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EFFECT OF TEMPERATURE ON THE PROXIMATE, FUNCTIONAL, CALORIFIC AND THERMAL PROPERTIES OF AFRICAN BREADFRUIT (*Treculia Africana*) SEED FLOURS

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ABSTRACT
This research is aimed to evaluate the effect of processing temperature on the proximate, functional, calorific and thermal properties of African breadfruit flours. The African breadfruit (Treculia africana) seeds were obtained from Relief Market, Owerri, Imo State, Nigeria. Samples were processed to flour while dried at 80 0C, 100 0C, 120 0C, and 140 0C for 2 hours. Proximate composition of the samples showed that; Moisture content (%) ranged from 12.07c±0.03 to 12.40a±0.02, Fat content (%) ranged from 0.24d±0.02 to 5.12b±0.01; Ash content (%) ranged from 1.24d±0.01 to 1.52a±0.02; Crude fibre content (%) ranged from 1.01d± 0.01 to 1.159a ±0.01; Protein content (%) ranged from 17.32d±0.05 to 18.51a±0.01; Carbohydrate content (%) ranged from 61.66d±0.08 to 62.51a±0.03; and Dry matter content (%) ranged from 87.21a±0.03 to 87.93c±0.06. The functional properties showed that; Bulk density (g/ml) ranged from 0.526c±0.00 to 0.572a±0.01; Foaming capacity (%) ranged from 3.75d±0.90 to 8.75a±0.90; Water absorption (g/g) ranged from 2.70c±0.07 to 3.15a±0.04; Oil absorption (g/g) ranged from 1.75b±0.04 to 2.25a±0.04; Swelling index ranged from 1.02b±0.01 to 1.07a±0.01 and Emulsion capacity (%) ranged from 71.01c±0.30 to 75.58a±0.80. The thermal and calorific properties showed that Thermal conductivity (W/m.oC) ranged from 0.2299d to 0.2692a; Specific heat capacity (Kj/Kg.oC) ranged from 1.5600d to 1.5990a; Thermal diffusivity (m2/s) ranged from 0.0924d to 0.0957a; Density (Kg/m3) ranged from 1288.04d to 1298.36a and Calorific value (Kcal/g) ranged from 324.71c to 368.29a respectively. The result in general showed that increase in drying temperature of the African breadfruit (Treculia africana) seeds has great influence on the quality of the final product, hence could be used in composites for confectionaries, instant breakfast meals and other food uses.

Keywords: Nutrients, Thermal properties, African breadfruit

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1.0 INTRODUCTION

The major nutrients in foods include carbohydrate, lipids, protein, minerals, vitamins and water which are derived from plant and animals (ogundeleolusola *et al.*, 2019). Animal flesh are consumed as food while plant is the only living organism that is capable of carrying out photosynthesis which makes them grow and are the major source of food in nature's chain (Shiyam *et al*., 2007). Food originated from plant may be classified into cereals, roots and tubers, sugars and syrups, legumes, pulses, nuts and oil seeds, vegetables and fruits (Ogundeleolusola *et al.*, 2019; Ekpo, 2001). Since creation, men has used a number of plants and plant products as a source of food and drugs and are always valued as such in fighting hidden hunger and in treatment of diseases.

Thermal properties of foods are important parameters needed for quality assessment, design, operation and control of processing equipment and good knowledge of these thermal properties enhances better understanding of effect of heat on food material during processing (Kiin-Kabari and Njoku, 2016; Njoku *et al.,* 2023). Application of low or high temperature to foods affects its constituents and causes changes on their functional quality which determines their usefulness in food formulations (Adeoye *et al.,* 2018; Njoku *et al.,* 2023).

African breadfruit (*Treculia africana*) is an indigenous food to many parts of tropical West and Central African countries such as Sudan, Mozambique, Angola and Nigeria. In Nigeria, it is most found in the Western and Eastern States (Ojinnaka *et al.,* 2013; Ayodele *et al.,* 2015). It is cultivated mainly 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). Presently, African breadfruit has become a delicacy and a specialized meal not only for the rich and the urban dwellers in Nigeria but also exported to cater for the African consumer's interest overseas (Nwabueze and Okocha, 2008).

The use of the African breadfruit can be diversified if the potentials of some of its constituents as raw materials in industrial applications can be established. This may present a more profiting utility of the crop, and hence the drive towards its voluminous cultivation (Ayodele *et al.,* 2015). Almost every food changes behaviour or exhibit rheological changes under various temperatures and therefore needs to be investigated. This study therefore provides the knowledge of the effect of heat processing on the proximate, functional, calorific and thermal properties of African breadfruit (*Treculia africana*) flour.

2.0 METHODS

2.1 Materials Procurement

African breadfruit (*Treculia africana*) seeds were obtained from Relief Market, Owerri, Imo State, Nigeria.

2.2 Sample Preparation

Matured breadfruit (*Treculia africana*) seeds were cleaned to remove foreign matter, it was hand sorted, cleaned, blanched at 105 ^{o}C for 5 min, drained, peeled, dehulled, and oven dried (Laboratory oven, DHG 9101.1SA) at 80 ^{0}C, 100 ^{0}C, 120 ^{0}C, and 140 ^{0}C for 2 hours respectively. The dried seeds were milled to flour using a disc mill (Atlas exclusive, Alzico Ltd mill) and sieved through a 250 mm mesh of US standard sieve. The samples were packaged in air tight properly labeled polythene sachets for further analysis.

