Comparative Studies of Starches from Breadfruit (Artocarpus Altilis) and Maize (Zea Mays)

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ORIGINAL RESEARCH

Abstract - The work is on comparative studies of starches from Breadfruit (Artocarpus altilis) and corn (Zea mays). Fine, fresh, Unripe but matured breadfruit and fresh corn used for this study were processed to extract starch using standard procedure. The starches produced from both were separately subjected to proximate, functional, pasting properties and organoleptic analysis. Results from the chemical analysis showed crude protein 1.25 % and 0.56 % for corn starch and breadfruit starch, moisture content 10.45 % and 10.83 % for corn starch and breadfruit starch, ash content 1.18 % and 1.85 % for corn starch and breadfruit starch, Fat content 0.65 and 0.48 % for corn starch and breadfruit starch and the starch yield 28.40 % and 16.26 % for corn starch and breadfruit starch. The result of pasting analysis revealed that when the starches were heated in an aqueous environment both undergo changes known as gelatinization and pasting. Both samples may be appropriate for products with high gel strength and elasticity requirements. The result of functional properties revealed that there was significant difference in the parameters analysed. Therefore, breadfruit starch compared favourably well with corn starch and thus can be used in so many areas where corn starch are acceptable.

Keywords- Zea mays, Artocarpus altilis, organoleptic and starch

1 Introduction

Starch is the predominant carbohydrate reserve found in plants. It is a major source of nutrition for humans and animals, and an important raw material for industry. Commercial starches are obtained from various botanical sources. Starch has unique functional properties but most of those used by diverse industries are modified before use, giving a wide range of useful product (Schirmer *et al.*, 2015). The application of starch is derived from its functional properties. Pasting is an important functional property. It is the development of high viscosity when starch-water suspensions are heated. This property is exploited for different food and non-food uses such as in adhesives.

Another significant functional property is the ability to create gels. This property is also used in different foods and non-food applications such as thermoplastics (Alcazar-Alay and Meireles, 2015). Starch is an important dietary component in human populations. The recent consensus on healthy-eating habits favours an increase in the proportion of polymeric plant carbohydrates (including starch) in the daily diet (Agnes *et al.*, 2017). However, the main objective of starch utilization in foods remains more functional than nutritional in our culture. This biopolymer could serve as an excellent raw material to modify food texture and consistency. Not only is the amount of starch important for the texture of a given food product, but starch type is equally critical (Santana and Meireles, 2014).

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Starch is deposited in form of granules, particularly crystalline, whose morphology, chemical composition and super molecular structure are characteristic of each particular plant species. Starch owes much of its functionality to two major high-molecular-weight carbohydrate components, amylose and amylopectin, as well as to the physical organization of these macromolecules into the granular structures (Raghunathan *et al.*, 2021).

Breadfruit (Artocarpus altilis) belongs to the family Moraceae. Due to its high carbohydrate content (76.7%), it has been used as an important source of energy over the years. However, proper usage is limited by the poor storage properties of the fresh fruit particularly in developing countries. It is therefore reasonable to maximize the potentials of this valuable fruit by processing it into different food products with better shelf life. Conversion to flour and starch would present a more stable form and increase its versatility. Also, there is a growing tendency towards finding alternative sources of starch from novel and underutilized starch sources. So far underutilized raw materials have been found useful in both foods and non-food industries. Functional properties of breadfruit as a component of composite flour have already been studied (Adepeju *et al.*, 2011).

The high carbohydrate content of breadfruit makes it a good source of starch. Native starches have always been used since ancient periods as raw materials to prepare different products. They are employed in foods because of their good thickening and gelling properties (Adebowale *et al.*, 2005). They have also been found to be good texture stabilizers and regulators in food systems. Corn starch is a valuable ingredient to the food industry, being widely used as a thickener, getting agent, bulking agent and water retention agent (Singh, *et al.*, 2003).

On the basis of amylase and amylopectin ratio, corn can be separated into normal, waxy and high amylase. In addition, sugary types corn, with high sugar content, also exists (Singh *et al.,* 2005) Native starch consists of about 75wt% branched amylopectin and about 25wt% amylase, that is linear or slightly branched. Starch granules swell when heated in excess water and their volume fractions and morphology play important roles in the theological behaviour of starch dispersions (Bertoft, 2017).

