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Research Paper

Physicochemical, functional and pasting properties of starch from breadfruit (*Artocarpus altilis*) in gurudi snack production

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Abstract. This study investigated the physicochemical, functional, pasting properties of starch from breadfruit (*Artocarpus altilis*) and sensory attributes of gurudi snack produced from the starches. Cassava starch gurudi was used as control. Firm, ripe and fresh breadfruits used for this study were processed to extract starch using standard procedures into fermented (FBS) and unfermented breadfruit starches (UFBS), with fermentation done for 24 h. Starches were analyzed for their physicochemical, functional and pasting properties. The starches were used to produce gurudi and product subjected to proximate analysis and sensory evaluation using a five-point hedonic scale. Results for the chemical composition of starches ranged from 13.33 to 18.37% for moisture, 0.10 to 0.83% for ash, 0.49 to 0.59% for fat, 1.83 to 3.13% for protein, 0.40 to 1.77% for fibre, 77.42 to 82.53% for carbohydrate, 25.20 to 27.52% for amylose, 44.58 to 56.92% for amylopectin, 70.25 to 84.44% for starch, 3.03 to 4.04% for sugar and 3.67 to 4.41% for starch damage respectively. Results of chemical analysis on breadfruit starches showed a significant difference ($p < 0.05$) in protein, fibre and starch damage over cassava starch. Functional properties showed that both breadfruit starches had increased values in water absorption capacity (WAC) and swelling power over cassava starch. Unfermented breadfruit starch (UFBS) had increased value for color over fermented breadfruit (FBS) and cassava starches. FBS and UFBS were not significantly different ($p < 0.05$) in bulk density and swelling power. Pasting properties showed significant different ($p < 0.05$) between cassava starch and breadfruit starch in all pasting properties except peak viscosity where all the starches were not significantly different ($p > 0.05$). Proximate analysis of the product (gurudi) showed that cassava starch gurudi had higher values for moisture 6.47 to 14.23%, ash 1.20 to 1.34%, fat 7.06 to 10.71% and protein 1.80 to .30% over breadfruit Gurudi. Unfermented and fermented breadfruit gurudi showed higher fibre of 3.13% and carbohydrate of 82.34% respectively, which may be as a result of the difference in starch origin and processing method (Fermentation). The protein content of cassava starch gurudi (CSG) and unfermented breadfruit starch gurudi (UFBSG) were not significantly different ($P > 0.05$). The present study showed breadfruit starch as a potential raw material for the production of gurudi based on the proximate and sensory quality and other industrial application based on pasting properties.

Keywords: Physicochemical, functional, pasting, starch, gurudi, proximate.

INTRODUCTION

Breadfruit *(Artocarpus altilis)*, is from the plant family *moraceae*, of the order *Rosales*, although officially classified as *Artocarpus altilis.* It is also known by other names such as “Ulu” in Hawaii, “Udia eto” in Ibibio (South-South), Ukwa in Igbo (South-East) Nigeria, “Panapan” in other areas of the world (Zerega, 2004).

Breadfruit is a round, green, seedless fruit which serves dual purpose; either as vegetable when matured but not

Figure 1. Matured seedless breadfruits.

ripe or as a fruit when matured and ripe. Although the quantity of protein in breadfruit is low, its quality is excellent (Liu *et al*., 2015), and it contains a high percentage of carbohydrate primarily starch (Graham and De Bravo 1981), which is an excellent source of calories for diet, rich source of fibre, vitamin C, minerals such as Potassium, and phytochemicals such as flavonoid (Turi, 2015), with an additional nutritional benefit of being gluten free (Jones *et al*., 2011).

Breadfruit is a useful substitute of root crops that is regarded as a poor man's substitute for yam in Nigeria because it is used in several traditional food preparations of yam but costs less than one-third of the cost of procuring yam in the market (Mayaki, 2003). Breadfruit has been processed into many forms such as starch (Akanbi *et al*., 2009) for its utilization in the food industries. They have also been used in salad dressings (Singh *et al.,* 1991) and cookies preparation (Kulp *et al*., 1994).

Across all civilization, culture and countries, starch has been the major source of energy in human diet (Eke, 2006). Since time immemorial when starch is mentioned, only starch from roots, tubers and grains quickly comes to mind and are the most utilized starch in Nigeria while starches from other sources like breadfruit are underutilized.

Gurudi is a baked starch based snack and a delicacy produced from cassava starch in combination with coconut, sugar, salt, spices and water (Sanni *et al*., 2006).