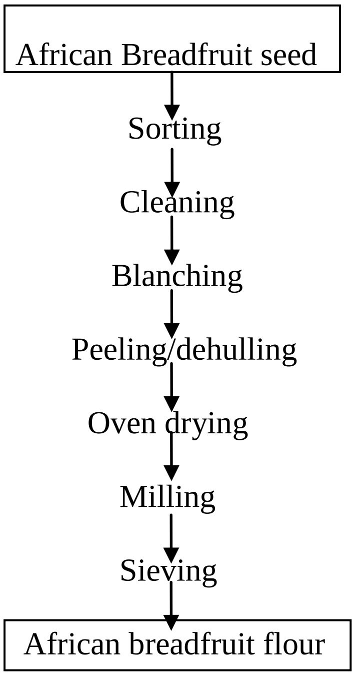

Fig 2.1: Flowchart for the production of African breadfruit (*Treculia africana*) seed flour (**Ajatta *et al.*, 2016**).

2.3 Determination of the Proximate Composition of Breadfruit (*Treculia africana*) Seed Flour.

The proximate compositions of the processed African breadfruit seed flours were determined according to the methods of AOAC (2012) and carbohydrate content was determined by difference as described by Ihekoronye and Ngoddi (1985).

2.3.1 Determination of moisture content

Moisture content was determined using the oven dry method. A clean dish with a lid was dried in an oven (Uniscope Surgifriend Medicals, England) at 105 ºC for 30 min. It was cooled in desiccators and weighed. Two grams (2 g) of sample was then weighed into the dish. The dish with its content was then put in the oven at 105 ºC and dried to a fairly constant weight. The loss in weight from the original sample (before heating) was reported as percentage moisture.

$$\% \text{ Moisture Content} = \frac{(W_2 - W_3)}{(W_2 - W_1)} \text{ X } 100$$

W_1 = Weight of Petri dish; W_2 = Weight of Petri dish + Weight of sample before drying
W_3 = Weight of Petri dish + Weight of sample after drying

2.3.2 Determination of ash content

Two grams (2 g) of sample was weighed into a crucible which had been pre-heated, cooled in desiccators and weighed soon after reaching room temperature. The crucible and content were then heated in a muffle furnace at 550 ºC for 6 h. The crucible was cooled in desiccators and weighed soon after reaching room temperature. The total ash was calculated as percentage of the original sample weight.

$$\% \text{ Ash Content} = \frac{(W_3 - W_1)}{(W_2 - W_1)} \text{ X } 100$$

W_1 = Weight of empty crucible; W_2 = Weight of empty crucible + sample before drying
W_3 = Weight of empty crucible + sample after drying

2.3.3 Determination of fibre content

Two grams (2 g) of the sample was defatted using diethyl ether. This was digested and filtered through the California Buchner system. The resulting residue was dried at 130 ºC for 2 h, cooled in desiccators and weighed. The residue was then transferred into a muffle furnace (Uniscope Surgifriend Medicals, England) and ignited at 550 ^{0}C for 30 min, cooled and weighed. The percentage crude fibre content was calculated as:

$$\% \text{ Crude Fiber} = \frac{\text{Loss in weight after incineration}}{\text{Original weight}} \times 100$$

2.3.4 Determination of fat content

Crude fat content was determined using soxhlet method. Samples were weighed into a thimble and loose plug fat free cotton wool was fitted into the top of the thimble with its content inserted into the bottom extractor of the soxhlet apparatus. Flat bottom flask (250 mL) of known weight containing 200 mL of hexane was fitted to the soxhlet apparatus. The apparatus was heated and fat extracted for 8 hrs. The solvent was recovered and the flask (containing oil and solvent mixture) was transferred into a hot air oven (Uniscope Surgifriend Medicals, England) at 105 ºC for 1 h to remove the residual moisture and to evaporate the solvent. It was later transferred into desiccators to cool for 15 min before weighing. Percentage fat content was calculated as.

$$\% \text{ Crude Fat} = \frac{\text{Weight of extracted fat}}{\text{Weight of sample}} \times 100$$

2.3.5. Determination of protein

The crude protein content was determined using the method described by Onwuka (2010). This was done by the Kjeldahl method. The total N_2 was determined and multiplied with factor 6.25 to obtain the protein content. The sample (1.0 g) was mixed with 10 ml of concentrated H_2SO_4 in a digestion flask. A tablet of selenium catalyst was added to it before it was heated in a fume cupboard until a clear solution was obtained (i.e. the digest) which was diluted to 100 ml in a volumetric flask using distilled water. The digest (10 ml) was mixed with equal volume of 45 % NaOH solution in a Kjeldahl distillation apparatus. The mixture was distilled into 10 ml of 4 % baric acid containing 3 drops of mixed indicator (bromoseresol green/methyl red). A total of 50 ml of distillates was collected and titrated against 0.02 N EDTA from green to deep red end points. The N_2 content and hence the protein content was calculated using the formula below:

$\% N_2 = (100/w \text{ x } (N \text{ X } 14)/1000 \text{ X } Vt/Va) – T – B$

$\% \text{ Protein} = \% N_2 \text{ x } 6.25$

Where,

W = weight of sample; N = Normality of titrant (0.02 H_2SO_4); Vt = Total digest volume (1000)

Va = Volume of digest analyzed (10 ml); T = Titre value of sample; B = Titre value of Blank.