This work was undertaken to examine some functional and physicochemical properties of corn and breadfruit native starches, as well as comparing these properties. It is hoped that the data generated from the studies will assist in recommending breadfruit as a potential source for novel starch which will be useful for both food and non-food industrial applications.

2 Materials and Methods

2.1 Materials

Breadfruit (*A. altilis*) was bought from a local market in Ile-Ife, Osun State, corn (Zea mays) was also bought from lkole market in Ekiti State, Nigeria.

2.2 Production of Breadfruit Starch

Mature breadfruits were thoroughly washed to remove dirt and unwanted materials. They were then peeled, cored and washed with clean water. The fruits were diced and milled. The slurry produced through milling was dispersed in 10 L distilled water before sieving (75µm, W.S Tyler Inc. England). Impunities were further removed by stirring with distilled water and decanting off supernatants after sedimentation. The starch obtained was air dried at 30 °C for 48 hrs. The production process is outlined in Figure 1.

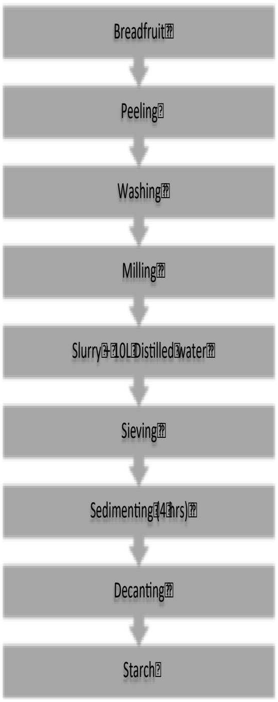

Fig 1: Flow chart for the production of breadfruit starch

2.3 Production of Corn Starch

Corns were sorted to remove unwanted materials and then washed with clean water. The grains then steeped, wet milled and allowed to settle to isolate starch filet the suspension and sieved to remove the fibre (Emmambux and Taylor, 2013). This is illustrated in Figure 2.

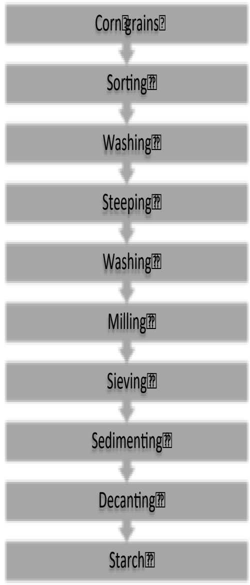

Fig 2: Flow chart for the production of corn starch

2.4 Breadfruit and Corn Starch Yield

Starches yield was derived using the calculation below:

$$\text{Starch yield (\%)} = \frac{\text{Weight of starch (g)}}{\text{Weight of edible portion}} \times 100 \qquad (1)$$

2.5 Proximate Analysis of Breadfruit Starch and Corn Starch

Moisture content, crude protein, crude fat, crude fibre and Ash were determined by the standard methods of AOAC (2010). Carbohydrate was expressed as a percentage of the difference between the addition of other proximate chemical components and 100%.

$$\text{Carbohydrate} = 100 - (\text{protein} + \text{crude fat} + \text{ash} + \text{fibre} + \text{moisture}) \qquad (2)$$

2.6 Functional Properties

2.6.1 Water Binding Capacity (WBC)

This was carried out using the Adebowale *et al.,* (2005) method. 37.5 m1 of distilled water was added into 2.5g of the breadfruit and corn starches and were centrifuged for 10 minutes at 300 rpm. Then the weight of the centrifuge tube and content were determined after decanting the water and allowed to drain for another 10 minutes, the bound water was determined by the change in weight. It was calculated by the formula:

$$\text{WBC} = \frac{\text{Bound water (g)}}{\text{Weight of sample (g)}} \times 100 \qquad (3)$$