Breadfruit represents a valuable food resource, although its current usage is limited by poor storage properties of the fresh fruit (Liu *et al.*, 2014) leading to increased post-harvest loses. Conversion to flour and starch which has been performed by several investigations provides a more stable storage form (Nochera and Ragone, 2016). Development of a convenient, nutritious, ready-to-eat breadfruit product could provide a local snack food with acceptable taste and nutritional value (Zerega, 2004). It is estimated that over 10million tones of breadfruit is produced in South Western Nigeria annually where it has been used in a number of food product (Akanbi *et al*., 2009). The full exploitation and utilization of breadfruit as food for man has been hindered by the rapid post-harvest losses, accounting for well over 60 to 70% of the harvest produced in 2 to 3 days (Ragone, 2007). It has been reported that breadfruit yield, in terms of food are superior to other starchy staples such as yam and cassava (Singh, 2009). Therefore, breadfruit starch production will provide solution to the high post-harvest losses as well as raw material for variety of products including gurudi which will add to the list of ready to eat snacks for consumers.

There is little or no information on the use of breadfruit starch in gurudi production. Therefore, the objective of this study is to extract and evaluate the effect of fermentation on the physicochemical, functional and pasting properties of starch from breadfruit and its inclusion in gurudi snack production.

MATERIALS AND METHODS

Sample collection

Samples of seedless breadfruit (*Artocarpus altilis*) were collected from five different breadfruit trees planted in Ikot Akpa Nkuk, Ukanafun Local Government Area of Akwa Ibom State, while cassava tubers were collected from the demonstration farm, Rivers State University. Other materials such as coconut, ground sugar, salt, spices, (nutmeg) and water were purchased from creek road market, Port-Harcourt, Rivers State, Nigeria (Figure 1).

Sample preparation

Breadfruit starch was extracted using a method described by Agboola *et al*. (1990), with some modifications in sifting and drying time (Figure 2). Eight sizeable seedless breadfruits were sorted, washed, peeled and chopped

Table 1. Recipe for gurudi formulation.

Samples	Cassava starch (g)	Fermented breadfruit starch (g)	Unfermented breadfruit starch (g)	Grated coconut (g)	Sugar (g)	Salt (g)	Spices (g)	Water (ml)
CAG	200	0	0	50	50	2.5	1.25	125
FBSG	0	200	0	50	50	2.5	1.25	125
UFBSG	0	0	200	50	50	2.5	1.25	125

KEY:
CAG – 100% Cassava starch gurudi
FBSG – 100% Fermented breadfruit starch gurudi
UFBSG – 100% Unfermented breadfruit starch gurudi

into smaller sizes manually using kitchen knife. The chopped breadfruit was divided into two (2) equal portions; the first was milled at maximum speed using Kenwood blender and sieved using a muslin cloth using water to wash. The fiber was rewashed to remove adhering starch and allowed to sediment for 8 h, while the second portion was allowed to ferment in deionized water at a ratio of 1:3 (W/V) for 48 h in a closed container and the water was changed after every 8 h before milling. The milled slurry was sieved using muslin cloth and also allowed to sediment for 8 h. Both samples were decanted and the wet sediment collected as starch. The resultant wet starch was thinly spread on a tray and sundried for 7 h to obtain dry starch. The dried starch sample was milled into fine powder with the aid of a Kenwood blender and stored in air high container until required for use.

Processing of cassava starch

The method described by Osunsami *et al.* (1989) as reported by Eke (2006) was used for the production of cassava starch (Figure 3). The cassava tubes were harvested, washed, peeled, grated and mixture filtered through a fine muslin cloth. The filtrate was allowed to sediment. The supernatant (effluent) was decanted and sediment washed off three times to obtain a white odorless and tasteless starch. The starch obtained was put in a clean jute bag and pressed using a screw press to dewater. The resultant wet starch was thinly spread on a tray and sun dried for 24 h. The starch granule was milled into fine powder, packaged in food grade polyethylene bags for laboratory analysis.

Gurudi formulation and preparation

The snacks were formulated and produced from the standard gurudi recipe according to the method described by Sanni *et al*. (2006) with some modifications. Different starch samples were mixed thoroughly with grated coconut, sugar, salt and spices. Water was added to make a smooth paste. The pastes were spread thinly on greased baking tray, baked in a hot oven at 200°C for 5 min after which the heat was reduced to 150°C for another 10 min (Table 1). The snack was removed from the oven, cut into desired shapes and baked until golden brown.

Chemical analysis of starches and gurudi

Breadfruit starch and gurudi snacks produced were subjected to Moisture, fat, protein and ash content of the samples were determined using AOAC (2012), crude fibre by AOAC (2000) and carbohydrate calculated by difference method. Color analysis was done by the method described by Francis (1998), while starch and sugar were determined by the methods described by Dubois *et al.* (1956) as reported by Eke (2006). Amylose content of samples was determined by the method of Williams *et al*. (1970) and amylopectin calculated by difference.

Pasting properties of the different starches were determined using a Rapid Visco Analyser (RVA, model 3C, Newport Scientific PTY Ltd, Sydney) according to Sanni *et al*. (2004).

Functional properties

Relative bulk density (RBD) was determined according to the method of Onwuka (2005), water absorption capacity(WAC) by the method of Sosulski (1962), swelling power and solubility of starch was determined the method described by Takashi and Sieb (1988). Starch dispersibility was determined by the method described by Kulkarni *et al*. (1991), while Least Gelation Concentration by the method of Coffman and Garcia (1977). The extent of starch damage (SD) was determined by the method described by McDermott (1980) as reported by Eke (2006).