2.3.6 Carbohydrate content determination

Carbohydrate content was determined by difference according to Ihekoronye and Ngoddy (1985). It was calculated using the formula below:

% Carbohydrate = 100 - % (fibre + protein + fat + ash + moisture contents).

2.4 Determination of the Functional Properties of African Breadfruit (*Treculia africana*) Seed Flour.

2.4.1 Water absorption capacity

The method described by Onwuka (2005) was used. One gram (1 g) of the flour sample was weighed into a 15 mL centrifuge tube and suspended in 10 mL of water. It was shaken on a platform tube rocker for 1 minute at room temperature. The sample was allowed to stand for 30 min and centrifuged (SM 800B Uniscope Surgifriends Medicals, England) at 500 rpm for 30 min. The volume of free water was read directly from the centrifuge tube. Density of water was taken to be 1 g/cm^3 as expressed below.

$$\text{WAC (\%)} = \frac{\text{Amount of water added} - \text{Free water}}{\text{Weight of Sample}} \times \text{Density of Water} \times 100$$

2.4.2 Oil absorption capacity

The method as described by Onwuka (2005) was used. One gram (1 g) of the flour was mixed with 10 mL refined oil in a centrifuge tube and allowed to stand at room temperature (30 ± 2 °C) for 1 h. It was centrifuged (SM 800 B Uniscope Surgifriends Medicals, England) at 500 rpm for 30 min. The volume of free oil was recorded and decanted. Oil absorption capacity was expressed as mL of oil bound by 100 g dried flour**.** Density of oil was taken to be 0.98 g/cm^{3}as expressed in the equation below.

$$\text{OAC (\%)} = \frac{\text{Amount of Oil added} - \text{Free Oil}}{\text{Weight of Sample}} \times \text{Density of Oil} \times 100$$

2.4.3 Bulk density

The method described by Onwuka (2005) was adopted for determination of bulk density. A graduated cylinder 10 ml was weighed and gently filled with the flour sample up to the 10 ml mark. The bottom of the cylinder was then tapped gently on a laboratory bench several times. This continued until no further diminution of the test flour sample in the cylinder after filling to mark was observed. Weight of cylinder plus flour were measured and recorded. Bulk density was calculated as follows.

$$\text{Bulk density (g/cm}^3\text{)} = \frac{\text{Weight of sample (g)}}{\text{Volume of sample (cm}^3\text{)}}$$

2.4.4 Foaming capacity

Foaming capacity was determined according to the method described by Onwuka (2005). Two grams (2 g) of flour sample was weighed and added to 50 ml distilled water in a 100 mL measuring cylinder. The suspension was mixed and properly shaken to foam and the total volume after 30 sec was recorded. The percentage increase in volume after 30 sec is expressed as foaming capacity.

$$\text{Foaming Capacity (\%)} = \frac{\text{Volume after whipping} - \text{Volume before whipping}}{\text{Volume before whipping}} \times 100$$

2.4.5 Swelling capacity (SC)

Swelling capacity was determined according to the method given by Robertson *et al.* (2000). About 100 mg of the sample was mixed with 10 ml of distilled water in a calibrated cylinder at room temperature. After equilibration for 8 h, the bulk volume was recorded and swelling capacity expressed as volume occupied by sample per gram of original sample dry weight.

$$\text{Swelling capacity \%} = \text{change in volume of sample/original weight of sample.}$$

2.4.6 Emulsification capacity

Two grams (2 g) of flour sample was blended with 25 ml seconds in a warring blender at 1600 rpm. After complete dispersion, 25 ml vegetable oil was added and blended for another 30 sec. The mixture was later transferred into a centrifuge tube and centrifuged at 1,600 rpm for 5 min. Calculation was carried out as follows:

Emulsification capacity (%) = X/Y x 100
Where,
X = height of emulsified layer; Y = height of whole solution in the centrifuged tube

2.5 Thermal Properties and Calorific Values of Breadfruit (*Treculia Africana*) Seed Flour.

The equations below on the thermal property models for food components given by Chio and Okos (1986), was used to calculate the individual thermal properties of the food components by applying the fractions obtained from the proximate compositions before summation to get the total at the various drying temperatures.

2.5.1 Determination of thermal conductivity

The thermal conductivity of the sample at 80 ^{o}C was calculated for protein using.
$K_p = \Sigma Xi_p P$
Where
K = Thermal conductivity of protein; Xip = summation of the thermal conductivity of protein
P = Fraction of the protein contained in the sample.
The above formula was applied to other proximate compositions of the sample. At the end, the thermal conductivity of all the individual proximate composition was summed to get the thermal conductivity of the sample using the formular below;
$K = K_p + K_{cf} + k_f + k_c + k_a$
Where
K_p = thermal conductivity of protein; K_{cf} = thermal conductivity of crude fibre; K_f = thermal conductivity of fat; K_c = thermal conductivity of carbohydrate; K_a = thermal conductivity of ash

The sample was repeated for the sample at 100 ^{0}C, 120 ^{0}C, and 140 ^{0}C respectively.

