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Comparative analysis of dried dehulled and undehulled african breadfruit (*treculia africana*) seeds using oven drier

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Abstract

This study investigated the effect of process variables on the moisture content and thermal properties of oven-dried dehulled (DBF) and undehulled (UBF) African breadfruit seeds. Moisture content was determined using the gravimetric method, and the effects of drying time and temperature were assessed. At 70 °C, with an air speed of 2.5 m/s and 240 minutes of drying, moisture content decreased from 66.7% to 12.53% for DBF and 12.95% for UBF. At 40 °C, the moisture content reduced to 15.7% (DBF) and 24.03% (UBF), while at 70 °C, it further decreased to 0.75% and 2.7% respectively. Proximate analysis and thermal property measurements followed. After drying, the specific heat capacity decreased from 2.2405 kJ/kgK to 1.681 kJ/kgK (DBF) and 1.9108 kJ/kgK (UBF). Thermal conductivity dropped from 0.3047 W/mK to 0.226 W/mK for DBF and 0.27 W/mK for UBF. Thermal diffusivity increased from 2.21×10^{-4} m²/s to 2.23×10^{-4} m²/s (DBF) and 2.3×10^{-4} m²/s (UBF). The results showed that DBF experienced greater changes in moisture content and thermal properties than UBF, which may be attributed to the hull in UBF retaining moisture during drying. This indicated that dehulling enhanced moisture removal and altered the thermal properties more significantly during oven drying of African breadfruit seeds.

Keywords: African breadfruit, moisture content, time, temperature, thermal properties

1. Introduction

Food is essential for human growth and development. Man draws energy for his daily activities from food. Presently, food security remains a global challenge facing mankind (Onu *et al*., 2020). Increase in the population of a geographical area increases the food consumption. The availability of land for cultivation decreased because of the numerous activities of man which include agricultural activities. In African countries where self-sufficiency in food is paramount, the rate of agricultural activities is very high. These agricultural activities include cultivation and harvesting of food crops. The African breadfruit (*Treculia africana* Decne) is a tropical tree found in many parts of west and tropical Africa. It belongs to the family of *Moracea* and the genus *Treculia*. It is known as 'Ukwa' by the Igbo tribes of Nigeria. The stem bark is grey in colour and produces white latex. The leaves are large and dark green on the surface and lighter underneath. It has a seeded fruit embedded in a spongy mesocarp. A brown coloured seed coat covers the milk white cotyledon (inner edible endosperm). The seeds are the edible part of the fruit. Under good environmental conditions, the yield from one tree is 200 kg of dried seeds (Ojimelukwe and Ugwuoma, 2021). However, its yield is not statistically measured and it is not found in the agricultural census of Africa. A mature tree can produce up to 30 fruits in a year and each fruit can yield up to 10 kg seeds after pulp removal. *Treculia africana* is presently considered an endangered species (Meregini AOA, 2005, World Agro Forestry Centre, 2004). African breadfruit seeds are highly nutritious and constitute a relatively cheap source of vitamins, minerals, proteins, carbohydrates and fats. It is mainly cultivated for food production due to its high nutritional value as each seed contains about 14 – 17 % crude protein, 2.5 % crude fibre and 35 – 60 % carbohydrate. The seeds are also good source of vitamins and minerals (Nwabueze and Okocha, 2008). The fruits contain polyphenols. Phyllocoumarin, catechin and 6, 9-dihydroxy megastigmane-3-one are phytochemicals isolated from *T. africana*. The raw sample contained 1.49 mg/100 g, 1.30TUI/mg, 32.03 mg/100 g, 2.07 mg/100 g, 4.00% and 3.24 mg/100 g of hydrogen cyanide (HCN), trypsin inhibitors, tannin, phytate, alkaloids (FAO, 2020).