Sensory evaluation of gurudi

Twenty semi trained panelists comprising staff and students from the department of Food Science and Technology Rivers State University, Nigeria, who were neither sick nor allergic to the raw materials were used

Table 2. Chemical composition of fermented and unfermented breadfruit starch.

Sample	Moisture %	Ash %	Fat %	Protein %	Fibre %	CHO %	Amylopectin	Amylose	Starch	Sugar %	Starch damage
CS	18.3±0.01[a]	0.10±0.00[b]	0.50±0.013[a]	1.83±0.00[c]	1.77±0.028[a]	77.42±0.042[b]	56.92±3.67	27.52±0.017[a]	84.44±0.00[a]	3.03±0.07c	3.67±0.00[c]
FBS	13.95±0.024[b]	0.83±0.06[a]	0.49±0.014[a]	1.83±0.00[b]	0.40±0.01[b]	82.53±0.017[a]	44.58±4.06	26.61±0.07[b]	71.19±0.040[b]	3.72±0.06[b]	4.06±0.00[b]
UFBS	13.33±0.045[b]	0.59±0.013[a]	0.59±0.00[a]	3.13±0.00[a]	1.20±0.08[a,b]	81.17±0.059[a]	45.05±4.41	25.20±0.011[b]	70.25±0.025[b]	4.04±0.01[a]	4.41±0.00[a]

Values are means of duplicate determination ± SD, means having the same letter within a column are not significantly different ($P < 0.05$).
KEY:
FBS – Fermented Breadfruit Starch
UFBS – Unfermented Breadfruit Starch
CHO – Carbohydrate
CS – Cassava Starch

for sensory evaluation. Panelists were instructed to evaluate the samples for colour, texture, aroma, taste, crispiness and overall acceptability on a five point hedonic scale as described by Iwe (2004). Water was provided for panelists to rinse their mouth after evaluating each product irrespective of whether the product was swallowed or not.

Statistical analysis

All experiments and analysis were carried out in duplicate. Data collected were subjected to analysis of variance (ANOVA) using Minitab ®, version16.0 software, and Duncan's multiple range test was used to separate the mean where significant difference existed.

RESULTS

Chemical composition of breadfruit starch

Table 2 shows the chemical composition of fermented and unfermented breadfruit starch samples. The moisture content of starches ranged from 13.33 to 18.37%, with sample C, unfermented breadfruit starch (UFBS) having the lowest and sample A (control) having the highest moisture content. Moisture content of 13.33 and 13.93% for breadfruit starches were not significantly different but agrees with the result of Rincon *et al*. (2004) who reported moisture content of 13%, but it was significantly different ($p < 0.05$) from moisture content of cassava starch in this study which is 18.3%, higher than 7.47 to 14.55% reported by Eke (2006). Higher moisture content may be due to drying method used (sun drying) and because of the difference in starch origin. The higher moisture content may be of advantage because the higher the moisture content, the lower the amount of dry solids in the starch. The moisture content of the starch which is above 10%, stipulated standard of the revised regulation of the Standard Organization of Nigeria (SON 1988) but below the recommended maximum value of 14% which indicates that the product may not have better storage stability.

Ash content of breadfruit starch ranged from 0.10 to 0.83% with sample A (cassava starch) having the lowest and sample C (UFBS) having the highest ash content. Ash content of 0.59 and 0.83% is obtained from the Breadfruit starch which is slightly below the results of Akanbi *et al*. (2009) and Rincon *et al*. (2004) who reported ash content of 1.77 and 1.1%, respectively. The ash content of breadfruit starch is significantly higher than ash content of cassava starch reported to be 0.10% in this study but agrees with the result of Eke (2006) who reported ash content of 0.06 to 0.52% for cassava starch. The ash of native starches contains mainly calcium, potassium and sodium (Swinkles, 1985). The ash content determines the measure of inorganic constituents present and the quality of ions bound to the raw starch FAO (1977).

Fat content of starches ranged from 0.49 to 0.59% with sample B (FBS) having the lowest and sample C (UFBS) having the highest fat content. Fat content obtained in the present study is slightly above the result of Akanbi *et al*. (2009) who reported fat content of 0.39% and slightly below the result of Iwaoka *et al*. (1994) who reported fat content of 0.80%. The low fat content of breadfruit starch and its product suggests that it is not susceptible to quick rancidity.

While protein content of breadfruit starches ranged from 1.83 to 3.13% with sample A (CS) and B (FBS) having the lowest and sample C (UFBS) recording the highest. The protein is higher than the result of Akanbi *et al*. (2009) and

Woolton *et al*. (1984) who reported protein content of 0.53 and 0.31% respectively. The difference in the protein content may be attributed to climatic conditions, processing and extraction methods used. The protein content of cassava and fermented breadfruit starch recorded the same values but significantly different ($p < 0.05$). Unfermented breadfruit starch recorded higher protein content which suggests that protein may have been lost during the fermentation process. Therefore, fermentation has effect on protein quantity.