2.6.2 Swelling Power and Solubility Index

This was determined by Kusumayanti *et al.,* (2015) method. It involved weighing 1g of sample into 50 ml centrifuge tube. 50nil of distilled water was added and gently mixed. The slurry was heated in a water bath for 15 minutes. The slurry was gently stirred during heating to prevent clumping of the starch. On completion of 15 minutes, the tubes containing the paste were centrifuged at 3000 rpm for 10 minutes using SPECTRA U.K (Merlin 503) centrifuge. The supernatant was decanted immediately after centrifuging. The weight of the sediment was observed and recorded. The moisture

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content of the gel was thereafter determined in order to ascertain the dry matter content of the gel.

$$\text{Swelling power} = \frac{\text{Weight of wet mass of sediment}}{\text{Weight of dry matter in the gel}} \quad (4)$$

2.6.3 Water Absorption Index (WAI)

This was carried out using the modified method of Ruales *et al.,* (2013). 2.5g of the breadfruit and corn starches were suspended in 30m1 of distilled water at 30 °C in a centrifuge tube, stored for 30 minutes intermittently and then centrifuged at 3000 rpm for 10 minutes. The supernatant was decanted and the weight of the gel formed were recorded. The Water Absorption Index (WAI) were then calculated as gel weight per gram dry sample.

$$\text{WAI} = \frac{\text{Grain Bound Water}}{\text{Weight of Sample}} \quad (5)$$

2.6.4 Bulk Density

This was determined by the method of Bertoft, (2017). A known amount of sample was weighed into 50 m1 graduated measuring cylinder. The sample was packed by gently tapping the cylinder on the bench top from a height of 5cm. The volume of the sample was recorded.

$$\text{Bulk density} = \frac{\text{Weight of Sample (g/mL)}}{\text{Volume of sample after tapping}} \quad (6)$$

2.6.5 Dispersibility

This was determined by the method described by Adebowale *et al.,* (2006). 10 g of flour were suspended in 100 m1 measuring cylinder and distilled water was added to reach a volume of 100 m1. The set up was stirred vigorously and allowed to settle for 3 hours. The volume of settled particles was observed and subtracted from 100. The difference was reported as percentage dispersibility.

2.7 Pasting Properties of Breadfruit and Corn Starches

This was determined using Rapid Visco Analyser (Newport Scientific Australia). 3.5g of the sample were weighed into the text canister. 2.5 g of breadfruit and corn starch samples were weighed into a dried empty canister, 25 ml of distilled water was dispersed into the canister containing the sample. The solution was thoroughly mixed and the canister were well fitted into the RVA as recommended. The slurries were heated from 50 to 95 °C with holding time of 2 minutes followed by cooling to 50 °C with 2 minutes holding time. The rate of heating and cooling were at constant rate of 11.15°C/minute. Peak viscosity, trough, breakdown, final viscosity, setback, peak time and pasting temperature were observed and recorded from the pasting profile with the aid of Thermocline for windows software.

2.8 Statistical Analysis

Data generated were subjected to appropriate statistical analysis (ANOVA) using a statistical package for the social sciences, SPSS (version 21). Mean separation was done using Duncan multiple range test and significance difference was accepted was accepted at 5% confidence level.

3 Results And Discussion

3.1 Proximate Composition of Breadfruit and Corn Starch

The proximate composition of breadfruit and corn starches is shown in Table 1. Crude protein contents of the starches were 1.25% and 0.56% for corn starch and breadfruit starch respectively, which is higher than 0.31% reported by Ashogbon and Akintayo, (2014). The difference in the protein content can be attributed to the climatic conditions and extraction methods involved (Ali *et al.*, 2023). Moisture content of 10.45% and 10.83% were obtained for the corn starch and breadfruit starch, respectively, which is lower when compared to 13% reported by Chisenga *et al.,* (2019). Dried products with low moisture contents indicate higher shelf life. The lower the initial moisture content of a product to be stored, the better the storage stability of the product (Bonsi *et al.*, 2014). The moisture contents of the starches were very closed to the 10% stipulated standard (Falade and Ayetigbo, 2015).

The fat content was 0.65% and 0.48% for corn starch and breadfruit starch respectively; these values are lower than 0.8% reported by Emenonye and Nwabueze (2016) which is an indication that the corn and breadfruit starches and other products made from them are not susceptible to quick rancidity due to the low-fat content.

