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Effect of moisture absorption and temperature on the thermal properties of dried tigernut

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A B S T R A C T

The effect of moisture absorption and temperature on the thermal properties of dried tigernut was studied. The proximate composition includes moisture content ranging from 0.97% to 6.45%, Ash content from 0.63% to 1.93%, fat from 12.95% to 16.63%, crude fiber from 18.71% to 33.78%, and carbohydrate from 43.58% to 58. 68%. The thermal properties were determined by using the value obtained from the proximate composition and calculated using the Okoi and choi's equation. The value obtained from the thermal properties are thermal conductivity which ranged from 0.28866 w/m°c to 0.3562 w/m°c, thermal diffusivity ranging from 0.1123m2/s to 0.2172ms/s and specific heat capacity ranging 1.8484 kg/kg°c to 1.9261 kg/kg°c. The percentage moisture absorption capacity was also analyzed in the sample which ranged from 46.6% to 94.4%. Thermal properties refer to the response in their temperature. The result obtained showed that the sample conditioned at 100°C had the highest thermal properties and this implied that the thermal properties of food is generally influenced by moisture, temperature and their proximate composition. Further studies should be carried out on the Rheological properties of tigernut, kinetic rate of reaction of the nutrient with respect to time and the thermal properties should be utilized for the design of equipment and for the mathematical model in terms of simulation and mass heat transfer in the material.

Keywords: Dried Tigernut; Moisture Absorption; Temperature; Thermal

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1. Introduction

Tigernut, *cyperus esculentus lativum* is a tuber of the family of cyperacae which produces rhizomes from the base of the tuner that is somewhat spherical. It is also known as yellow nut sedge, earth or ground almonds, "Souchet" in French, "ermandeh" in German and "Chufa" in Spanish. It is cultivated throughout the world and widely found in the northern parts of Nigeria (Chinma *et al;* 2010). Tigernut are edible, sweet, nutty, flavored tubers which contains protein, carbohydrates, sugar and lots of oil and fiber. They can be consumed either raw, cooked or roasted. Due to lack of information on their nutritional potential, tiger nut is grossly underutilized, the nuts being seasonal has a high-water content and has to be properly dried before storage so as to ensure longer shelf life. The harvest usually occurs in November or December and after harvesting and cleaning, it is spread on the ground to dry. The drying occurs usually in the sun and takes up to three months with the tigernut having to be turned manually every day for uniform drying. Sun-drying has been reported to have drawbacks of both requiring long drying time and poor product quality (Chou and Chua, 2001; Soysal et al; 2001; Therdthai and Zhou, 2009). An increase in the utilization of the crop and formulation of a wide range of possible product will require that the traditional drying techniques of tigernut be replaced with efficient drying system like the use of industrial dryer such as solar and hot air dryer (Ertekin and Yaldiz, 2004) Tigernut has been reported to have high nutritional content. Research has shown that 100g of tigernut contains 386Kcal, 7% protein, 6% fiber, 21% glucose, 35% fat (oil), 31% starch (Muhammad et al; 2001), and minerals (mostly phosphorus and potassium) and vitamins E and C (Belewu and Belewu 2007). Fig 1 shows the nature of tigernut when freshly harvested, dried and processed into flour.

Considering the well documented nutritional content of tigernut, substitution of wheat flour with tigernut flour for cake production is

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advocated as cake prepared from such composite flour could help in reducing protein, energy and micronutrients deficiency prevalent in developing countries such as Nigeria (Chinma et al; 2010).

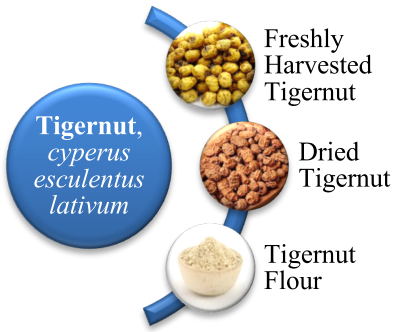

Fig. 1. Tigernut (Cyperus esculentus lativum).

A thermal property refers to the response of materials to the application of heat and change in their temperature. It is the physical properties of a solid body related to application of heat energy. They are those properties that control the thermal and storage of heat in a particular food (Lozano, 2006). Thermal properties of a material include Thermal conductivity, thermal diffusivity and specific heat capacity.