Fiber content of starches ranged from 0.40 to 1.77% with Sample B (FBS) recording the lowest and sample A (CS) having the highest. Breadfruit starch recorded fiber content of 0.40 and 1.20% lower than the fiber content of cassava starch reported to be 1.77% in this study. There was a significance difference in the fiber content as unfermented breadfruit starch had higher fiber content than fermented Breadfruit starch. The higher fiber content has both nutritional and processing significance for starch. While carbohydrate content of the starches ranged from 77.42 to 82.53% with Sample A (CS) having the least carbohydrate content and sample B (FBS) having the highest carbohydrate content. The study showed that samples with high fiber had low carbohydrate.

Amylose content ranged from 25.20 to 27.52% with sample C (UFBS) having the lowest value and sample A (CS) having the highest amylose, while amylopectin ranged from 44.58 to 56.92% with sample B (FBS) recording the lowest and the control (CS) having the highest amylopectin content. The amylose content of 22.20 and 25.58% falls within the result of Akanbi *et al*. (2009) and Eke (2006) who reported amylose content of 22.52 and 22.61%respectively. This is higher than the result of Wootton *et al*. (1984) who reported amylose content of 19.4%. The amylose content may have been higher because according to Raja and Ramakrishna, (1990) “heat treatment causes a reduction in the amylose content of cassava product”. Breadfruit starch which is moderately high in amylose content can help in reducing the risk factor for diabetes and cardiovascular diseases (Behall and Howe, 1995). High amylopectin presence in food has also been reported to increase human insulin levels (Behall *et al*., 1988).

Sugar content ranged from 3.03 to 4.04% with sample A (CS) recording the lowest and sample C (UFBS) recording the highest value, while starch content of samples ranged from 70.25 to 84.44% with Sample C (UFBS) having the lowest and sample A(CS) having the highest starch content. Starch and sugar content also showed that samples with low sugar values had high starch contents. The variation in the bread fruit samples showed that fermentation decreased the sugar content of breadfruit. The starch content of 70.25% for unfermented Breadfruit and 71.19% for fermented breadfruit is in agreement with the results of Oladunjoye *et al*. (2016) who reported starch content of 60% and above but disagrees with the results of Rincon *et al*. (2004) who reported starch content of 18.05%, Onwueme (1978), Omobuwajo and Wilcox (1989) who reported starch content of 15.4%. However, there can be variation in the starch content of Breadfruit depending on the maturity stage, variety, climate and agronomic conditions (Rahman *et al*. (1999).The high Breadfruit starch content of 70.25 and 71.19% from this study is of significant importance in domestic and industrial utilization.

The percentage starch damage ranged from 3.67 to 4.41% with sample A (CS) having the lowest starch damage and sample C (UFBS) having the highest value. The extent of starch damage may be due to the milling, extraction and drying methods (Soison *et al*., 2015). Starch damage is a starch granule that is broken up into pieces and directly affects water absorption, mixing properties, as well as starch rheology. The present study showed that water absorption capacity increased with an increase in starch damage.

Functional properties of breadfruit starches

Table 3 shows the functional properties of starches from fermented and unfermented breadfruit. Bulk density of starches ranged from 0.56 to 0.62 g/lm with sample C (UFBS) having the least value and sample A (CS) having the highest. The result of bulk density in the present study is slightly below the result of Akanbi *et al.* (2009) who reported bulk density of 0.63 g/ml and slightly above the result of Adeoye *et al*. (2017) who reported bulk density of 0.34 to 0.46 g/cm. Bulk density is a measure of heaviness of a sample. According to Quartey-Nelson *et al.* (2007), low bulk density product could be useful in infant food formulation.

Water absorption capacity ranged from 0.04 to 1.56 ml/g with Sample C (CS) having the least and sample B (FBS) having the highest value. Result of the present study showed that fermentation positively affected water absorption capacity. Water absorption capacity is the amount of water taken up by flour or starch to achieve a desired consistency and create a quality end-product. It is also a useful indicator of whether protein can be incorporated with the aqueous food formulations, especially those involving dough handling (Osungbaro *et al*., 2010). The high water absorption capacity of the starch suggests they could be useful in soup formulations (Olaofe *et al*., 1994).

Swelling power of the starches ranged from 3.88 to16.75 g/g with sample A (CS) having the least value and sample C (UFBS) having the highest. Breadfruit starch recorded a swelling power of 16.18 g/g and this has been reported to be due to its lower degree of intermolecular association (Tian *et al*., 1991). Swelling power indicates the water holding capacity of starch, which has generally been used to demonstrate differences between various types of starches (Crosbie, 1991). Food eating quality is often connected with the retention of water in the swollen starch granules Rickard *et al*., 1992). Since the swelling power is high, it suggests

Table 3. Functional properties of fermented and unfermented breadfruit starch.

