Determination Of Drying Characteristics Of Local Seeds (Melon And Fluted Pumpkin Seeds): Drying Kinetics Models

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***Abstract*-This study presents the influence of drying operation in melon seed and fluted pumpkin seed and, on the other hand, to study the drying kinetics, by applying different kinetics models to the experimental drying data. Slices of the fluted pumpkin (8mm and 6mm) and melon (3.5mm and 2.5mm) seeds were dried at different temperatures 40°C, 50°C, 60°C and 70°C at 15 min interval for a total period of 195 min. The dry basis moisture content was calculated. It was observed that as the drying temperature increased, the rate at which drying occurred also increased, and drying achieved at shorter time. The result showed that at 70°C the period of drying for the fluted pumpkin seeds (8 mm and 6 mm) was 120 min and 105 min respectively, while at 40°C the time for drying was 180 min and 165 min respectively. Then for the melon seeds (3.5 mm and 2.5 mm) drying at 70°C occurred at a period of 105 min and 90 min respectively, while at 40°C, the drying time for the melon seeds of thicknesses 3.5 mm and 2.5 mm was 105 min and 90 min respectively. Proximate analysis conducted before and after drying processes of the pumpkin seed shows that the results for the drying at 30°C are quite similar to those for the drying at 70°C but having some values like moisture, fat and protein contents reduced after drying while the crude fiber, ash and carbohydrate contents increased. The experimental data of the pumpkin and melon seeds were fitted into kinetic models; Newton, Logarithmic and Henderson & Pabis, and Logarithmic kinetics model is the best model.**

Keywords—Melon; Pumpkin; Drying Kinetics; Kinetic Model; Drying; Proximate Analysis

INTRODUCTION

Drying of materials is often the final operation in a manufacturing process, carried out immediately prior to packaging or dispatch (Richardson et al., 1991). Drying can be defined as the removal of relatively small amount of water from solids or nearly solid materials. Water is usually removed by circulating air or some other gas over the material in order to carry away the water vapour. Every year large volumes of high quality seeds are lost for planting purposes because of excess moisture. Drying is the most commonly used method of food preservation which involves the removal of moisture from a material to a level at which microbial and enzymatic activities are greatly minimized (Henriquez et al., 2014). Safe seed moisture content varies with crop species, but generally 14% or less is considered satisfactory for short term storage (Kelly, 1988).

The mechanism responsible for this process in fruits and vegetables is diffusion, which is due to the simultaneous heat and mass transfer that occurs in the material during a falling rate period (Diamante et al., 2010; Tzempelikos et al., 2014; Udomkun et al., 2015). The rate of heat and mass transfer depends on the drying conditions of temperature, relative humidity, air velocity and material thickness (Pandey et al., 2010; Jangam, 2011). Thus, there is a need to apply appropriate drying technique that will describe the drying process accurately. The most common drying technique used for the biological and agricultural products is thin layer convective drying (Sacilik, 2017; Kadam et al., 2011). Seeds are also susceptible to drying injury in several ways. First, they are sensitive to high temperatures, depending on the species (Kernick, 1961). Seeds may also be injured by drying too rapidly or by over drying. To obtain a good dryer performance seed moisture content, depth of seed in bin, air temperature and air volume must be controlled (Copeland, 1976).

Despite the essence of kinetics, modeling of particulate or thin-layer drying of materials is necessary to understand the fundamental transport mechanism and a prerequisite to successfully simulate or scale up the whole process for optimization or control of the operating conditions. Simple models with a reasonable physical meaning are effective for engineering purposes. Mathematical modeling of dehydration process is an inevitable part of design, development and optimization of a dryer. It mainly involves elaborative study of kinetics, which describes the mechanisms and the influence that certain process variables exert on moisture transfer. In other words, it can be used to study the drying variables, evaluate the drying kinetics and to optimize the drying parameters and the conditions. A proper drier design requires knowledge on the characteristics of the material and the drying kinetics. It is noted that higher temperature implies larger driving force. It also accelerate the drying process, as the temperature provides a larger water vapor pressure deficit.