2.5.2 Determination of thermal diffusivity

Thermal diffusivity of the protein content of the sample was calculated at 80 ^{0}C using;
$\alpha_P = \Sigma Xi_P XP$
Where
αp = thermal diffusivity of protein; Xip = Summation of the thermal diffusivity of protein
P = the fraction of the protein contained in the compositions of the sample.

The thermal diffusivity of all the individual proximate composition was summed up to get the thermal diffusivity of the sample using the formula below;

$X_{80^{o}C} = X_{Protein} + X_{Crudefibre} + X_{Fat} + X_{Carbohydrate} + X_{Ash}$

The same was repeated for the sample at 100 ^{0}C, 120 ^{0}C, and 140 ^{0}C.

2.5.3 Determination of the specific heat

Specific heat of the protein content of the sample was calculated at 80 ^{0}C using;
$Cp_p = \Sigma Xi_P P$

Where
Cp_p = specific heat of protein; Xip = Summation of the specific heat of protein,
P = fraction of the protein contained in the sample.

The above formular was applied to other proximate compositions of the sample.

The specific heat of all the individual proximate composition was summed up to get the specific heat of the sample using the formula below;

$$Cp_{80\,^0C} = Cp_{Protein} + Cp_{Crudefibre} + Cp_{Fat} + Cp_{Carbohydrate} + Cp_{Ash}$$

The same process was repeated for the samples at 100 ^{0}C, 120 ^{0}C, and 140 ^{0}C respectively.

2.5.4 Determination of density
Density of the protein content of the sample was calculated at 80 ^{0}C using;
$$\rho_p = \Sigma Xi_P \rho$$
Where
ρp = density of protein; Xip = summation of the density of protein; P = the fraction of the protein contained in the sample.

The above formula was applied to other proximate compositions of the sample.

Density of all the individual proximate composition was summed up to get the density of the sample using the formula below;
$$\rho_{80\,^0C} = \rho_{Protein} + \rho_{Carbohydrate} + \rho_{Crudefibre} + \rho_{Ash} + \rho_{Fat}$$

The same was repeated for the sample at 100 ^{0}C, 120 ^{0}C, and 140 ^{0}C respectively.

At the end, the results of the thermal properties of the sample at 80 ^{0}C, 100 ^{0}C, 120 ^{0}C, and 140 ^{0}C were tabulated.

2.5.5 Determination of Calorific Value
The total calorific energy value was calculated using the equation as described by Serebermich *et al.* (2016).
TVC = (Carbohydrate + Protein) 4 + (Lipid) 9 (Kcal/g)
This is based on the fact that one (1 g) of carbohydrate and protein has calorific value of 4 Kcal/g and 9 Kcal/g respectively.

2.6 Statistical Analysis
Data generated in this research were subjected to analysis of variance (ANOVA) as described by Ihekoronye and Ngoddy (1985). Tukey's test was used to separate means and the differences between the means was considered to be significant at $P<0.05$.

3.0 RESULTS AND DISCUSSION

3.1 Effect of Different Processing Temperatures on the Proximate Composition of African Breadfruit Flours.

Table 3.1 shows the result of the proximate composition of African breadfruit flours produced at different processing temperatures of 80 ^{o}C, 100 ^{o}C, 120 ^{o}C, and 140 ^{o}C. The moisture content (%) of the African breadfruit flour ranged from $12.07^c \pm 0.03$ to $12.40^a \pm 0.02$ with significant difference ($p>0.05$). African breadfruit flour obtained at 80 ^{0}C had the highest value of moisture content while that obtained at 140 ^{0}C had the least value. This showed clearly that increase in drying temperature favoured the sample's moisture contents hence a reduction which would ensure greater shelf life, although within the allowable limits of the moisture content of flours. Therefore in a very clear term, the higher the drying temperature, the lower the moisture content of the African breadfruit flour. Nasir and Titilayo, (2020), reported that the moisture content of instant plantain flour (8.50 %) was significantly ($p< 0.05$) higher than that of instant breadfruit flour (6.93 %). Moisture content obtained in the present study is higher than that reported (10.75 %) by Adegunwa *et al.* (2014), and are within the stipulated moisture content for flours. The fat content (%) of the African breadfruit flours ranged from $0.24^{d}\pm0.02$ to $5.12^{b}\pm0.01$ with significant difference ($p>0.05$), with the sample obtained at 80 ^{0}C having the highest value while that obtained at 140 ^{0}C had the lowest value. This thus means that the fat content decreased significantly with increased temperature hence the fat content of the African breadfruit was seriously affected by the increased temperature. The percent fat content of instant plantain–breadfruit flour followed the same trend of 1.64 % to 2.53 % (Nasir and Titilayo, 2020), which can be compared with the values obtained in this present study but completely disagrees with the fat content of African breadfruit flour obtained at 80 ^{0}C in this present work. The positive impact breadfruit has on the fat contents of composite flour suggests nutrient enrichment in the flour blends because of high protein and fat in African breadfruit (Nwabueze *et al.*, 2008). This has shown that increasing the drying temperature of African breadfruit would greatly destroy or degrade the fat content of the resultant flour.