Sample	Bulk density (g/ml)	WAC (ml/g)	Swelling power (g/g)	Solubility (%)	L.G.C (%)	Dispersibility (%)	Colour (%)
CS	0.62 ± 0.00[a]	0.40 ± 0.01[c]	3.88 ± 0.83[b]	63.44 ± 3.34[a]	6.00 ± 0.00[a]	59.50 ± 0.071[a]	75.82 ± 4.24[c]
FBS	0.57 ± 0.01[b]	1.56 ± 0.02[a]	16.18 ± 0.11[a]	8.26 ± 0.13[b]	4.00 ± 0.00[b]	68.00 ± 0.00[b]	76.35 ± 8.49[b]
UFBS	0.56 ± 0.00[b]	0.80 ± 0.01[b]	16.75 ± 0.11[a]	4.87 ± 0.14[b]	4.00 ± 0.00[c]	60.00 ± 0.00[a]	77.46 ± 2.83[a]

Value are means of duplicate determination ± SD, means with different superscript in the same column are significantly different at ($p<0.05$)
KEY:
CS – Cassava starch
FBS – Fermented breadfruit starch
UFBS – unfermented breadfruit starch
WAC – Water Absorption Capacity
LGC – Least Gelation Concentration

that it may find application in noodles production (McComick *et al*., 1991).

Solubility of starches ranged from 4.87 to 63.44% with sample C (UFBS) having the lowest and sample A (CS) having the highest value. Solubilty of starch in this study is close to the results of Baafi and Safo-Kantanka, (2007) who reported solubility of 7.57%. According to these researchers, solubility of a product is an indicator of quality. Singh *et al*. (2005) reported that solubility is the percentage amount of starch leached out into the supernatant in the swelling volume determination. The result also shows that there is a relationship between the solubility and swelling power. The higher the solubility, the lower the swelling power.

The Least Gelation Concentration (LGC) of starch was 4.00 and 6.00%. Samples of breadfruit starch (FBS and UFBS) had the lowest gelation concentration and sample A (CS) had the highest gelation concentration. The higher gelation concentration of cassava starch could be attributed to its origin which is a tuber while breadfruit is either a fruit or vegetable. According to Udensi (2001), gelation is an aggregation of denatured molecules which is a quality parameter influencing the texture of food in terms of gel-formation or firming agent and would be useful in food systems such as puddings and snacks which requires thickening and gelling or if it could be useful as a glazing agent.

The dispersibility of starches ranged from 59.50 to 68.00% with sample B (FBS) having the least, and sample A (CS) having the highest values. The dispersibility of starch is higher than the result of Akanbi *et al*. (2009) who reported dispersibility of 40.6%. Dispersibility is the measure of reconstitution of starch or starch blend in water and the higher the dispersibility, the better the flour reconstitutes in water Kulkurni *et al*. (1991).

Color values for the starches ranged from 75.82 to 77.46% with sample A (CS) having the least color and sample C (UFBS) having the highest color value. Color is an important intensity sensory attribute of any food because of its influence in acceptability. The color intensity of the starches is 76.35% for fermented breadfruit starch and 77.46% for unfermented breadfruit starch. Fermentation therefore affected the color of breadfruit starch. Starch extracted under perfect condition is pure white in color and it is an important criterion for starch quality (Kulp *et al*., 1994).

Pasting properties of fermented and unfermented breadfruit starch

Increase in viscosity of a starch suspension to a gel or paste is associated to increase in temperature. Table 4 shows the pasting properties (RVU) of fermented and unfermented breadfruit starches. The peak viscosity ranged from 5437.00 to 6229.50 RVU with sample A (CS) recording the lowest value and sample C (UFBS) having the highest peak value. Peak viscosity is the maximum viscosity developed during or soon after the heating portion of the test. Maximum viscosity of starch suspensions heated in excess water occurs after granule swelling has ceased and increase in viscosity is due mainly to exudates released from the granules (Miller and Wilding, 1973). The higher moisture content of the starches contributes to a progressive decrease in the peak viscosity. The peak viscosity of breadfruit starch in this study is 5746.00 RVU for fermented breadfruit starch (FBS) and 6228.00 RVU for unfermented breadfruit starch (UFBS) higher than

Table 4. Pasting properties of fermented and unfermented breadfruit starch.

Sample	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown viscosity (RVU)	Final viscosity (RVU)	Setback viscosity (RVU)	Pasting time (min)	Pasting temp (°C)
CS	5437.00±164.00[a]	2325.00±58.0[b]	3112.00±106.10[a]	3097.00±46.70[b]	772.00±113[c]	3.87±0.00[c]	76.03±0.18[b]
FBS	5746.00±274.20a	4934.00±145.70[b]	812.00±128.70[b]	7363.00±244.70[a]	2429.00±99.3[b]	5.80±0.00[b]	79.20±0.07[a]
UBS	6228.50±102.50[a]	5017.00±90.5[a]	1211.50±12.00[b]	7864.05±7.80[a]	2847.50±98.30[a]	5.40±0.00[a]	79.23±0.04[a]

Values are mean of duplicate determination ± SD, means havingdifferent letter within a column are significantly different (p<0.05).
KEY
CS – Cassava starch
FBS – Fermented breadfruit starch
UFBS – Unfermented breadfruit starch

2330.00 to 3142.50 RVU reported by Adeoye *et al*. (2017) and 121.25 RVU reported by Akanbi *et al*. (2009). The result also shows that fermentation reduced the peak viscosity. The higher peak viscosity of the starch might be related to the ratio of amylose to amylopectin. The loosely packed starch granules with lower protein to starch ratio in the fine fractions seem to hydrate and swell more rapidly in the presence of heat. The peak viscosity of both starches is not significantly different.