Thermal conductivity of a material is a measure of its ability to conduct heat. It is commonly denoted by K. Thermal conductivity is an important parameter in the design of food processing equipment. It controls the heat-flux in food during processing such as cooking, frying, freezing, sterilization, drying or pasteurization. Thermal conductivity is the rate of heat transfer through a material in steady state. This is influenced by a number of factors such as the moisture content, porosity and orientation of material (Stroshine and Hamann, 1994; Mohsenin 1990). Thermal conductivity data is needed for calculating energy demand for the design of equipment and optimization of thermal processing of foods (Polley *et al;* 1980). Thermal conductivity and other properties affect sensory quality of food as well as energy saving during processing (Opuku *et al;* 2006).

Thermal diffusivity of a material is the rate or the measure of how quickly a body can change its temperature. It is a material specific property for characterizing unsteady heat condition. This value describes how quickly a material reacts to a change in temperature. In other to predict cooling process or to stimulate temperature field, the thermal diffusivity must be known. It is a requisite for solving the Fourier Differential equation unsteady heat condition.

Specific heat is the measure of the amount of heat per unit mass required to raise the temperature by one degree Celsius. The relationship between heat and temperature change is usually expressed in the form described below, where C is the specific heat. The relationship does not apply if a phase change is encountered because the heat added or removed during change does not change temperature.

2. Material and Methods

2.1. Sample Preparation

Fig 2 illustrates the process of Tigernut flour production from the raw Tigernut. The locally sourced dried Tigernut from Owerri in the eastern part of Nigeria was sorted and washed very well for about three times to remove dirt. It was conditioned with moisture at different temperature ranges (70°C, 80°C, 90°C, 100°C) for 25 hours and dried in the oven at 60°C for 4 hours.

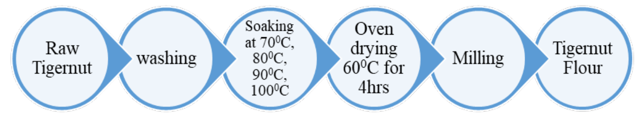

Fig. 2. General Process of Tigernut Flour Production

2.2. Methods For Proximate Analysis

Proximate analysis on the conditioned and dried Tigernut was carried out using the AOAC 2010 method, except for crude fat that the continuous solvent extraction method was described by Pearson (2000).

2.3. Determination of the percentage moisture absorption

The percentage moisture absorption was determined using the following equation.

$$\% ABC = \frac{F_f - F_i}{V_i - V_f} \times 100 \quad (1)$$

Where

ABC = absorption capacity

F_f = final weight of sample after water adsorption at different temperature

F_i = initial weight of the sample before moisture absorption at ambient temperature

V_i = initial volume of water at ambient temperature

V_f = final volume of water at a defined temperature.

3. Results and Discussion

3.1. Proximate Composition of Dried Tigernut at Different Temperature

The fiber Table 1 shows the result of the proximate composition of dried Tigernut conditioned at different temperatures. From the table, moisture content of the samples ranged from 0.97% - 6.45% and sample AOD had the highest value while sample AOA had the lowest value among the samples. From the table, it was seen that the moisture content of the samples increased with increase in temperature. This could be because temperature affects the moisture content of food sample. The moisture content of food is very important regarding its storage. An increase in moisture content indicates decrease in shelf life of a food. This shows that the sample conditioned at 70°C will last more in storage than other samples. The moisture content of all samples was within acceptable range limit of not more than 10% for long term storage of food. Moisture content of food is influenced by the type of food, food variety and the storage conditions (Oppong *et al;* 2015). The low Moisture content of foods enhances its storage stability by preventing the growth of mold and reducing biochemical reaction.

Table 1. Proximate Composition of Dried Tigernut at Different Temperature. Data presented are the mean value at standard deviation of the duplicate sample. Keyword: AOA, drity tigernut conditioned at 70ºc, AOB, dry tigernut conditioned at 80ºc, AOC, dry tigernut conditioned at 90ºc, AOD, dry tigernut conditioned at 100ºC.