Table 4.3: Proximate composition of African breadfruit flour produced at different processing temperatures (80 ^{o}C, 100 ^{o}C, 120 ^{o}C, and 140 ^{o}C).

PROPERTIES (%)	80 ^{O}C	100 ^{O}C	120 ^{O}C	140 ^{O}C	LSD
Moisture content	$12.40^{a}\pm0.02$	$12.33^{a}\pm0.03$	$12.24^{c}\pm0.03$	$12.07^{c}\pm0.03$	0.09
Fat content	$5.12^{b}\pm0.01$	$0.54^{b}\pm0.06$	$0.39^{b}\pm0.01$	$0.24^{d}\pm0.02$	0.08
Ash content	$1.24^{d}\pm0.01$	$1.38^{c}\pm0.02$	$1.44^{b}\pm0.05$	$1.52^{a}\pm0.02$	0.04
Fibre content	$1.01^{d}\pm0.01$	$1.06^{c}\pm0.01$	$1.11^{b}\pm0.01$	$1.159^{a}\pm0.01$	0.02
Protein content	$18.51^{a}\pm0.01$	$18.14^{b}\pm0.03$	$17.77^{c}\pm0.03$	$17.32^{d}\pm0.05$	0.08
Carbohydrate content	$61.66^{d}\pm0.08$	$61.68^{c}\pm0.01$	$61.95^{b}\pm0.04$	$62.51^{a}\pm0.03$	0.10
Dry matter content	$87.60^{a}\pm0.02$	$87.21^{a}\pm0.03$	$87.76^{b}\pm0.07$	$87.93^{c}\pm0.03$	0.09

The ash content (%) of the African breadfruit flours ranged from $1.24^{d}\pm0.01$ to $1.52^{a}\pm0.02$ with no significant difference ($p<0.05$), hence the African breadfruit flour obtained at 80 ^{0}C had the least ash content while that obtained at 140 ^{0}C had the highest ash content. From the table of results, the ash content increased exponentially from 80 ^{0}C to 140 ^{0}C. The ash content of breadfruit-blend samples as reported by Nasir and Titilayo (2020), ranged from 2.36 % to 2.99 %, which is higher than the values obtained in this present work. The high percent ash content of instant breadfruit flour as suggested could be a good source of minerals, hence improving the mineral content of the composite flours (Nasir and Titilayo, 2020). This has shown that African breadfruit seeds when processed, considerable attention should be given to the drying temperature which would greatly influence the ash content which also in-turn influences the mineral content due to high drying temperature. The crude fibre content (%) ranged from $1.01^{d}\pm0.01$ to $1.159^{a}\pm0.01$ with no signicant difference ($p<0.05$). The African breadfruit flour sample obtained at 80 ^{0}C had the least crude fibre content while that obtained at 140 ^{0}C had the highest value of fibre content. It was noticed from the trend of the result that the crude fibre content increased with increasing temperature which implied that temperature is a serious factor which affects the property of foods. The fiber content of breadfruit is generally lower than plantain and most food components (Nasir and Titilayo, 2020). Fiber is reported to have beneficial effects on preventing colon cancer because it aids digestion and facilitates bowel movement (Shankar and Lanza, 1991). With the values shown in the table, the fibre content has proven an increase as the drying temperature of the seeds was increased which implies that higher drying temperature favoured the crude fibre content of African breadfruit flour, which would consequently improve their chances of having beneficial effect to prevent colon cancer by aiding digestion and facilitating bowel movement.

The protein content (%) of the African breadfruit flours ranged from $17.32^{d}\pm0.05$ to $18.51^{a}\pm0.01$ with significant difference (p>0.05) where the sample obtained at 80 ^{0}C had the highest protein content while that obtained at 140 ^{0}C had the least value of protein content. As shown in the result table, the protein content of the African breadfruit flours decreased with increased temperature. The African breadfruit can very well be used to blend or formulate composites with other flours to enrich the protein quality either for confectioneries or other uses. Its high protein content makes it a very expensive delicacy eaten by all in the eastern part of Nigeria. The protein contents of African breadfruit flour blends as reported by Nasir and Titilayo, (2020), varied significantly from 3.30 % to 3.59 %, which was low compared to the value obtained in this research work. The positive impact breadfruit has on the protein contents of composite flours suggest nutrients enrichment in the flour blends because of high protein in breadfruit (Nwabueze *et al.,* 2008). The trend of the result as shown has proven that increase in drying temperature of the seeds decreased significantly the protein content of African breadfruit flour due to denaturation of protein, therefore moderate drying temperature would help preserve or improve the protein content of the processed flour. The carbohydrate content (%) ranged from $61.66^{d}\pm0.08$ to $62.51^{a}\pm0.03$ with significant difference (p>0.05) where African breadfruit flour obtained at 80 ^{0}C had the least value of carbohydrate while that obtained at 140 ^{0}C had the highest value which showed that the carbohydrate content improved with increase in drying temperature and would consequently reduce at decreased drying temperature. The dry matter content of the African breadfruit flour is described as the quantity left after the moisture content has been determined and ranged from $87.21^{a}\pm0.03$ to $87.93^{c}\pm0.03$ where African breadfruit flour obtained at 100 ^{0}C had the least dry matter content while that obtained at 140 ^{0}C had the highest dry matter content with significant difference at (p>0.05).

