol. 2, no. 2, p. e00075, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[4] Nalan Gökoðlu, and Pynar Yerlikaya, "Determination of Proximate Composition and Mineral Contents of Blue Crab (Callinectes Sapidus) and Swim Crab (Portunuspelagicus) Caught off the Gulf of Antalya," *Food Chemistry*, vol. 80, no. 4, pp. 495–498, 2003. [CrossRef] [Google Scholar] [Publisher Link]

[5] Xugan Wu et al., "Comparison of Gender Differences in Biochemical Composition and Nutritional Value of Various Edible Parts of the Blue Swimmer Crab," *Journal of Food Composition and Analysis*, vol. 23, no. 2, pp. 154–159, 2010. [CrossRef] [Google Scholar] [Publisher Link]

[6] Deniz Ayas, "The Effects of Season and Sex on the Nutritional Quality of Muscle Types of Blue Crab Callinectes sapidus and Swimming Crab Portunus Segnis," *Natural and Engineering Sciences*, vol. 1, pp. 1–14, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[7] Safa Bejaoui et al., "First Investigation in the Biochemical Analysis of the Invasive Crab Portunus Segnis from Tunisian Waters," *Journal of the American Oil Chemists Society*, vol. 94, pp. 673–682, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[8] David Boon, "Discoloration in Crab Meat," *Journal of Food Science*, vol. 40, pp. 25, 1975.

[9] Keith A. Crandall, "Collecting and Processing of Freshwater Crayfishes," *Journal of Crustacean Biology*, vol. 36, no. 5, pp. 761-766, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[10] D.S. Zibokere, and E.W. Egbe, "Estimating the Drying Kinetics of Spiced Okpokuru (Orycles Rhinoceros) with the use of Some Thin Layer Models," *Research Journal of Engineering and Engineering and Environmental Sciences*, vol. 5, no. 2, pp. 563-574, 2020. [Google Scholar]

[11] K.M. Sahay, and K.K. Singh, *Unit Operations of Agricultural Processing*, Vikas Publishing House Pvt Ltd., 2004.

[12] ASAE, Standard, Publication of the American Society of Agricultural and Bioresources Engineering, vol. 41, pp. S368, 2000.

[13] Nuri N. Mohsenin, *Physical Properties of Plant and Animal Materials, Physical Characteristics and Mechanical Properties*, Gorgon Beach Science Publishers, USA, vol. 1, pp. 123-144, 1986.

[14] Junling Shi et al., "The Drying and Quality Characteristics of Fresh and Sugar Infused Blueberries are Dried with Infrared Radiation Heating," *LWT-Journal of Food Science and Technology*, vol. 41, no. 10, pp. 1962 – 1972, 2008. [CrossRef] [Google Scholar] [Publisher Link]

[15] Jie Chen et al., "Mathematical Modelling of Hot Air Drying Kinetics of Momordica Charantia Slices and Its Color Change," *Advanced Journal of Food Science and Technology*, vol. 5, no. 9, pp. 1214–1219, 2013. [Google Scholar] [Publisher Link]

[16] Haydar Kucuk et al., "A Review on Thin-Layer Drying-Curve Equations," *Drying Technology*, vol. 32, no. 7, pp. 757-773, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[17] Hao-Yu Ju et al., "Drying Characteristics and Modeling of Yam Slices under Different Relative Humidity Conditions," *Drying Technology*, vol. 34, no. 3, pp. 296–306, 2016. [CrossRef] [Google Scholar] [Publisher Link]