African bread fruit is also a nutritious feed for livestock. Farm and wild animals feed on the fruit head, the unfermented pod, the seed, the bran and the leaves. The wood may be used for making furniture, pulp, paper, firewood, building; as well as fibre-board. Chimpanzees break the fruits into small pieces and eat it. In Malawi, blue monkeys are very fond of the fruits while in Tanzania the leaves are used as fodder (Ajayi, 2008). It may be used as a brewing adjunct to provide fermentable sugars. It is used for erosion control and for reforestation. The fresh pulp can be utilized as fodder (Murch *et al*., 2007). African breadfruit is a food security that helps meet the nutrient needs of people and also provides income to rural poor households that produce, process and/or preserve this crop. Like most food and agricultural products, this food product contains water at harvest and is therefore highly perishable if stored or left long in that state (Nwajinka *et al*., 2014). This simply means that its shelf life is very short. This is as a result of the activities of the microorganisms which require moisture as a medium to live and survive (Ezedinma *et al*., 2021). Moisture control creates an environment that is unfavorable for microorganisms and enzymes, which are mainly responsible for food spoilage (Deepak *et al*., 2019). The absence of water makes food items inhospitable for the growth and activities of these microorganisms. Hence, to preserve food items is to limit the activities and growth of the microorganisms in the food (Onu, *et al*., 2016). Also to consume a healthy fruit all year long, different factors and strategies should be considered and applied. One of these strategies includes preservation through drying.

Drying is one of the efficient preservation techniques if correctly applied (Onu *et al*., 2022). Sun drying has been the local method for the preservation of this food crop but in this study oven drying was used as the drying method. Oven drying involves the evaporation of water or another liquid such as solvent from the surface being dried. In oven drying, hot air is allowed to pass through the product in a manner to transfer the heat to the food product and moisture is removed. A major advantage of drying using oven is exposing the food product to hot air consequently causing uniformity in drying and also makes the product hygienically safe for human consumption. There are some process parameters that drying process depends on that significantly affect the moisture content reduction in the food products. The study of the influence of these factors was carried out in this study. Despite the fact that Nigeria is one of the largest producers of this food crop, there is insufficient data on the thermal properties of the drying of the dehulled and undehulled product, hence, the need for this research which tends to provide the comparative analysis of the dried dehulled and undehulled African breadfruit seeds. It will also provide the necessary technical information on drying of dehulled and undehulled African Breadfruit seeds produced in Nigeria which will be useful in the optimal design of the dryers for effective and optimal storage of such Nigerian food crop.

2.0 Materials and methods

2.1 Collection and preparation of the samples

The fresh agricultural product which is African bread fruit seeds were sourced from a local market in Awka, Anambra State, Nigeria and was properly identified by the Botany department of Nnamdi Azikiwe University, Awka. The African bread fruit seeds were manually sorted and washed with tap water and were parboiled at 100ºC for 10minutes after which the water was separated from the seeds with a sieve. The dehulling and winnowing of the seeds were done manually.

2.2 Experimental Procedure

Both the dehulled and undehulled samples were dried using an oven dryer (Drier Box, DHG-9030). Before loading the machine, it was allowed to run for some time till a steady condition when the drying temperature was constant at its set value. Afterwards, 20g of the sample was loaded into the drying chamber and was allowed to dry. The sample was weighed with a digital weighing balance and the mass was recorded every twenty minutes until the moisture content of the sample reached equilibrium with the drying air. The drying air temperatures and sample weight were continuously measured and recorded during the drying experiments. The temperature was measured by digital thermometer and the mass of the sample was obtained using a digital weighing balance (M-Metlar, model M311L, China). There were four temperature levels (40°C, 50°C, 60°C, 70°C) used in this work. The data were analyzed and used for determination of the drying parameters.

2.3 Proximate Analysis

Proximate analysis was performed using standard method of Association of Analytical Chemists (AOAC 2000)

2.3.1 Moisture content determination

The initial moisture content of African bread fruit seeds was determined using gravimetric method, by drying 20g of African bread fruit seeds at 100 ^oC for 10hours in a laboratory oven (Drier Box, DHG-9030) till all the moisture have been completely removed. This was done three times to obtain a reasonable average. The moisture content was calculated using equation 1.

$$MC = \frac{M_1 - M_2}{M_1}\ x\ 100 \qquad (1)$$

Where

MC is the moisture content of the sample after drying.