Parameter (%)	(AOA)	(AOB)	(AOC)	(AOD)
Moisture	0.97 ± 0.04	1.55 ± 0.01	2.35 ± 0.01	6.45 ± 0.04
Ash	1.90 ± 0.01	0.63 ± 0.01	1.93± 0	1.65± 0.04
Fat	12.95± 0.11	15.89± 1.29	15.02± 1.14	16.63± 0.23
Protein	5.25± 0	3.94± 0	5.25± 0	8.75± 0
Crude fiber	33.78± 0.51	18.71± 1.23	22.42± 0.62	23.08± 0.54
Carbohydrate	45.20±0.57	58.68 ±1.23	55.60 ± 0	43.58 ±0.73
Energy value	1652.17 ± 5.59	1653.17 ± 4.37	1584.7 ± 4.29	1498.78 ± 1.64

The ash content of the samples ranged from 0.63%-0.93%. Sample AOC having the highest value and sample AOB having the lowest value. The results were similar to the range of 1.00%-3.00% as reported by Oppong *et al;* 2015. Ash content is an indication of the mineral content of a food. This therefore suggests that samples AOC could have a greater source of mineral than other samples. Ash content indicates the level of mineral and also it may be a quality for contamination in a given food sample (Karitha and Parimalavalli, 2014). Ash content indicates the inorganic constituent's composition after organic materials (fat, protein and carbohydrates) and moisture have been removed (Iwe *et al;* 2016) by oxidation/incineration. It is basically the mineral content of food samples. Minerals are essential nutrients which serves a variety of essential metabolic functions and among the part of molecules such as adenosine triphosphate (ATP), hemoglobin and deoxyribonucleic acid (DNA) (Iwe *et al;* 2016).

The fat content of the samples ranged from 12.95%-16.63% in contrast Oladele and Aina (2007) reported a higher fat value (33.13-35.44%) for a fresh brown variety of Tigernut. The lower fat level maybe beneficial as it ensures longer shelf life and stability for the product (Reche *et al;* 2000) due to all fats and fat containing foods contains some unsaturated fatty acid and hence are potentially susceptible to oxidative rancidity. Tigernut in comparison to other starchy roots and tubers such as sweet potatoes, yam and cassava have interestingly, significantly higher fat content and could contribute up to 60% of fat to a child's daily fat need and more than 49% of fat to an adult daily fat requirement (FAO/WHO/UNU; 2002). The fat content of Tigernuts is relatively similar to that of nuts and seeds but are higher than that of cereal.

The percentage protein content of the samples ranged from 3.94%-8.75%. It was seen from the result that sample AOB had the least value of protein while sample AOD had the highest value. The protein content of Tigernuts in this present study is in line with the range reported by (Tigernut traders *et al;* 2005). Crude protein is defined as the value obtained by quantitating nitrogen in a sample by Kjeldahl method in which nitrogen compound in the sample is degraded by sulfuric acid to become ammonia. (AOAC, 2010). Tigernut protein content compare well with that of cereals such as sorghum (Ndubuisi *et al*; 2009). Tigernut can be a source of plant protein if it is bioavailable.

The crude fiber content in the Table 1 ranged from 18.7%-33.78% with sample AOA having the highest and AOB having the lowest value, this is in contrast with the value of (Temle *et al;* 1998) who got 5.50% fiber content. Crude fiber reduces the rate of the release of glucose into the blood stream and also reduces the inter colonic pressure hence reducing the risk of colon cancer (Gibney, 1989). The percentage carbohydrate of the samples ranged from 43.57%-58.68%. Sample AOB had the least carbohydrate value while sample AOD had the least carbohydrate value. The high carbohydrate value in sample AOB suggested that it can be used in combating protein-energy malnutrition as there will be carbohydrate to provide energy to the body in order to spare protein so that protein could be used for its primary function (building the body and repairing worn out tissues) rather than being used as energy sources. Carbohydrates are good sources of energy (But and Batool; 2010).

3.2. Thermal Properties of Dried Tigernut

Table 2 shows the thermal properties of Tigernut at different temperatures. The data collected shows the thermal conductivity of dried Tigernut to increase with increase in temperature. The value ranged from 0.2866W/M°C to 0.3562W/M°C sample AOD that was conditioned at 100°C had the highest value followed by 90°C, 80°C and 70°C. This was in agreement with the work analyzed by Yang *et al;* (2002) Aviara and Haque, (2001) that worked don raw rice and ground sheanut kernel. Their work agreed that as the temperature and water content of a food sample increases, so as the thermal conductivity. Research done by Moshsenu, 1990 on the three crops (cassava, yam and plantain) found that the thermal properties of the crops are functions of their moisture content and temperature. Thermal conductivity is a measure of heat transferred across a specific medium. Thermal conductivity is higher at elevated temperature (Reza, 2012).