Trough viscosity ranged from 2325.00 to 5017.00 RVU with sample A (CS) having the lowest trough viscosity and sample C (UFBS) having the highest trough values. Trough viscosity is the minimum viscosity after the peak, normally occurring around the commencement of cooling. It is the ability of the granules to remain undisrupted when the starch paste is subjected to a holding period of constant high temperature of (95°C for 2 min, 30 s) and mechanical shear stress. The trough viscosity of unfermented breadfruit starch is significantly higher than fermented breadfruit starch (4934.00 RVU).

Breakdown viscosity ranged from 812.00 to 3112.00 RVU with sample B (FBS) having the lowest trough and sample A (CS) having the highest trough. Breakdown viscosity (BV) is a measure of cooked starch to disintegration. Fermented breadfruit starch had breakdown value of 812.0 RVU, while unfermented breadfruit starch had a value of 1211.5 RVU, which disagrees with the result of (Adeoye *et al*., 2017) who reported breakdown viscosity value of 7.92 RVU. The smaller the breakdown viscosity, the higher the paste stability (Hugo *et al*., 2000). From the present result, fermented breadfruit starch will be more stable than the unfermented and cassava starches respectively.

Final viscosity ranged from 3097.00 to 7864.50 RVU with sample A (CS) having the lowest and sample C (UFBS) having the highest. Final viscosity is the measured ability of starch to form a viscous paste after cooking and cooling. As gelatinization dispersion of starch is cooled, a loose paste or gel is formed depending on the starch concentration. At concentrations above the critical limits, a three-dimensional network is established, where the swollen granules become embodied into a continuous matrix of entangled amylose molecules (Ring, 1985). Such a complex polymer matrix set as a viscoelastic gel in which the molecular associations involving hydrogen bonding between chains are mainly physical rather than covalent cross links (Appelquist and Debet, 1997). The formulation of such gel is indicated by increased viscosity and is known as the final viscosity in the pasting curve. Final viscosity of breadfruit starch for this study was 7363.0RVU for fermented breadfruit starch and 7864.5 RVU for unfermented breadfruit starch. The increase in viscosity which occurs as a result of cooling is mainly due to re-association between starch molecules especially amylose.

Setback viscosity ranged from 772.00 to 2847.50 RVU with sample A (CS) having the lowest setback value and sample C (UFBS) having the highest. Setback viscosity is measured as the difference between final viscosity and the trough. It is a phase of the pasting curve after cooling the starches at 50°C. This stage involves re-association, retrogradation or re-ordering of starch molecules. It is co-related with texture of various products. The setback viscosity of breadfruit starch in this study is 2429.0 and 2847.50 RVU for fermented and unfermented breadfruit starch respectively and it agrees with the result of Adeoye *et al*. (2017) who reported setback viscosity of 2729.50 RVU. The higher the setback value, the lower the retro-gradation during cooling and the lower the staling rate of the products made from the starch Adeyemi and Idowu (1990).

Pasting time ranged from 3.87 to 5.80 min with sample A (CS) recording the lowest pasting time

Table 5. Mean sensory evaluation scores of breadfruit and cassava starch gurudi.

Sample	Colour	Texture	Aroma	Taste	Crispiness	Overall acceptability
CSG	4.35 ± 0.59[ab]	3.30 ± 0.57[b]	3.90 ± 0.97[a]	4.05 ± 1.19[ab]	2.85 ± 1.18[b]	3.69 ± 0.61[ab]
FBSG	3.40 ± 0.88[c]	3.25 ± 1.07[b]	3.25 ± 1.16[a]	3.40 ± 1.10[b]	3.35 ± 1.27[ab]	3.33 ± 0.85[b]
UBSG	4.00 ± 0.97[abc]	3.80 ± 0.83[ab]	3.60 ± 0.88[a]	3.20 ± 1.20[b]	4.10 ± 1.17[a]	3.74 ± 0.66[ab]

Value are means of duplicate determination ± SD, means having different letters within a column are significant different (P<0.05)
KEY
CSG – 100% Cassava starch gurudi
FBSG – 100% Fermented breadfruit starch gurudi
UFBSG – 100% Unfermented breadfruit starch gurudi

Table 6. Proximate composition result for cassava and breadfruit starch gurudi.