Telfairia (fluted Pumpkin) seeds

Telfairia occidentalis is a tropical vine grown in West Africa as a leaf vegetable and for its edible seeds. Common names for the plant include fluted gourd, fluted pumpkin, ugu (in the Igbo language) and ikong-ubong (in the Efik/Ibibio language). Telfairia occidentalis is a member of cucurbitacae family and is indigenous to southern Nigeria. The fluted gourd grows in many nations of West Africa, but is mainly cultivated in Igbo land and Calabar land and it is used primarily in soups and herbal medicines.

Although the fruit is inedible, the seeds produced by the gourd are high in protein and fat, and can therefore contribute to a well-balanced diet. The plant is a drought tolerant, dioecious perennial that is usually grown trellised. The seed (Ugu seed) contains valuable oil and other useful by products. Before the oil can be extracted, it has to pass through some operations like handling, cracking, separation, size reduction etc. The parameters needed in form of engineering properties of the seed to design and construct effective processing, storage and handling equipment are not readily available.

Melon seed

Melon seed is botanically known as citrullus colocynthis (*curcurbita citrullus L. or citullus Lanatus Thumb*) and belongs to the cucurbitacea family. Yoruba named it egusi. It is tendril climber or crawling annual crops with fibrous and shallow root system. Citrullus lanatus are among the economically most important vegetable crops worldwide and are grown in both temperate and tropical regions. The seeds are less expensive and widely distributed. (Igwenyi et al, 2011) report that citrullus colocynthis seeds or citrullus lanatus seeds contain about 50% oil, 8.28% potassium, 34.86% protein, 1.49% calcium, 42.29% oil, 3.37ppm copper and 162.76ppm sodium. It is also an excellent source of nutritional minerals and vitamins such as carbohydrate, protein, fat, zinc, vitamin B1 (Thiamine) dietary fiber, sulphur, magnesium, vitamins B2 (Riboflavin), niacin and manganese.

Jayaraman and Christina (2013) carried out a phytochemical analysis of the melon plant extracts. The study showed the presence of cucurbitacin A, B, C,D, E(α-elaterin), saponins, alkaloids, anthranol, saponarin, tannins, tryphan, terpenoids, J, L, caffeic acid, flavones glycoloids, steroids, trace elements, and sulfur containing amino acids in this plant.

MATERIALS AND METHODS

Materials

Freshly harvested melon seeds and fluted pumpkin seeds were purchased from Eke Awka market in Awka, Anambra state. The seeds were brought and air-dried at room temperature for some minutes, for surface moisture removal.

Sample preparation

The fluted pumpkin *(Telfairia occidentalis)* and melon seed were extracted from there buds. The undersized and damaged seeds were manually removed and the good ones were washed to remove dirty and separated from their seed coat. Different thickness of the pumpkin (8 mm and 6 mm) and the melon seed (3.5 mm and 2.5 mm) were obtained for the drying process. 100 g and 50 g of the pumpkin and melon seeds respectively, were weighed and drying observed under the temperatures 40^{o}C, 50^{o}C, 60^{o}C and 70^{o}C at 15 min interval for a period of 195 min (3 h: 25 min), in a convective air dryer. For each temperature at 15 min interval, the drying was stopped and the weight of the sample recorded till a constant weight was achieved.

Proximate analysis

Proximate analysis of the *Telfairia* seed (pumpkin) was carried out to obtain its fat content, moisture content, protein, crude fiber, carbohydrate and ash content before drying and after drying at temperature 70^{o}C for a period of three (3) hours.

Moisture content determination

The result obtained from drying process of pumpkin and melon seeds at the various temperatures were was used to calculate the moisture content using the equation below;

$$\%\boldsymbol{moisture\ content} = \frac{W_1 - W_2}{\boldsymbol{Weight\ of\ sample}} \boldsymbol{x\ 100} \qquad \textbf{(1)}$$

Where;

W_1 = Weight of petri dish and sample before drying

W_2 = Weight of petri dish and sample after drying

The result generated was used to plot graphs of moisture content versus time.

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Drying kinetics

Thin layer convective hot air drying techniques enables the effective control and uniform distribution of drying air and temperature conditions over the material (Da Silva et al., 2015) thereby improving the overall quality of the final product. Thin layer drying curve models are often employed to evaluate the drying process of food products and may be categorized into three groups, namely; Theoretical, Semi-theoretical, Empirical models (Erbay and Icier, 2010). Semi-empirical models where used to model the drying behaviours of the pumpkin and melon seeds at the various temperatures. The models are displayed in the table below.

