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Physico-chemical and pasting properties of starch from three plantain cultivars grown in Nigeria

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Starch was extracted from three different plantain (*Musa paradisiaca*) cultivars: agbagba, cadaba and French horn, and the physico-chemical and pasting properties of the starch were investigated. The percentage starch yield ranges from 6.67 (cadaba) to 15.00% (French horn). pH values fall between 4.46 to 5.50 with the highest pH occurring in cadaba (5.50). A higher moisture content of 13.15% was observed in French horn which was significantly different ($p \geq 0.05$) from 11.56% recorded in Agbagba. The swelling power showed no significant difference ($p \geq 0.05$) between the cultivars studied. However, Agbagba cultivar had higher starch solubility (7.49%) as compared to other cultivars. Although, a higher amylose (%) was observed in three cultivars (29.96 - 30.91%), it showed no significant difference ($p \geq 0.05$) which also affected the amylopectin. The peak viscosity and trough was higher in starches from French horn (163.17 and 135.00 RVU, respectively) with the lowest breakdown viscosity of 28.17 RVU. Pasting temperature was observed to be higher in Agbagba (94.75°C) with a corresponding peak time of 5.58 min; however there was no significant difference ($p \geq 0.05$) in peak time (which is an indication of cooking time) between the cultivars studied.

Key words: Plantain starch, cultivars, pasting properties, physico-chemical properties.

INTRODUCTION

Plantain (*Musa paradisiaca*), a member of the banana family, originating in Southeast Asia serves as a major starchy staple food with great economic value in many parts of the African Subcontinent. It provides a rich source of dietary energy and also a good source of carbohydrate (Adeniji et al., 2007). The efforts of research bodies like International Institute of Tropical Agriculture (IITA) has developed several cultivars of plantain that has led to availability of high yielding varieties of plantain, disease and pest-resistant, combined with good post-harvest qualities (FAO, 2005). Almost all the known edible-fruited cultivars arose from two diploid species, *Musa acuminata* and *Musa balbisiana* (Simmonds, 1996).

Nigeria is one of the largest plantain producing countries in the world (FAO, 2006). However, about 35 to 60% post- harvest losses had been reported and attributed to lack of storage facilities and inappropriate

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technologies for food processing. Technological improvement in methods for long term preservation could thus be a way of attending to this problem (Anon, 1991). Unripe plantain can be peeled, diced and dried to make chips. Since unripe plantain contain large amounts of starch (over 80% of dry weight), their processing into flour and starch is of interest as a possible resource for food and/or other industrial purposes. Starch contributes greatly to the textural properties of many foods and is widely used in food and industrial applications as thickener, stabilizer and gelling agent (Marriot et al., 1981).

The starch in unripe plantain consists of mainly amylose and amylopectin and this is replaced by sucrose, fructose and glucose during ripening. The relative proportion of amylose and amylopectin and the organization within solid granules determine the physicochemical and functional properties of starch, as well as the susceptibility for physical (for example, gelatinization) and chemical modifications (for example, hydrolysis). Da mota et al. (2000) and Bihaderis et al. (1993) reported that the type of the starch used is a critical factor in the modification of food texture rather than the amount of starch used.

Pasting properties is an important index in determining the quality of starch. Plantain starches have been reported to have potentials for commercial utilization due to its pasting properties and physiochemical properties (Saifullah et al., 2009; Odenigbo et al., 2013). Knowledge on these starch and physiochemical properties of various cultivars of plantain in Nigeria could enhance the potential commercial utilization of plantain starch in food and pharmaceutical industry. The objective of this study was therefore to produce plantain starch from different plantain cultivars; as well as investigate their physico-chemical and pasting properties.

MATERIALS AND METHODS

Three bunches of unripe plantain cultivars: Agbagba, Cadaba and French horn was bought from Rivers State Agriculture Development Programme farm (ADP) Rumuodumaya, Port Harcourt, Nigeria and transported to the Department of Food Science and Technology Laboratory for processing.

Extraction of starch

Starch was extracted from the different plantain cultivars by a modification of the method of Kim et al. (1995). The fruits were weighed (6 kg), washed, peeled and the pulp diced into 5-6 cm cubes for easy disintegration during maceration. They were then macerated at low speed in a Waring blender (McConnellsburg, PA) with water (1:4 w/v) for about 2 min. The slurry was then filtered through a muslin cloth.