Sample	Moisture	Ash%	Fat %	Protein	Fibre	CHO
CSG	14.23 ± 0.18[a]	1.34 ± 0.03[a]	10.71 ± 1.84[a]	2.30 ± 0.00[a]	1.87 ± 0.59[b]	70.61 ± 1.04[b]
FBSG	6.47 ± 0.23[b]	1.20 ± 0.11[b]	7.06 ± 1.57[b]	1.80 ± 0.00[a]	1.15 ± 0.00[b]	82.34 ± 1.80[a]
UFBSG	7.43 ± 0.21[b]	1.24 ± 0.00[b]	7.84 ± 2.60[b]	2.26 ± 0.00[a]	3.13 ± 0.35[a]	81.74 ± 1.04[a]

Value are means of duplicate determination ± SD, means having the same letters within a column are not significant different (P<0.05).
KEY
CSG – 100% Cassava starch gurudi
FBSG – 100% Fermented breadfruit starch gurudi
UFBSG – 100% Unfermented breadfruit starch gurudi

and sample B (FBS) recording the highest time. Pasting time is the time at which the peak viscosity occurred in minutes, indicating that the unfermented breadfruit starch cooked in a shorter time of 5.40 min than the fermented breadfruit starch which pasting time occurred at 5.80 min.

Pasting temperature ranged from 76.03 to 79.23°C with Sample A (CS) recording the lowest temperature and sample C (UFBS) recording the highest temperature. The pasting temperature of breadfruit starch in this study is 79.20 and 79.23°C which is higher than the results of Adeoye *et al*. (2017) who reported pasting temperature of 50.40 to 53.98°C. The pasting temperature provides an indication of the minimum temperature required to cook a given sample and also indicate energy lost in cooking, which depends on the size of starch granules. Small granules are more resistant to rapture and loss of molecular order, so this might explain the relatively high pasting temperature. The ability of starch to imbibe water and swell is primarily dependent on the pasting temperature. The higher the pasting temperature, the faster the tendency for the paste to be formed Dreher and Berry (1983). Hence, in the presence of water and heat, starch granules swell and form paste by imbibing water. The pasting temperature of breadfruit in the present study is higher than that of cassava starch.

Sensory evaluation result of gurudi from cassava and breadfruit starch

Color of gurudi ranged from 3.40 to 4.35 with sample B (FBSG) fermented breadfruit Starch gurudi having the least color and sample A (CSG) 100% cassava starch gurudi having the most preferred color (Table 5). This is expected because cassava starch naturally has a brilliant white color which has impacted on the finished product gurudi. Texture analysis of gurudi ranged from 3.25 to 3.80 with sample B (FBSG) having the least value and sample C (UFBSG) unfermented breadfruit starch gurudi having the most preferred texture. Aroma of Gurudi ranged from 3.25 to 3.90 with sample B (FBSG) having the least aroma value and sample A (CSG) having the most preferred aroma. Taste of gurudi ranged from 3.20 to 4.05 with sample C (UFBSG) having the least preferred taste and sample A (CSG) having the most preferred taste. Crispiness of gurudi ranged from 2.85 to 4.10 with sample A (CSG) being the least crispy and sample C (UFBSG) the most-crispy. The overall acceptability ranged from 3.33 to 3.74 with sample B (FBSG) being the least in overall acceptability and sample C (UFBSG) having the highest overall acceptability.

Proximate composition result of gurudi

Table 6 shows the proximate composition result of cassava and breadfruit starch gurudi. The moisture content of the gurudi snack samples ranged for 6.47 to 14.23% with sample B (FBSG) having the lowest moisture and sample A (CSG) having the highest moisture value. The results of the present study indicates that 100% cassava starch gurudi (CSG) recorded a higher moisture content than breadfruit starches and this