Table 1: Kinetic Models from Literature (Yaldyz and Ertekyn, 2001; Tohrul and Pehlivan, 2003; Lahsasni Et Al., 2004).

MODELS	EQUATION
Newton	MR = exp(-Kt)
Logarithmic	MR = a exp(-Kt) + c
Henderson & Pabis	MR = a exp(-Kt)

Moisture ratio

The data obtained experimentally for different temperatures under consideration can be plotted in the form of moisture ratio (MR) versus time, MR is defined thus;

$$MR = \frac{W - W_e}{W_o - W_e} \quad (2)$$

Where;

W = moisture content at time, t.

W_e = Equilibrium moisture content.

W_o = Initial moisture content

Linearization of the models

Models	Equation
Newton	**In (MR) = kt**
Logarithmic	**In (MR) = kt + a + c**
Henderson & Pabis	**In (MR) = kt + a**

RESULT AND DISCUSSION

Proximate analysis

\The moisture content, ash content, crude fiber, fat, protein, and carbohydrate contents of the *Telfairia* seed were obtained twice. First, at 30°C before the drying began, and secondly after drying at 70°C for three (3) hours, which is the highest temperature and time utilized during the practical. The result can be a guide on the temperature to be used for the drying of the fluted pumpkin seed to retain its nutritive value.

Table 2: The result from proximate analysis of Fluted pumpkin seed

Composition	Before Drying (at room temperature)	After Drying (70°C; 3hours)
Moisture content	49.8%	5.926%
Ash content	2.2%	3.563%
Fat content	10.5%	3.844%
Crude Fiber content	10.15%	12.5%
Protein content	10.85%	6.30%
Carbohydrate	16.5%	68.271%

The result of the proximate analysis showed that the water, fat, and protein contents of the fluted pumpkin seeds reduced after drying. The moisture content would be an advantage since its shelf life, handling, storing and transportation would be improved. But its fat and protein reduction has reduced its nutritive value; therefore a temperature less than 70°C and time less than 3 hours of oven drying should be considered. Ash, crude and carbohydrate content of the fluted pumpkin seed increased after the drying process. This shows that the more the seed dries the more its ash, crude and carbohydrate level. This is an advantage, therefore; care should be taken in choosing temperature and time for oven drying, bearing in mind to achieve an optimum result.

The graph of moisture content against time was plotted for the four samples; 8mm and 6mm slices of pumpkin seeds and 3.5 and 2.5mm slices of melon seeds.

Moisture content

Effect of Temperature and Time on the Drying of Telfairia Seed at Thickness Of 8mm and 6mm.

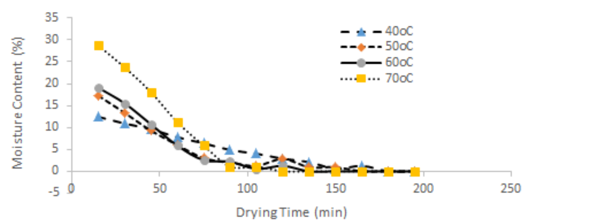

Fig 1: Graph of moisture content against drying time, for Pumpkin of 8mm thick

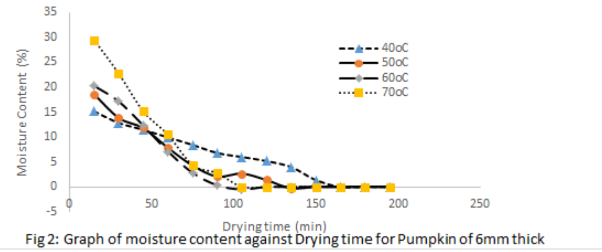

Fig 2: Graph of moisture content against Drying time for Pumpkin of 6mm thick

Effect of Temperature and Time on the Drying of Melon Seed at Thickness Of 3.5mm and 2.5mm.