M_1 is the initial mass before drying

M_2 is the mass after oven drying

For any weight of the sample at any time, the moisture content at that weight was determined from eqn. (1), (Onu, 2017).

$$M_{t(db)} = M_o\%_{(db)} - \left(\frac{100(W_o - W_t)}{(1 - M_{o(wb)})W_o}\right) \qquad (2)$$

Where;

$M_{t(db)}$ = Moisture content at any time %(db),

M_o % (db) = initial moisture content % (db),

M_o(wb) = initial moisture content % (wb),

W_t = weight of sample at any time, g and

W_o = initial weight of sample, g

2.3.2 Determination of ash content

Ash content was determined according to AOAC (2000). A silica dish or crucible was washed and dried in an oven at 80 ^oC for 10 minutes. The silica dish was collected from the oven with a tong into desiccators to cool for 10 minutes. The silica dish was weighed with an electronic weighing balance and recorded as W_1. 2g of the sample was scooped into the crucible on an electronic weighing balance and the weight was recorded as W_2. The crucible + content were transferred onto a bunsen burner with a blue flame. The organic component was allowed to be driven off. The sample was ashed to grey colour. On completion of the incineration, the crucible + ash were transferred into desiccators to cool. The weight was taken and recorded as W_3 and the % ash content was calculated using equation (3)

$$\%\text{ ash content} = \frac{W_3 - W_1}{W_2 - W_1} x \frac{100}{1} \qquad (3)$$

W_1 = weight of crucible,

W_2 = weight of crucible + ash,

W_3 = weight of ashed sample + crucible.

2.3.3 Crude fibre determination

Crude fibre refers to the residue of a feed that is insoluble after successive boiling with dilute acid and alkali. To determine the crude fibre content, defat 2g of sample with three 25mL portion of ether. Transfer extracted sample in a beaker and boil under reflux for 30 minutes in a 1.25% sulfuric acid solution. Remove beaker and filter contents through funnel precoated with linen or several layers of cheese cloth. Wash with boiling water until the washings are no longer acid. Return the residue to a beaker and add 200 mL of boiling 1.25% sodium hydroxide solution and boil exactly for 30 minutes. Remove beaker and filter contents through a thin but close pad of washed and ignited asbestos in a Gooch crucible. Dry in an oven at 130 $\pm$ 2 °C for 2 hours. Cool in a desiccator and weigh. Incinerate at 600 $\pm$ 15 °C to constant weight (30 minutes usually sufficient). Cool in desiccator and weigh.

The loss in weight after incineration x 100 is the percentage of crude fibre.

$$\%Crude\ fibre = \frac{weight\ of\ fibre}{weight\ of\ sample} x \ \ 100 \qquad (4)$$

2.3.4 Crude fat determination

Crude fat is the term used to refer to the crude mixture of fat-soluble material present in a sample. First of all, rinse all the glass apparatus by petroleum ether and dry it in the oven at 102 °C and after removing it keep in the desiccators. Weigh 5 gram of grounded and dried sample and place it in the thimble. Place the thimble in the soxhlet extractor. Take a 150 mL round bottom flask and clean it and fill the flask with 90 mL petroleum ether. Place the whole setting on a heating mantle and allow the petroleum ether to boil. Continue the extraction process for several hours, almost 6 hours. Remove the condensing unit from extraction unit and allow the sample to cool down. Finally, it removes the entire lipid. Collect almost all the solvent after distillation. Place the sample in the oven and after removing it place in the desiccator. Take the weight of the sample.