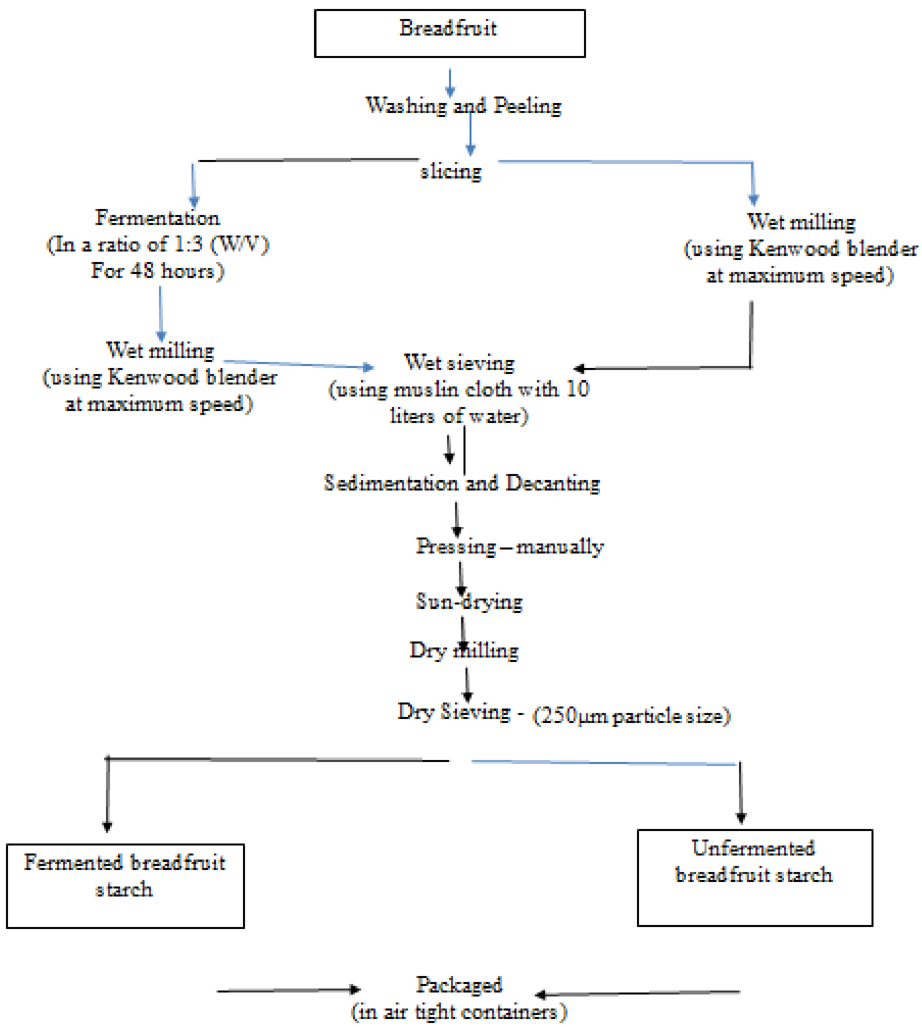

Figure 2. Extraction process for breadfruit starch. Source: Modified from Agboola *et al*. (1990).

may be due to differences in starch origin which could affect water retention. Changes in the structure and properties of the starch are attributed to the presence of water around the granules during processing.

The ash contents of gurudi ranged from 1.20 to 1.34% with sample B (FBSG) having the lowest ash value and sample A (CSG) having the highest ash content, while the fibre content of the gurudi snack ranged from 1.15 to 3.13% with sample B (FBSG) having the least fibre and sample C (UFBSG) having the highest fibre content. The improved nutritional values in ash and fiber were enhanced by the addition of ingredients such as coconut, salt and spices.

The fat contents of the starches ranged from 7.06 to 10.71% with sample B (FBSG) having the lowest fat and sample A (CSG) having the highest fat content, while protein content of the starches ranged from 1.40 to 2.30% with sample C (UFBSG) having the lowest protein and sample A (CSG) having the highest proteins content. The increase in fat and protein content is as a result of the addition of grated coconut meal in the production process

The carbohydrate content of gurudi ranged from 70.61 to 82.34% with sample A (CSG) having the lowest and sample B (FBSG) having the highest carbohydrate content, with fermentation not significantly affecting the finished product.

CONCLUSIONS

Breadfruit as an underutilized crop has shown to be a raw material for the extraction of acceptable starch for domestic and possible industrial use. Result of the present study showed that breadfruit starch has substantial qualities in terms of chemical, functional and pasting properties to compete favorably with cassava starch. The result of the study revealed that breadfruit byproducts like starch will have better shelf-life with improved drying methods other than sun-drying which

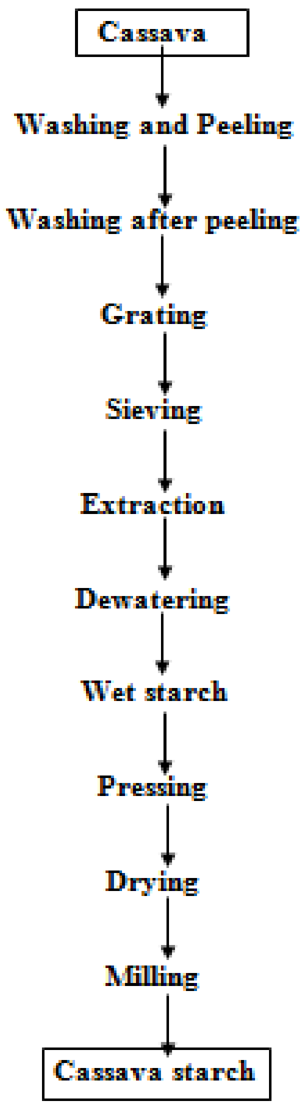

Figure 3. Extraction process of cassava starch. Source: Osunsami *et al*. (1989) as reported by Eke (2006).

seemed to affect moisture content of the starch as well as reduced starch damage. Fermentation improved the functional properties such as water absorption capacity, solubility and dispersibility, which are important in product development, but reduced the quantity of protein and fibre in breadfruit gurudi as well as sensory attributes, while the unfermented breadfruit product competed favorably with the control sample cassava. The organoleptic assessment of breadfruit starch is suggestive of it suitability as a snack raw material.

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