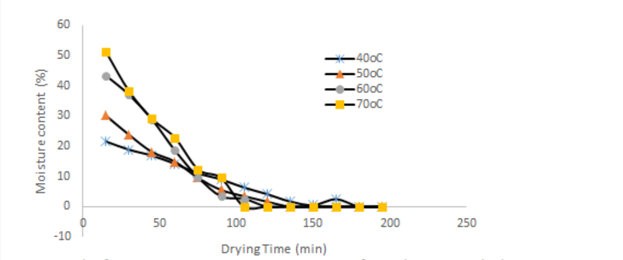

Fig 3: Graph of moisture content against Drying time for Melon 3.5mm thick

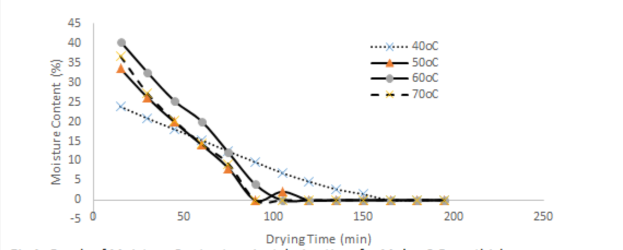

Fig 4: Graph of Moisture Content against drying time for Melon 2.5mm thick

The above plots showed similar activity; as the drying time and temperature increased, the moisture content also reduced. The seeds reduced in weight as drying proceeded and maximum reduction observed within the time range of 90-185min. The thickness of the samples also affected the rate of drying, the thicker the sample the higher time required for drying. 8mm slice of pumpkin dried at 120min while 6mm dried at 105min. Similarly, 3.5mm slice of melon dried at 105min while 2.5mm dried at 90min.

Thin layer model

To obtain a suitable model to predict the drying kinetics of pumpkin and melon seeds, the experimental data (moisture content) was used to obtain the experimental moisture ratio (dimensionless) (Eq. 1) (Akpinar, 2006; Ronoh et al., 2009). The models; Newton, Logarithmic and Henderson and Pabis where linearized and fitted into the non-linear forms of the models to obtain the predicted moisture ratio (dimensionless). Curves of predicted moisture ratio versus drying time (min) were plotted to obtain the statistical indicator R^2, (Tables 4.2 – 4.3) which was used to compare for the best model. The best model describing the thin layer slices of the seeds is that which has the highest R^2 value.

Comparison of Kinetic Models for Different Thickness of Pumpkin and Melon Seed at 40°c, 50°c, 60°c and 70°c

For pumpkin 8mm thick

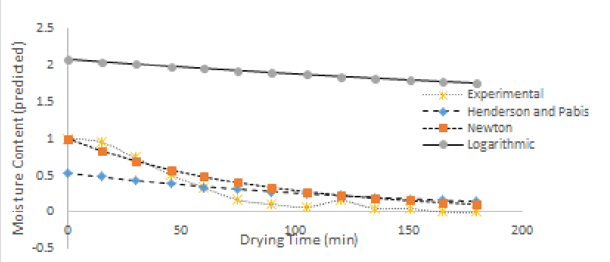

Fig 4.6: graph of moisture content (predicted) against drying time

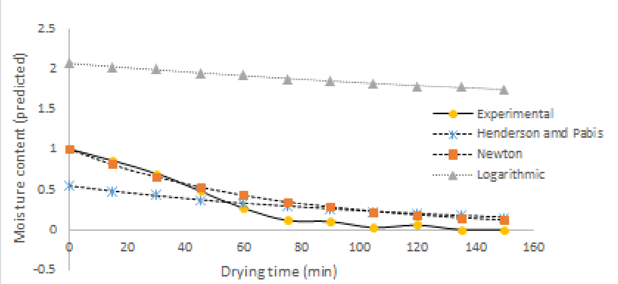

Fig 4.7: Graph of moisture content (predicted) against drying

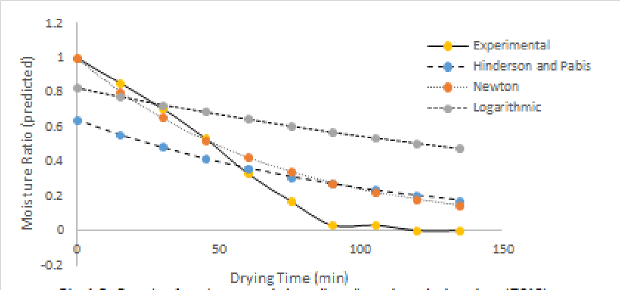

Fig 4.8: Graph of moisture ratio(predicted) against drying time (70°C)