$$\%\ Crudefat = \frac{W_2 - W_1}{P} x\ 100 \qquad (5)$$

Where

W_1 is the weight of empty thimble

W_2 is the weight of thimble with sample

P is the weight of sample

2.3.5 Crude protein determination

The method is the digestion of sample with hot concentrated sulphuric acid in the presence of a metallic catalyst. Organic nitrogen in the sample was reduced to ammonia; this was retained in the solution as ammonium sulphate. The solution was made alkaline, and then distilled to release the ammonia. The ammonia was trapped in dilute acid and then titrated. Exactly 0.5g of sample was weighed into a 30 ml Kjehdal flask (gently to prevent the sample from touching the walls of the side of each and then the flasks was stoppered and shaken. Then 0.5g of the Kjedahl catalyst mixture was added. The mixture was heated cautiously in a digestion rack under fire until a clear solution appeared. The clear solution was allowed to stand for 30 minutes and allowed to cool. After cooling about 100 ml of distilled water was added to avoid caking and then 50 ml was transferred to the kjedahl distillation apparatus.

A 100ml receiver flask containing 5ml of 2% boric acid and indicator mixture containing 5 drops of Bromocresol blue and 1 drop of methlene blue was placed under a condenser of the distillation apparatus so that the tap was about 20cm inside the solution. The 5 ml of 40% sodium hydroxide was added to the digested sample in the apparatus and distillation commenced immediately until 50 drops gets into the receiver flask, after which it was titrated to pink colour using 0.01N hydrochloric acid.

% Nitrogen = Titre value x 0.01 x 14 x 4 (6)

% Protein = % Nitrogen x 6.25 (7)

2.3.6 Carbohydrate determination: (Differential method)

% Carbohydrate = 100 - (%Protein + %Moisture + %Ash + %Fat + %Fibre) (8)

3.0 Result and Discussion

3.1 Effects of Process Variables on Moisture Content Reduction

3.1.1 Effect of temperature on moisture content reduction using oven dryer

Figure 1 reveals the effect of temperature on the drying process. It was done using the oven dryer for temperatures in the range of 40 ºC and 70 ºC. This temperature was used because using a higher temperature may cause the food item to be hardened on the surface (Adu et al, 2012). From the results gotten, there's an indication that increase in the temperature decreased the drying time. This is because as the temperature increased, the average kinetic energy of the moisture also increased, making it easier for the moisture to diffuse out of the products. In the drying of dehulled African breadfruit (DBF) and undehulled African breadfruit (UBF), as the drying temperature reduces from 70 ºC to 40 ºC, the time taken to reach the equilibrium moisture content in the product was 240 minutes for both DBF and UBF. At 40 ºC, the moisture content decreased from 66.7% to 15.7% and 24.03335% for DBF and UBF respectively. Also at 70 ºC, the moisture content decreased from 66.7% to 0.75% and 2.7% for DBF and UBF respectively. According to Wankhade *et al.*, (2012) and Saeed *et al.*, (2008), air temperature has a significant effect on the moisture content of samples. Increase in temperature decreases the drying time because both the thermal gradient inside the object and the evaporation rate of the product increased (Mohammad *et al*., 2013).