Table 2. Proximate Thermal Properties of Dried Tigernut. Data presented are the mean value at standard deviation of the duplicate sample. Keyword: AOA, dry tigernut conditioned at 70ºc, AOB, dry tigernut conditioned at 80ºc, AOC, dry tigernut conditioned at 90ºc, AOD, dry tigerrnut conditioned at 100ºc.

Parameter (%)	(AOA)	(AOB)	(AOC)	(AOD)
Thermal conductivity (W/M^0C)	0.2866	0.2965	0.3363	0.3562
Thermal diffusivity (M^2/S)	0.1123	0.1130	0.1135	0.2172
Specific heat capacity (Kj/ kg ºC)	1.8484	1.8499	1.185	1.9261

The thermal diffusivity ranged from 0.1123M^2/s to 0.2172M^2/s. The highest being the sample conditioned at 100°C and the lowest being the sample conditioned at 70°C. The results were compared with the work done by Pan and Singh (2001), Hobani and Al-Askar which showed a linear increase in the thermal diffusivity as temperature increases. Thermal diffusivity gives a measure of how quickly the temperature of a body will change when heated it cooled. Material with high thermal diffusivity will heat or cool quickly; conversely, substances with low thermal diffusivity will heat or cool slowly (Lewis, 1996).

The specific heat capacity ranged from 1.8484 Kj/Kg°C to 1.9261Kj/Kg°C. The specific heat capacity of the sample conditioned at 100°C was seen to be the highest while the sample conditioned at 70°C was the lowest. The values for the specific heat capacity where within the range as adapted by Anon (2005c, 2007a), Singh and Heldman (2001a) and Polley *et al;* (1980) the specific heat of a sample ranges at about 1.80Kj/Kg°C for potatoes. Hence specific heat capacity is a measure of the amount of heat energy required to change the temperature of 1kg of a material by 1°k. It is important as it will give an indication of how much energy will be required to heat or cool an object of a given mass by a given amount.

3.3. Moisture Absorption Capacity of Dry Tigernut at Different Temperature

Table 3 shows the moisture absorption capacity of the tiger nut analyzed at different temperature. The moisture absorption capacity of the sample range 46.6% to 94.4% at different temperature. The MAC was seen to be highest in sample AOB and least in sample AOD the water absorbed increases significantly as the temperature used in soaking the saw materials increased. Moisture absorption capacity is known as the amount of moisture taken up by food to achieve the decibel consistency and create quality food product. Therefore, the increased water moisture absorption capacity and the amount of water absorbed ids attributed to the increased temperature in comparison with the work done by Adegunwa et al (2017) who worked on the water absorption capacity of tigernut plantain it showed the plantain has highest amount of starch and fiber in the flour than that of tigernut critical function of protein on various food production.

Table 3. Moisture Absorption Capacity of Dry Tigernut at Different Temperature. Keyword: AOA, dry tiger nut conditioned at 70ºc, AOB, dry tigernut conditioned at 80ºc, AOC, dry tiger nut conditioned at 90ºc, AOD, dry tiger nut conditioned at 100ºC.

SAMPLE	Amount of Water Absorbed (ml)	Percentage Absorption Capacity
AOA	70	86.2%
AOB	75	94.4%
AOC	85	75.9%
AOD	140	46.6%

4. Conclusion

The study covered the proximate thermal properties and moisture absorption capacity of dry tiger nut. The study showed the effect of moisture and temperature on the thermal properties of the dry tiger nut. The thermal properties of the dry tiger nut ranger from 0.2866 w/mºc to 0.3363w/mºc for thermal conductivity and the sample conditioned at 100ºc had the highest value. For thermal diffusivity, the highest value was seen in the sample conditioned at 100oc with the value 0.2172 m2/s and specific heat capacity had the highest value at the sample conditioned at 100oc with the thermal conductivity of food are dependent on moisture and temperature and thermal properties of food generally depend on their proximate composition, moisture and temperature.

Tiger nut is a food being used worldwide which are also diversified for different product. Therefore, further studies should be carried out on the following.

I. The rheological properties of tiger nut

II. Kinetic rate of reaction of the nutrient with respect to time

III. Lastly, the thermal properties should be utilized for the design of equipment and for the mathematical model interims of stimulated and mass heat transfer in the material.

Conflict of interest

The authors declared that they have no conflict of interest.

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