6mm thick

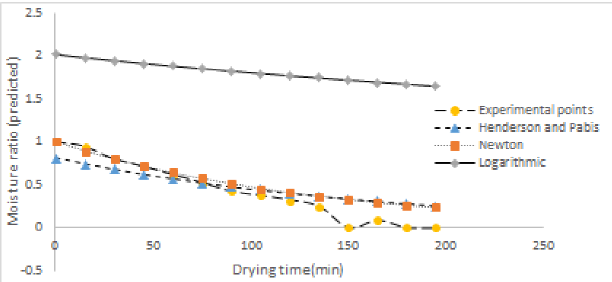

Fig 9: Graph of moisture ratio (predicted) against drying time (40°C)

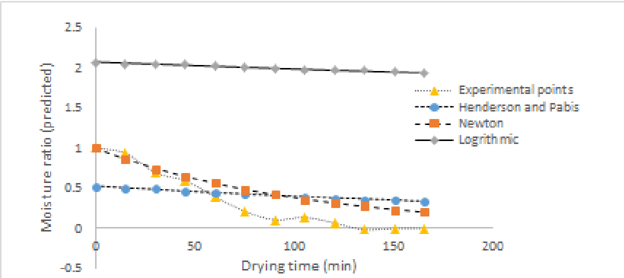

Fig 10: graph of moisture ratio (predicted) against drying time (50°C)

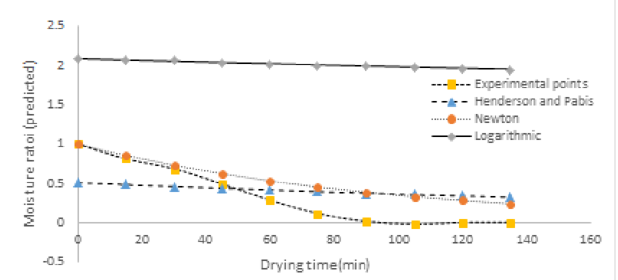

Fig 11: Graph of mosture ratio (predicted) against drying time (60°C)

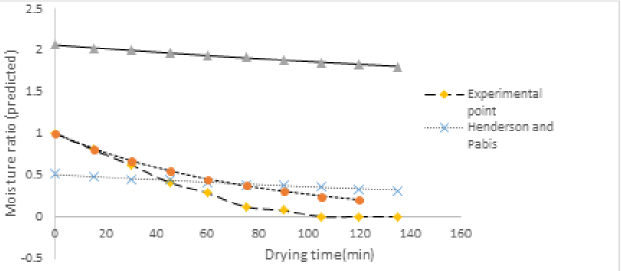

Fig 12: Graph of moisture ratio (predicted) against drying time (70°C)

For melon 3.5mm thick

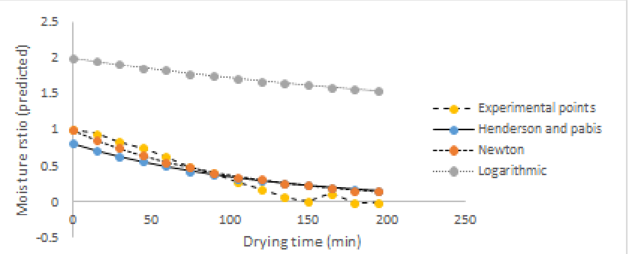

Fig 13: Graph of moisture ratio against Drying time at (40°C)

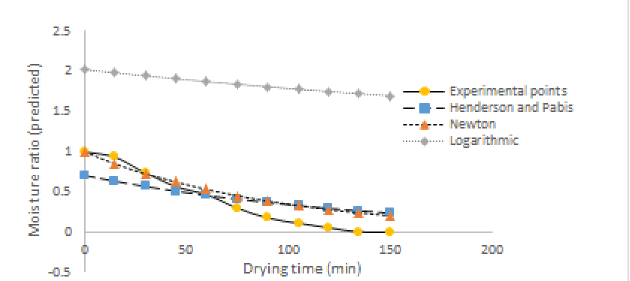

Fig 14: Graph of moisture ratio (predicted) against drying time

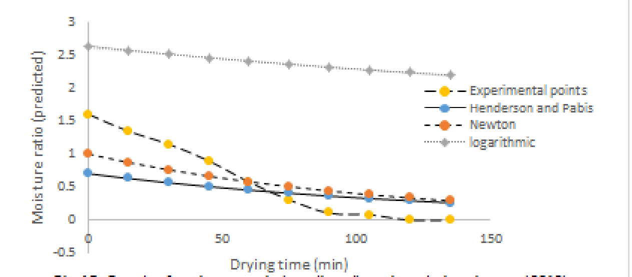

Fig 15: Graph of moisture ratio (predicted) against drying time at (60°C)