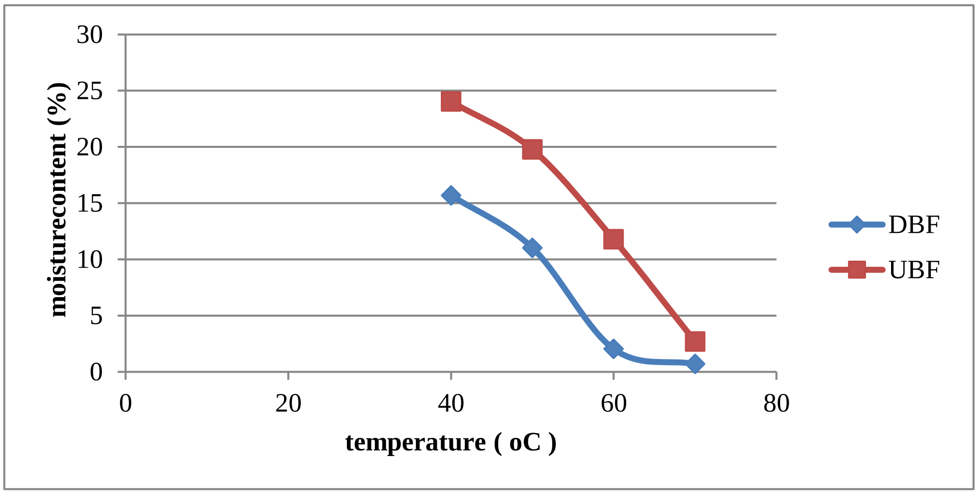

Figure 1 Effect of temperature on moisture content using oven dryer

3.1.2 Effect of time on moisture content using oven dryer

Figure 2 shows the plot of moisture content against drying time. It was observed that both dehulled and undehulled African bread fruit loses moisture as time increases. This means that decrease in moisture content increases with the drying time. At a time intervals of 20minutes, the moisture content was recorded. Figure 2 shows that the moisture content of both dehulled and undehulled African bread fruit decreased from 66.7% to 12.5333% and 12.95% respectively at 240mins drying time with an air speed of 2.5m/s and temperature of 70ºC. It was observed that dehulled African bread fruit lost more moisture than the undehulled this maybe as a result direct contact with the drying air. The moisture content decreases continuously with drying time (Wankhade et al, 2012).

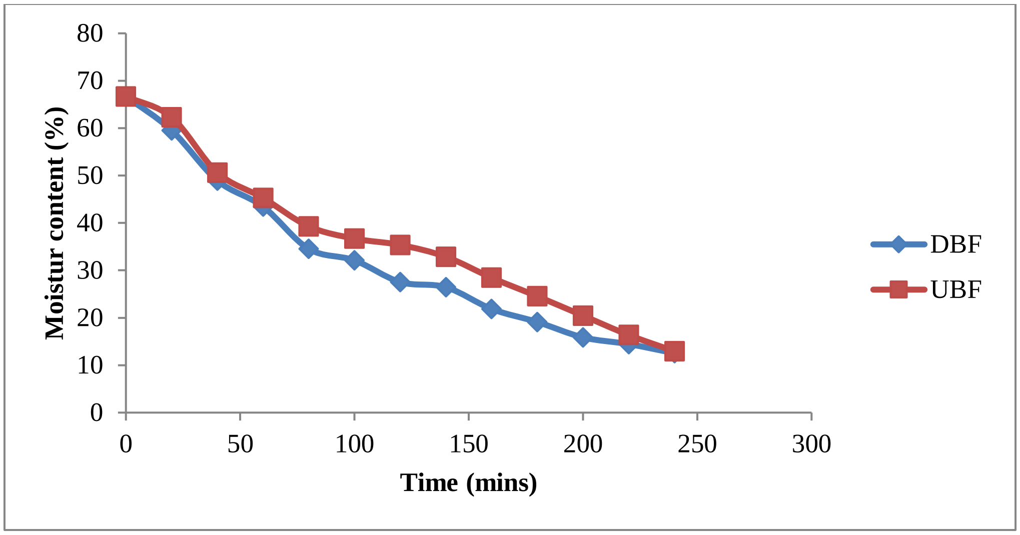

Figure 2 Effect of time on moisture content reduction using oven dryer

3.2 Proximate analysis

Proximate analysis was used to determine the different compositions of dehulled African bread fruit (DBF) and Undehulled African bread fruit (UBF) samples before drying and after drying. The results of the proximate analyses were presented in Table 1. The highest moisture content was observed in raw sample of African bread fruit (ABF) at 30.405 %. The high moisture content was expected since African bread fruit (ABF) contains great amount of moisture in their raw form. The moisture content of UBF decreased significantly after drying with the oven dryer to 18.51% while DBF decreased after drying to 14.49%. The analysis of crude fiber showed that it increased for both samples after drying. The range of the results obtained for crude fiber is within the range obtained by Nwabanne (2009) for fermented ground cassava. The results also showed that the samples have relatively high protein and fat contents. It revealed that the percentage of protein and fat contents decreased on drying for both samples. These results are in agreement with the work done by Luther *et al.*, (2003). The results also showed that the ash contents of both dehulled and undehulled bread fruit decreased after dssrying. The ash content of the raw ABF was 8.18% but it decreased on drying to 7.78% for DBF and 3.76% for UBF. The carbohydrate contents of raw ABF increased after drying. The carbohydrate content of raw ABF was 12.64% and it increased to 28.94% after drying for DBF and also increased to 37.72 % for UBF.