3.2 Effect of Different Processing Temperatures on the Functional Properties of African Breadfruit Flours.

Table 3.2 below shows the results of the effect of different processing temperatures (80 ^{o}C, 100 ^{o}C, 120 ^{o}C, and 140 ^{o}C) on the functional properties of African breadfruit flours. The bulk density (g/ml) of African breadfruit flour ranged from $0.526^{c}\pm0.00$ to $0.572^{a}\pm0.01$ with sample processed at 80 ^{0}C having the highest value while sample processed at 140 ^{0}C had the least value with no significant difference (p>0.05). It could be seen that the bulk density decreased as the drying temperature increased which implies that increase in drying temperature of African breadfruit seeds decreases the bulk density of the processed flour. Generally, high bulk density improves dispersibility and lessens paste viscosity, an essential consideration in baby feeding (Padmashrre *et al.,* 1987; Nasir and Titilayo, 2020). Ajatta *et al.* (2016), reported on the functional properties of wheat-breadfruit-cassava composite flours and the bulk density ranged from 0.82 g/ml - 0.85 g/ml which is higher than the value obtained in this study. The values obtained for the bulk densities were still lower than the range reported by Malomo *et al. (*2012) in a study on yam-soy blend (0.71 - 0.8 g/ml). Loose structure of the starch polymers could result in low bulk density. Low bulk density is desired in flour blends as it's contributes to lower dietary bulk, ease of packaging and transportation (Aluge *et al*., 2016). The foaming capacity (%) ranged from $3.75^{d}\pm0.90$ to $8.75^{a}\pm0.90$ with sample processed at 80 ^{0}C having the least value while sample obtained at 140 ^{0}C had the highest value of foaming capacity with significant difference (p>0.05). Foams are formed by the trapping of pockets of gas in liquid or solid food (Cantat *et al.*, 2013). In most foam, the gas volume is large, with thin liquid or solid films separating the gas regions. Foams in foods and other materials often disappear with time. Good foam capacity and stability are desired attributes for flours intended for use in the production of various baked products such as angel cakes, muffins, *akara*, cookies, etc., and also perform as functional agents in many other food formulations (El-Adawy, 2001). Protein in the dispersion can lower the surface tension at the air-water interface, thus often due to protein which forms continuous cohesive thin film around air bubbles in the foam (Kaushal *et al*., 2012).

Table 3.2: Functional properties of African bread fruit flour produced at different processing temperatures of 80 ^{o}C, 100 ^{o}C, 120 ^{o}C, and 140 ^{o}C.

PROPERTIES	80 ^{O}C	100 ^{O}C	120 ^{O}C	140 ^{O}C	LSD
BD (g/ml)	$0.572^{a}\pm0.01$	$0.556^{b}\pm0.00$	$0.541^{b}\pm0.00$	$0.526^{c}\pm0.00$	0.17
FC (%)	$3.75^{d}\pm0.90$	$5.00^{c}\pm0.00$	$6.25^{b}\pm0.90$	$8.75^{a}\pm0.90$	0.08
WAC (g/g)	$3.15^{a}\pm0.04$	$2.70^{c}\pm0.07$	$2.90^{b}\pm0.07$	$3.10^{a}\pm0.07$	0.12
OAC (g/g)	$2.25^{a}\pm0.04$	$2.10^{a}\pm0.07$	$1.80^{b}\pm0.07$	$1.75^{b}\pm0.04$	0.21
SI	$1.05^{a}\pm0.01$	$1.05^{a}\pm0.01$	$1.02^{b}\pm0.01$	$1.07^{a}\pm0.01$	0.03
EC (%)	$75.58^{a}\pm0.80$	$72.95^{b}\pm0.60$	$71.01^{c}\pm0.30$	$72.73^{b}\pm0.30$	0.50

BD = Bulk Density (g/ml); WAC = Water Absorption Capacity (g/g); FC = Foaming Capacity (%); OAC = Oil Absorption Capacity (g/g); SI = Swelling Index; EC = Emulsion Capacity (%).