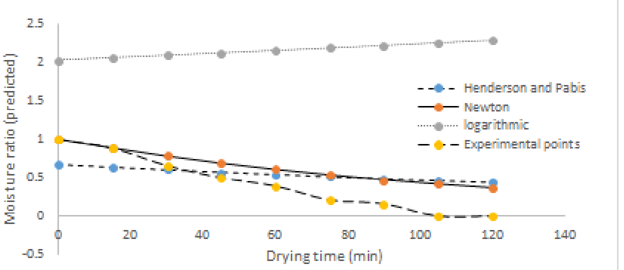

Fig 16: Graph of moisture ratio (predicted) against drying time at (70°C)

1) 2.5mm thick

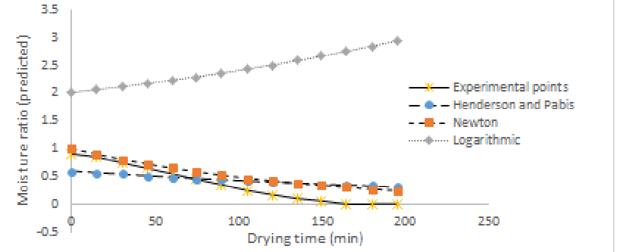

Fig 17: Graph of moisture ratio (predicted) against drying time at (40°C)

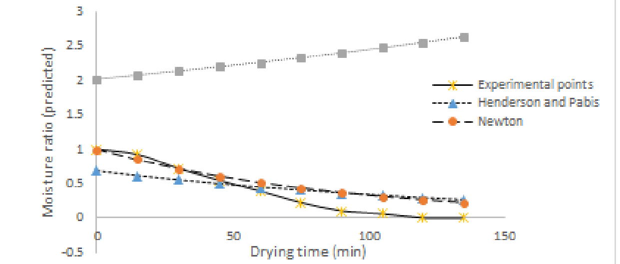

Fig 18: Graph of moisture ratio (predicted) against Drying time at (50°C)

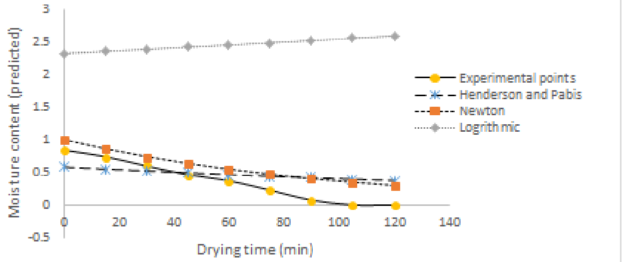

Fig 19: Graph of moisture ratio (predicted) against Drying time at (60°C)

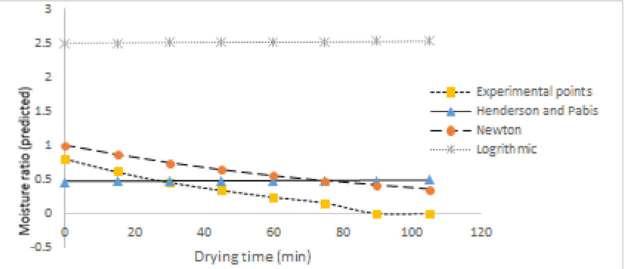

Fig 20: Graph of moisture ratio (predicted) against Drying time at

The result as shown in Table 3, for the pumpkin and melon seeds, shows that the best model is Logarithmic, with the value 0.994 at 70°C for 8mm slice of pumpkin seeds, this is the highest R^2 value compared to the other models, with Newton having value, 0.9177 at 50°C as the least. For 6mm slice of pumpkin, It can be deduced that best model is Logarithmic (0.9992 at 50°C), followed by Henderson and Pabis (0.9962 at 50°C) and Newton (0.9618 at 40°C), Logarithmic being the overall best for the Pumpkin seed.