Table 1: Proximate analysis results of the samples

Material	WC	AC	PC	CF	FC	CC
Parameters	(%)	(%)	(%)	(%)	(%)	(%)
Raw ABF	30.41	8.18	35.70	3.10	9.97	12.64
DBF	14.49	7.78	30.45	6.78	7.55	28.94
UBF	18.51	3.76	31.15	7.80	5.09	37.72

WC is the water content; AC is the ash content; PC is the protein content, CF is the crude fibre; FC is the fats content, and CC is the carbohydrate content

3.3 Thermal Properties

The thermal properties of dehulled and undehulled African bread fruit analyzed were the specific heat capacities, thermal conductivities and thermal diffusivities.

3.3.1 Specific heat capacities

The specific heat capacities were calculated according to equation 9 (Luther et al, 2003).

$$C_p = 1.42X_c + 1.549X_p + 1.675X_f + 0.837X_a + 4.187X_w \quad (9)$$

Where; C_p is the Specific heat capacity (kJ/kgK) and X_c, X_p, X_f, X_a and X_w are the respective mass fractions of carbohydrate, protein, fat, ash and water obtained from the proximate analysis.

The results presented in Table 2 and Fig. 3 for specific heat capacities dehulled and undehulled African bread fruit showed a decrease in the specific heat capacities after drying. The specific heat capacity of raw African bread fruit was 2.2405 kJ/kgK. However, the specific heat capacities of the oven dried dehulled and undehulled African bread fruit were 1.681 kJ/kgK and 1.9108 kJ/kgK, respectively. From the result obtained (Fig. 3), the specific heat capacities of undehulled African bread fruit (1.9108 kJ/kgK) were higher than that of dehulled (1.681 kJ/kgK). This is probably because of the hull present in the undehulled which would have reduced the effect of heat on the sample leading to higher water content since, according to Luther et al. (2003), water has the greatest effect on specific heat capacity among other constituents.

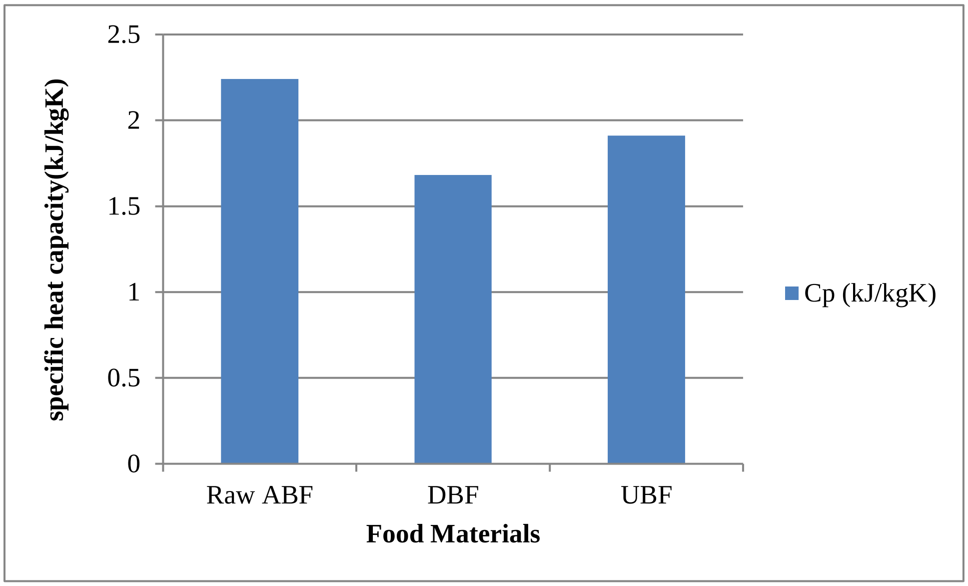

Figure 3 Specific heat capacity of the samples

4.3.2 Thermal conductivities

Thermal conductivity is a measure of the ease with which heat flows through a material. According to Nwabanne (2009), thermal conductivity of the food samples can be calculated using equation 10.