Table 1. Proximate Composition of Breadfruit Starch and Corn Starch

Parameters	Corn Starch	Breadfruit Starch
Crude protein	$1.25^{a} \pm 0.01$	$0.56^{b} \pm 0.04$
Moisture content	$10.45^{a} \pm 0.05$	$10.83^{a} \pm 0.18$
Ash content	$1.18^{b} \pm 0.03$	$1.85^{a} \pm 0.20$
Fat	$0.65^{a} \pm 0.12$	$0.48^{b} \pm 0.03$
Carbohydrate	$86.47^{a} \pm 0.02$	$86.28^{a} \pm 0.01$
Starch yield	$28.40^{a} \pm 0.09$	$16.26^{b} \pm 0.80$

Values are means of triplicate determinations ± SD. Means with different superscript in the same row are significantly ($p \leq 0.05$) different from each other

The ash content of corn and breadfruit starches is 1.18 and 1.85% respectively; these are slightly high than the value reported by Rincon *et al.*, (2004) who reported an ash content of 1.1%. The starch yield for corn starch and breadfruit starch from this study were 28.40% and 16.26% respectively. This is of significant importance in domestic and industrial food utilization and is similar to the one reported by Singh *et al.*, (2003). There can be variation in the starch content of breadfruit depending on maturity stage, variety, different climatic and agronomic conditions (Cai *et al.*, 2014).

3.2 Chemical and Functional Properties of Corn Starch and Breadfruit Starch.

The functional properties of breadfruit starch and corn starch are shown in Table 2. pH values were 6.12 and 6.02 for corn starch (COS) and breadfruit starch (BFS) respectively, which is slightly different from 5.51 reported by Guo *et al.*, (2018) for starches. This variation may be due to the different agronomic conditions of cultivation. The COS and BFS have high swelling power and this has been reported by Nwokocha and Williams, (2011) to be due to its lower degree of intermolecular association. The high-water absorption index exhibited by these starches may further be explained by the higher swelling power. Similar result has been reported by Glenn *et al.*, (2014).

The bulk density of the starches in g/ ml are 0.494 and 0.488 for COS and BFS respectively. The values are relatively the same. The dispersibility values are 45.60% and 43.75% for COS and BFS respectively. The values are relatively the same. Dispersibility is a measure of the ease of reconstitution of flour or flour blends in water meaning the higher the dispersibility values the better the flour reconstitutes in water (Daudt *et al.*, 2014). The Total Titrable Acidity (TTA) values for the COS and BFS are 0.043cm$^{3.}$ and 0.017cm^3. The TTA when related with the pH values of 6.12 and 6.02 showed that the starches have low acid content. Titrable acidity and pH can be used to evaluate food quality in the post-harvest period due to its influence on processing conditions (Vieira *et al.*, 2014; Tumwesigye *et al.*, 2017).

Table 2. Chemical and Functional Properties of COS and BFS

Parameters	Values	
	COS	BFS
pH	6.12^a±0.22	6.02^a±0.82
Bulk Density (g/mls)	0.494^a±0.29	0.488^a±0.22
Water Binding Capacity (%)	9.66^a±0.17	9.78^a±0.62
Water Absorption Capacity (%)	93.75^a±0.33	93.88^a±0.01
Dispersibility (%)	45.605^a±0.46	43.782^b±0.05
Total Titrable Acidity (TTA) (cm^3)	0.043^a±0.17	0.017^b±0.00

Values are means of triplicate determinations ± SD. Means with different superscript in the same row are significantly (p≤0.05) different from each other.
Key: COS - Corn Starch; BFS - Breadfruit Starch