For the melon 3.5mm thick table 3 shows that the best model is Logarithmic having the highest R^2 value of 0.9993 at 70°C, followed by the Henderson & Pabis; 0.9963 at 70°C and then Newton; 0.9807 at 70°C. For melon seed of 2.5mm thickness, we can deduce from (table 3) that the best model is logarithmic with R^2 value of 1 at 70°C. Logarithmic model being the best model for the melon seed.

TABLE 3: Results of the fittings with the different models for pumpkin, 8mm thickness

Thin Layer Models	40°C	50°C	60°C	70°C
Newton				
K	0.0046	0.0047	0.0056	0.0061
R^2	0.9337	0.9177	0.9218	0.9346
Henderson and Pabis				
K	0.0047	0.0021	0.0025	0.0034
a	2.4022	1.6326	1.6562	18139
R^2	0.9314	0.9694	0.9704	0.969
Logarithmic				
K	0.0032	0.0018	0.0022	0.0026
a	7.0972	7.8585	7.8209	2.2489
c	0.1409	0.1272	0.1280	0.4447
R^2	0.986	0.9941	0.994	0.994

Results of the fittings with the different models for pumpkin 6mm, thickness

Newton				
K	0.0038	0.0047	0.0055	0.0065
R^2	0.9618	0.9549	0.9619	0.9533
Henderson and Pabis				
K	0.0028	0.0012	0.0014	0.0014
a	2.1317	1.6866	1.6505	1.6505
R^2	0.975	0.9962	0.9959	0.9959
Logarithmic				
K	0.0019	0.0008	0.001	0.0019
a	7.3419	7.9669	8.0454	7.8311
c	0.1362	0.1256	0.1243	0.1277
R^2	0.9952	0.9992	0.992	0.9968

Results of the fittings with the different models for melon 3.5mm, thickness

Newton				
K	0.0042	0.0052	0.0052	0.0052
R^2	0.9372	0.9533	0.9715	0.9807
Henderson and Pabis				
K	0.0032	0.0031	0.0032	0.002
a	2.0651	1.9373	1.9507	1.9427
R^2	0.9538	0.9774	0.9814	0.9963
Logarithmic				
K	0.0024	0.0022	0.0032	0.0021
a	7.2594	7.4753	13.766	7.5874
c	0.1378	0.1338	0.1160	0.9980
R^2	0.9908	0.9955	0.9921	0.9993

Results of the fittings with the different models for melon 2.5mm, thickness

Newton				
K	0.0038	0.0056	0.0058	0.006
R^2	0.9637	0.9591	0.9718	0.9795
Henderson and Pabis				
K	0.0015	0.0031	0.0017	0.006
a	1.7814	1.9273	1.7727	2.5883
R^2	0.9918	0.9828	0.9961	0.9795
Logarithmic				
K	-0.0047	-0.0045	-0.0022	-0.0003
A	7.1107	7.4521	10.1482	12.1496
C	6.3907	0.9958	8.4762	0.7991
R^2	0.9908	0.9966	0.9993	1.000

CONCLUSION

The results from this study show that the drying process is greatly affected by temperature, time, and thickness. From the results obtained in drying Melon and *Telfairia* seed in an oven at temperatures 40°C-70°C, drying time; 195 min (interval of 15 min) and at different thicknesses (8 mm and 6 mm for *Telfairia* seed, 3.5 mm and 2.5 mm for melon seed), it can be said that; firstly; increase in temperature increases the rate at which drying occur (that is, takes shorter time), while decrease in temperature reduces the rate at which drying occurs (hence, longer time is required) . Secondly, the thicker a material is, the longer time it would take for it to dry.

It can be concluded from the proximate analysis that *Telfairia* seed is nutritive having fat content; 10.5%, ash content; 2.2%, crude fiber; 10.5%, protein; 10.5% and carbohydrate; 16.5%. Therefore care should be taken while reducing its moisture content so as not to destroy its nutrients as it was observed that some of the nutrients like fat, protein reduced after drying at 70°C for 195 min (3 hr).

The result from the kinetic study showed that the best model for *Telfairia* and Melon seeds is the Logarithmic, since it has the highest R^2 value compared to the Newton and Henderson & Pabis model.

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