The filtrate was allowed to stand for 2 h for starch to settle and the supernatant was discarded. The sediment (starch) was put in a jute bag and pressed to remove water. The starch was dispersed on aluminum foil and oven dried in an air oven (DHG 9140A) at 55°C for 12 h. Dried starch samples were milled, sieved, weighed and their weights noted, packaged and sealed in polythene bag prior to analyses. The starch yield was calculated using the formular below:

$$\text{Starch yield (\%)} = \frac{W1}{W2} \times 100$$

Where W1 is the weight of starch extracted in kg from a known weight (W2) of the plantain fingers. W1 = weight of dried starch; W2 = weight of plantain.

Physico-chemical properties of starch

The pH, moisture content and ash content of starch from the three plantain cultivars were determined using the method of AOAC (1990). The percentage solubility and swelling power were determined according to the method described by Svarovsky (1987); and the water binding capacity of starch was done using the method of Medcalf and Gille (1965).

Determination of percentage amylase and amylopectin

The amylose content of starch extracted from the three plantain cultivars was determined using the iodine colorimetric method reported by Zakpaa et al. (2010). A standard curve for amylose was prepared using different concentrations ranging from 0 - 70 mg of pure amylase. These were weighed into separate 100 ml volumetric flasks and 1 ml of ethanol, 10 ml of distilled water and 2 ml of 10% NaOH were added. The flask with their contents was heated in water bath until a clear solution was obtained. The samples were cooled and diluted to mark with distilled water. Five (5 ml) of the solution was measured into a 500 ml volumetric flask and 100 ml of distilled water added and immediately acidified with drops of 6 M Hcl. The contents were mixed before 5 ml of iodine solution was added and made up to mark with distilled water. The absorbance of each standard was measured using a spectrophotometer (UV - visible model 754, China) at a wavelength of 640 nm. 100 mg of plantain starch was weighed into 100 ml volumetric flask and the above procedures repeated. The concentration of amylose was calculated from the standard curve. The percentage amylopectin was calculated from the amylose obtained.

Pasting properties

The pasting properties of the flours were characterized by using Rapid Visco Analyzer (RVA) (model 3c, Newport scientific PTV Ltd, Sydney) as described by Delcour et al. (2000) and Sanni et al. (2006). 2.5 g of each sample was accurately weighed into a weighing vessel, 25 ml of distilled water was dispensed into a new canister. Samples were transferred into the water surface of the canister, after which the paddle was placed into the canister. The blade was vigorously joggled up and down through the sample ten times or more until no flour lumps remained either on the water surface or on the paddle. The paddle was placed into the canister and both were inserted firmly into the paddle coupling, so that the paddle is properly centred. The measurement cycle was initiated by depressing the motor tower of the instrument. The test was then allowed to process and terminated automatically.

RESULTS AND DISCUSSION

The result for the physico-chemical properties are as presented in Table 1. Values for moisture content ranged

Table 1. Physico-chemical properties of starch from three different cultivars of plantain.

Parameter	French horn	Cadaba	Agbagba
Moisture content (%)	11.56 ± 0.05[b]	12.86 ± 0.05[a]	13.15 ± 0.020[a]
Ash (%)	0.05 ± 0.03[a]	0.29 ± 0.09[b]	0.45 ± 0.02[ab]
Swelling power (%)	9.48 ± 0.42[a]	10.76 ± 0.72[a]	10.10 ± 0.69[a]
Solubility (%)	7.49 ± 1.70[a]	3.55 ± 0.04[b]	5.02 ± 0.76[ab]
WBC (%)	65.50 ± 1.70[a]	54.40 ± 0.14[b]	62.90 ± 0.28[a]
Amylase (%)	29.96 ± 0.14[a]	30.66 ± 0.28[a]	30.91 ± 0.21[a]
Amylopectin (%)	70.04 ± 0.14[a]	69.34 ± 0.28[a]	69.09 ± 0.21[a]
pH	4.46 ± 0.09[a]	5.50 ± 0.14[a]	4.70 ± 0.56[a]
Starch yield (%)	15.00 ± 0.01[a]	6.67 ± 0.02[c]	13.30 ± 0.04[b]

Mean ± SD of duplicate determinations. Values in the same row with different superscripts differ significantly ($p < 0.05$). WBC; water binding capacity.