$$k = 0.25X_c + 0.155X_p + 0.16X_f + 0.135X_a + 0.58X_w \quad (10)$$

Where; k is thermal conductivity of sample (W/m K) and X_c, X_p, X_f, X_a and X_w are the respective mass fractions of carbohydrate, protein, fat, ash and water present in each seed. The results are shown in Figure 4 and table 2.

The results show that the thermal conductivities of the samples decrease on drying with the oven dryer. The thermal conductivities of raw African bread fruit was 0.3047 W/mK. For DBF, it decreased to 0.226 W/mK after drying.

Also, UBF decreased to 0.27 W/mK after drying. This is in accordance with the results obtained by Luther et al (2003) who stated that the thermal conductivities of most food materials is in the range of 0.2 to 0.5 W/mK. Thermal conductivity of a food material is strongly influenced by the material's water content.

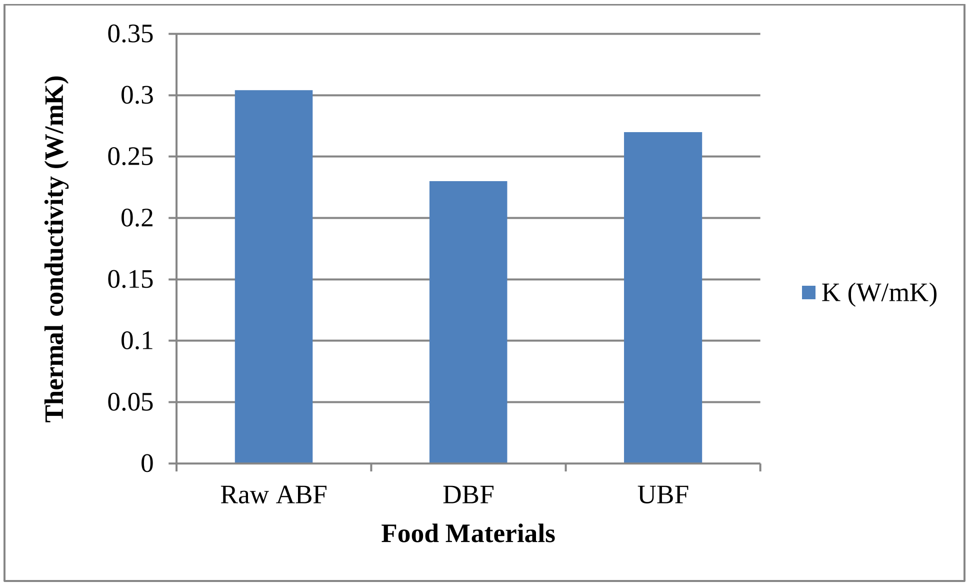

Figure 4 Thermal conductivity of the samples

4.3.3 Thermal diffusivity of the samples

Thermal diffusivity (α) is a measure of how fast heat propagates or diffuses through a material. The thermal diffusivity of the samples was determined according to Luther et al, (2003) as given by equation 11.

$$\alpha = k/\rho C_p \quad (11)$$

where; α is the thermal diffusivity of sample (m^2/s), C_p is the Specific heat capacity, ρ is the bulk density, k is the thermal conductivity. The results obtained are plotted in Figure. 5. The thermal diffusivities of the samples increased on drying. The thermal diffusivity of raw African bread fruit was 2.21×10^{-4} m^2/s. For DBF, it increased to 2.23×10^{-4} m^2/s after drying. In the same vein, the thermal diffusivities of the UBF also increased to 2.3×10^{-4} m^2/s after drying. The range of values obtained in this report is in agreement with that obtained by Nwabanne (2009) who reported a value between 9.0×10^{-4} m^2/s to 2.0×10^{-4} m^2/s. Thermal diffusivity is very relevant in transient heat transfer where temperature varies with time and location. Thermal diffusivity is a combination of three basic thermal properties which are thermal conductivity, density and specific heat capacity (Luther et al, 2003).