Water absorption capacity (g/g) of the African breadfruit flours ranged from $2.70^{c}\pm0.07$ to $3.15^{a}\pm0.04$ where the sample processed at 100 ^{0}C had the least value and sample processed at 80 ^{0}C had the highest water absorption capacity with no significant difference (p>0.05). The reason for the fluctuation of the water absorption capacity of the seed flour could be as a result of irregular heating during the drying process using the hot air oven. Nasir and Titilayo, (2020), reported the water absorption capacity of African breadfruit composite flour to be significantly different (P<0.05) and ranged from 250 % to 335 % which conformed with the findings of Adegunwa *et al*, (2014) and Ajatta, *et al.*, (2016) and in turn agrees with the findings in this research. The observed trend in water absorption capacity might be due to the amount of hydrophobic amino acids because of high protein content of breadfruit that hinders the ability of its starch to absorb water (Kaur and Singh, 2006). The tendency of flours to absorb water and swell is known as water absorption capacity, and it improves yield and consistency of food products, thus given the food bulkiness (Osundahunsi *et al.,* 2003). The oil absorption capacity (g/g) ranged from $1.75^{b}\pm0.04$ to $2.25^{a}\pm0.04$ with sample processed at 80 ^{0}C having the highest while sample processed at 140 ^{0}C had the least value of oil absorption capacity with significant difference (p>0.05). This implies that increase in drying temperature decreased the oil absorption capacity of African breadfruit seed flour possibly due to the influence of heat on the particle size of the flour. The ability of flour to retain flavor is governed by its oil absorption capacity, which is very important in food formulations (Odoemelam, 2000), this thus mean that sample processed at 140 ^{0}C would retain flavor more than other samples due to its low oil absorption capacity while sample processed at 80 ^{0}C will not retain flavor as much as other samples due to its high oil absorption capacity. This current findings in not in agreement with the report giving on African breadfruit composite flour where there was significant difference (p< 0.05) and increase in oil absorption capacity of the composite flours as the amount of breadfruit flour included in the composite increased, ranged from 0.99 g/g to1.39 g/g (Nasir and Titilayo, 2020). This work can be compared with the breadfruit's oil absorption capacity obtained in a study between the values 1.25 g/g and 2.8 g/g as reported by Appiah *et al.*, (2011) and Odoemelam, (2005) respectively. The flavor holding capabilities of flours is high with lower oil absorption capacity (Oladele and Aina, 2007; Nasir and Titilayo, 2020). Swelling index of African breadfruit flour ranged from $1.02^{b}\pm0.01$ to $1.07^{a}\pm0.01$ with sample processed at 140 ^{0}C having the highest value while sample processed at 120 ^{0}C had the least value of swelling index with no significant difference ($p<0.05$). From the trend of the result, the samples processed at 80 ^{0}C and 100 ^{0}C both had same swelling index of $1.05^{a}\pm0.01$, where the entire result fluctuated as the temperature at which the samples were dried increased. The swelling capacity of instant plantain-breadfruit flours varied significantly from 4.62 g/g to 7.38 g/g (Nasir and Titilayo, 2020), this variance may be attributed to the level of protein because a high protein content in flour reduces the starch granules affinity for water hence decreasing the swelling power (Aprianita *et al.*, 2009). Swelling capacity is also a function of the ratio of α-amylose and amylopectin ratios, and low amylopectin contents in flour will result in low swelling capacity. Finally, the emulsion capacity (%) of the African breadfruit seed flour ranged from $71.01^{c}\pm0.30$ to $75.58^{a}\pm0.80$ where sample processed at 80 ^{0}C had the highest value while sample processed at 120 ^{0}C had the least value of emulsion capacity with no significant difference ($p>0.05$). From the trend of the result, the emulsion capacity of the breadfruit seed flour decreased as the temperature decreased which implies that drying temperature has a significant role in the functional properties of flours. The result is also in agreement with those of Lin *et al*. (1974) on the emulsifying properties of sunflower and soybean flours and protein concentrates.

3.3 Effect of Different Processing Temperatures on the Thermal and Calorific Properties of African Breadfruit Seed Flours.

The table below shows the effect of different processing temperatures of 80 ^{o}C, 100 ^{o}C, 120 ^{o}C, and 140 ^{o}C on the thermal and calorific properties of African breadfruit flours. The thermal conductivity (W/m.^{o}C) of African breadfruit flour processed at different temperature ranged from 0.2299^{d} to 0.2692^{a}, where sample processed at 80 ^{0}C had the least value while sample processed at 120 ^{0}C had the highest value whereas there was a decrease at 140 ^{0}C with significant difference ($p>0.05$). This implied that thermal conductivity of the African breadfruit flour increased with increase in temperature which means as the drying temperature increased, the rate of conductance of heat also increased. Compared to other fluid foods, Choi and Okos (1983) found that the thermal conductivity of tomato juice increased with increasing temperature in the range of 20-150 ^{o}C but decreased with increasing solid content in the range of 4.8-80 %. Similarly, Tansakul and Chaisawang (2006) found that the thermal conductivity of coconut milk increased linearly with temperature but decreased linearly with fat content. They suggested that the influence of fat content on thermal conductivity was stronger than that of temperature (Sopa *et al.*, 2008). The specific heat capacity (Kj/Kg.^{o}C) of African breadfruit flours ranged from 1.5600^{d} to 1.5990^{a}, where the highest value was showed by sample at 140 ^{0}C while sample processed at 80 ^{0}C had the least value with significant difference ($p>0.05$). This implies that increase in drying temperature increases with the specific heat capacity of African breadfruit flour. Abodenyi *et al.* (2018), on their report on some engineering properties of breadfruit seed varieties relevant to handling recorded that the increase in moisture content resulted to increase in specific heat capacity of the two varieties. *Var. Africana* increased from 2869.70 J/kg.^{0}C to 3909.63 J/kg.^{0}C while, *Var. Inversa* increased from 2811.35 J/kg.^{0}C to 3777.30 J/kg.^{0}C as the moisture increased from 6.85 to 28.85 %. The increase in specific heat capacity of breadfruit varieties is in agreement with the findings of Abodenyi *et al.* (2018), but the result of this research is significantly lower than the values obtained. This property can be used to determine the amount of heat required in the processing of the seed. It can also be used to design equipment and facilities for drying, preservation and processing of African breadfruit seed, for making industrial products such as beverages, snacks pastas, flours, and cosmetics and in the pharmaceuticals, the knowledge of the specific heat capacity is important (Abodenyi *et al.*, 2018).