Table 3 shows the swelling power and solubility at different temperatures of COS and BFS. The swelling of starch in water is an important structural characteristic towards ascertaining its suitability for processing and culinary applications. Starch can undergo different stages of swelling from water absorption of amorphous regions of swelling of starch granules to the disintegration of the granules (Chisenga *et al.*,2019). The swelling power of COS and BFS increases with increase in temperature of the starch, but there was a rapid increase in the swelling power from 70 °C to 80 °C. This was similar to the findings of Vedha *et al.*, (2014) and Akanbi *et al.*, (2009). Starch in excess water from dispersions. When dispersion is heated, swelling, starch granule, gelatinization and solubilization occurs which influence the properties of both continuous and dispersed phases and paste development. The swelling power has been related to the associative binding within the starch granules and apparently, the strength arid character of the micellar network which is related to amylose content of the starch. Low amylose content produces high swelling power. As a result of swelling, there is an increment in the solubility showing the highest value at 90 °C. The results are also similar to the ones reported by (Bonsi *et al.*, 2014) for starch.

Table 3. Swelling Power and Solubility Index of Corn starch and Breadfruit starch

Temperature	Swelling Power		Solubility g/100g	
(°C)	COS	BFS	COS	BFS
60	32.23^a±0.22	28.45^b±0.00	2.56^a±0.28	2.42^a±0.11
70	41.84^a±0.17	41.67^a±0.02	2.68^a±0.40	2.50^b±0.37
80	134.03^a±0.01	133.52^a±0.33	5.72^a±0.24	5.38^b±0.38
90	195.30^a±0.45	193.10^b±0.40	6.90^a±0.51	6.59^b±0.12
100	204.00^a±0.62	203.42^a±0.29	8.04^a±0.22	7.96^b±0.10

Values are means of triplicate determinations ± SD. Means with different superscript in the same row are significantly (p≤0.05) different from each other.
Key: COS - Corn Starch; BFS - Breadfruit Starch

3.3 Pasting Properties

Table 4 shows the pasting temperature (PT), Peak viscosity (PV), breakdown (BD), final viscosity (FV) and setback (SB) values. The property of starch to absorb water and swell is primarily dependent on the pasting temperature. The higher the pasting temperature, the faster the tendency for paste to be formed (Pascoal *et al.*, 2013). Hence in the presence of water and heat, starch granules swell and form paste by imbibing water (Yuan *et al.*, 2007). The pasting temperature were found to be 76.95 °C and 84.45 °C for COS and BFS respectively and these values is almost the same as 78 °C reported by Bezerra *et al.*, (2019). The pasting temperature depends on the size of the starch granules, small granules are more resistance to rupture and loss molecular order so, this might explain the relatively high pasting temperature (Glenn *et al.*, 2014).

Table 4. Pasting properties of Corn starch and Breadfruit starch

Parameters	RVU	
	COS	BFS
Pasting Temperature (PT) (°C)	76.95^b ± 0.01	84.45^a ± 0.00
Peak Viscosity (PV)	137.83^a ± 0.00	120.17^b ± 0.35
Final Viscosity (FV)	160.42^a ± 0.20	153.58^b ± 0.07
Break Down (BD)	15.86^a ± 0.23	8.17^b ± 0.56
Setback(SB)	33.08^b ± 0.31	48.58^a ± 0.61

Values are means of triplicate determinations ± SD. Means with different superscript in the same row are significantly (p≤0.05) different from each other.
RVU= Rapid Visco Units. COS-Corn Starch; BFS- Breadfruit Starch.

However, the peak viscosities (PV) were 137.83RVU and 120.17 RVU for COS and BFS respectively. Higher PV may be as a result of the differences in protein content (Sandhu and Singh, 2007). 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 COS and BFS also have breakdown values of 15.86RVU and 8.17RVU which are higher than that reported by Zhu and Wang, (2013). The setback values were 33.08RVU and 48.58RVU for COS and BFS respectively; the higher the setback value, the lower the retro gradation during cooling and the lower the staling rate of the products obtained from the starch (Ricon and Padilla, 2004).

The final Viscosity (FV) value were 160.42 and 153.58 for COS and BFS, this marked increase is due to the alignment of the chains of amylose in the starch (Flores-Fanas *et al.*, 2000).

4 Conclusion

For all the parameters studied, it can be concluded that breadfruit starch compares favourably well with corn starch. It has an array of functional, pasting and proximate properties that can facilitate its use in so many areas where the properties of corn starch (that had been known and confirmed) are acceptable.

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