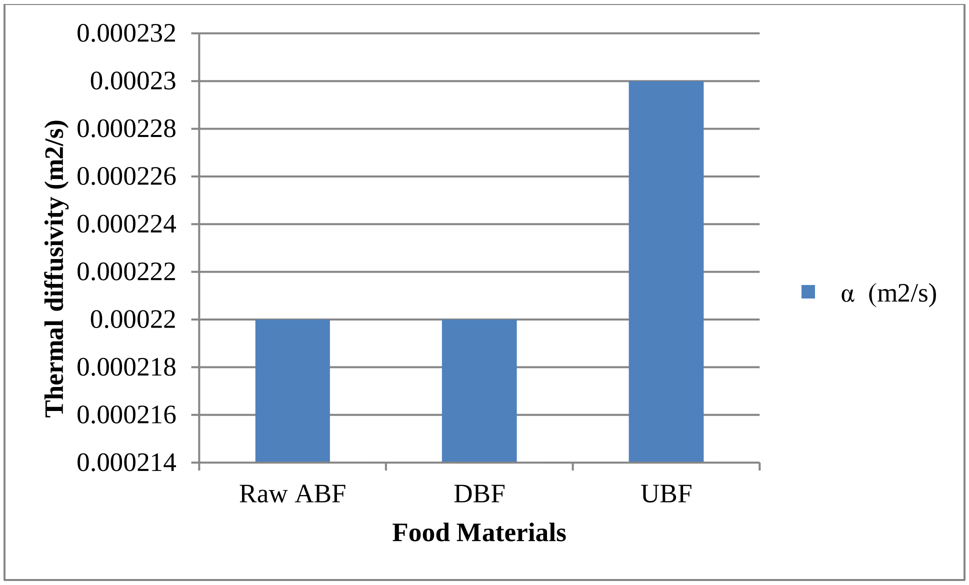

Figure 5 Thermal diffusivity of the sample

Table 2: Thermal properties of the samples

Food material	**Cp (kJ/kgK)**	**K (W/mK)**	**α (m^2/s)**
Raw ABF	2.2405	0.3041	0.000221
DBF	1.6810	0.2300	0.000223
UBF	1.9108	0.2700	0.00023

4.0. Conclusion

African breadfruit has been studied to determine the effects of process variables on the moisture content of oven-dried dehulled and undehulled African breadfruit and its thermal properties. Moisture content decreased with time, temperature and air speed. This was observed more in DBF than UBF because the hull held back water and reduced the effect of heat. Also for the thermal properties; the specific heat capacity of DBF decreased more than UBF. Also, thermal conductivity of DBF decreased more than UBF while thermal diffusivity of DBF increased more than UBF and these will be useful in designing industrial dryers. Therefore, oven drier can be conveniently used to reduce the moisture content in both dehulled and undehulled African breadfruit seeds, thereby increasing the shelf life.

5.0 Recommendation

a. Further study should be carried out to determine the implication of drying on the nutritional content of the dried samples.
b. Other types of dryer e.g. solar dryer, microwave, freeze dryer etc can be used to compare with the dryer used in this study.

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Nomenclature

WC= water content, %;
AC= ash content, %;
PC= protein content, %;

CF= crude fibre, %;
FC= fats content, %;
CC= carbohydrate content, %;
C_p= Specific heat capacity (kJ/kgK);
K= thermal conductivity of sample (W/m K);
α= thermal diffusivity of sample (m^2/s);
ABF= African breadfruit
DBF= dehulled African breadfruit
UBF= undehulled African breadfruit

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