Table 3.3: Thermal and calorific properties of African bread fruit flour produced at different processing temperatures (80 ^oC, 100 ^oC, 120 ^oC, and 140 ^oC)

PROPERTIES/SAMPLE	80 ^OC	100 ^OC	120 ^OC	140 ^OC	LSD
Thermal Conductivity (W/m.^{o}C)	0.2299^d	0.2357^c	0.2692^a	0.2621^b	0.11
Specific Heat Capacity (Kj/Kg.^{o}C)	1.5600^d	1.5730^c	1.5870^b	1.5990^a	0.09
Thermal Diffusivity (m^2/s)	0.0924^d	0.0942^c	0.0956^b	0.0957^a	0.01
Density (Kg/m^3)	1298.36^a	1294.13^b	1289.38^c	1288.04^d	0.15
Calorific value(Kcal/g)	366.76^b	324.71^c	368.29^a	368.19^a	0.13

The thermal diffusivity (m^2/s) ranged from 0.0924^d to0.0957^a , however the sample processed at 80 ^{0}C had the least value while sample at 140 ^{0}C had the highest value of thermal diffusivity with no significant difference ($p<0.05$). In this case, an increase in temperature increased the thermal diffusivity of African breadfruit seed flour. Sopa *et al.* (2008) reported that the thermal diffusivity of some food flour ranged from 0.770×10^{-7}- 0.831×10^{-7} m^2/s with standard deviations varying from 0.011×10^{-7} to 0.063×10^{-7} m^2/s which is not in agreement but can be compared with the values obtained. The thermal diffusivities of the flours as verified were greatly influenced by the increased drying temperatures, which with no significance increased the thermal diffusivities. Density (ρ) is the unit mass per unit volume. The SI unit for density is (Kg/m^3). In particular, when the foodstuff is a porous solid, density plays an important role in heat transfers intrinsically or through the definition of porosity. From the table shown, the density (Kg/m^3) of the processed African breadfruit flour ranged from 1288.04^d to 1298.36^a with sample processed at 140 ^{0}C having the least value while sample processed at 80 ^{0}C had the highest value of density with no significant difference ($p>0.05$), which is an indication that the density of African breadfruit flour decreased with increase in temperature. Sopa *et al.* (2008), in their work on effects of temperature and concentration on thermal properties of cassava starch solutions reported that the value of cassava starch ranged from 1044.0-1119.8 kg/m^3, the standard deviation was in the range of 1.7-10.9 kg/m^3. The principal solids content of these samples is carbohydrate starch granule and its concentration directly affects the density (Sopa *et al.*, 2008). Finally, the calorific value (Kcal/g) of the African breadfruit flour ranged from 324.71^c to 368.29^a Kcal/g where sample processed at 100 ^{0}C had the least value hence sample processed at 120 ^{0}C had the highest calorific value with no significant difference ($p>0.05$), where the values fluctuated as the temperature was increased. The results for the caloric value obtained agreed with the value reported by Priyanka *et al.* (2018), that the calorific value of composite flour was calculated to be 346.67 Kcal/g where as in wheat flour it was found to be 341.69 Kcal/g and significant difference was found between energy content of composite flour and wheat flour at $p<0.01$ level of significance.

4.0 CONCLUSION AND RECOMMENDATION

From the result of the analysis carried out on the effect of different processing temperatures on the proximate composition of African breadfruit flour which were processed at 80^{0}C, 100^{0}C, 120^{0}C and 140^{0}C showed that the moisture, fat and protein contents of the samples decreased from 80 ^{0}C to 140^{0}C which would favour the keeping quality of the flours and as a result of denatured protein. The result also showed that the ash, fibre, carbohydrate and dry matter contents of the flours were significantly increased as the drying temperature increased which at 120^0C to 140^0C can be adopted by commercial manufacturers of flours where high ash, fibre and carbohydrate contents are desired in flours. Finally, the effect of drying temperature on the thermal properties of African breadfruit flours were generally increased as drying temperature was increased. At 140^0C, almost all the properties were increased, except in few where fluctuations were noticed and a decrease in density of the flours. This would help guide food processors and engineers, including commercial food manufactures on the best choice of temperature and processing practices.

The investigation on the pasting characteristics of the processed flour is hereby recommended, so as to assist the food manufacturers to understand the proper food use and applications of the processed flours in respect to its visco-elasticity. Finally, African breadfruit flour is recommended for use in food formulations, as food binders, thickeners, instant swallow, and composites formation with other flours to enrich the nutritional quality of foods either in confectioneries or other uses.

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