from 11.56% in agbagba to 13.15% in French horn. The values obtained for moisture content falls within the range of 10 to 13.5% reported by Onwueme (1982). Agbagba starch with the least moisture content of 11.56% gave the highest value for ash (0.5%). The result for pH falls between 4.46 to 5.50. Onwueme (1982) also reported pH values of 4.47 - 5.50 for a good starch quality. Swelling power ranged from 9.48 (Agbagba) to 10.76% in Cadaba. These values were comparable with the observation of Zakpaa et al. (2010) who reported swelling power of 10.28% for giant horn plantain. Safo-Kantanka and Acquistucci (1996) reported that the swelling power of a starch based food is an indication of the strength of the hydrogen bonding between the granules. Eke-Ejiofor and Owuno (2012) also reported the findings of Richard et al. (1991) which further described swelling power as a factor of the ratio of amylose to amylopectin, the characteristics of each fraction in terms of molecular weight/distribution, degree/length of branching and conformation. Swinkels (1985) reported that a good quality starch has a low solubility and a higher swelling power. There was no significant difference ($P \geq 0.05$) in swelling power values for all the starches. The solubility of cadaba starch (3.55%) was significantly lower than the other two cultivars. Solubility according to Hari et al. (1989) reflects the extent of intermolecular cross bonding within the granule. Values for solubility for French horn was 5.02% and Agbagba (7.49%), the value for French horn is close to the value of 5.28% reported by Zakpaa et al, (2010) for giant horn plantain starch.

The water binding capacity (WBC) of the plantain starches ranged from 54.40 - 65.50%. Water absorption capacity is the ability of flour particles to entrap large amount of water such that exudation is prevented. Niba et al. (2001) described water absorption capacity as an important processing parameter that has implications for viscosity, while Wooten and Bamnuaruchi (1978) describes it as important in determining the quality and texture of some food products because it stabilizes them against effects such as syneresis which sometimes occur during retorting and freezing. The WBC value of 54.40% obtained for cadaba was very close to the value of 54.07% obtained for giant horn by Zakpaa et al. (2010).

Amylose levels of the starches ranged from 29.96 - 30.91% with cadaba and French horn significantly different from agbagba ($P \geq 0.05$). Michael (1990) reported that amylose level in starches range between 21 to 30%. The values obtained in the study falls within the range given by Michael (1990). Result for amylopectin showed Agbagba was significantly higher with a value of 70.04%. Values for starch yield ranged from 6.67% in cadaba to 15% in French horn.

The result of pasting characteristics is as shown in Figures 1, 2 and 3. Peak viscosity which is the maximum viscosity developed during or soon after the heating process is lower in agbagba starch (133.50 RVU) and higher in French horn (163.17 RVU). Peak viscosity is a measure of the ability of starch to form a paste on cooking (Adewole et al., 2012).

Adewole et al. (2012) reported a value of 166.00 RVU for plantain starch which was comparable to values obtained for French horn (163.17 RVU) and Cadaba (161.17 RVU). This high viscosity showed that the starches formed a paste on cooking with a corresponding pasting temperature of 86.05 and 85.95°C for French horn and Cadaba, respectively. Peak viscosity is indicative of the strength of pastes, which are formed from gelatinization during processing in food application. It also reflects the extent of granule swelling (Liang and King, 2003).

Trough values ranged from 85.08 to 135.00 RVU. French horn gave the highest trough (hold) value. These values were lower than 141.75RVU reported by Adewole et al. (2012) which could be as a result of varietal or environmental differences. The holding strength is the ability of granules to remain undisrupted when the starch

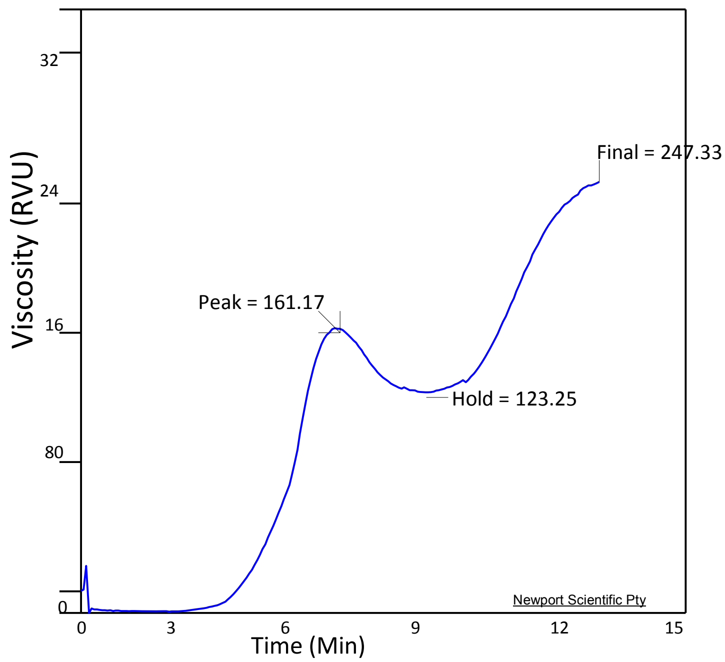

Figure 1. Pasting curve of cadaba plantain starch.

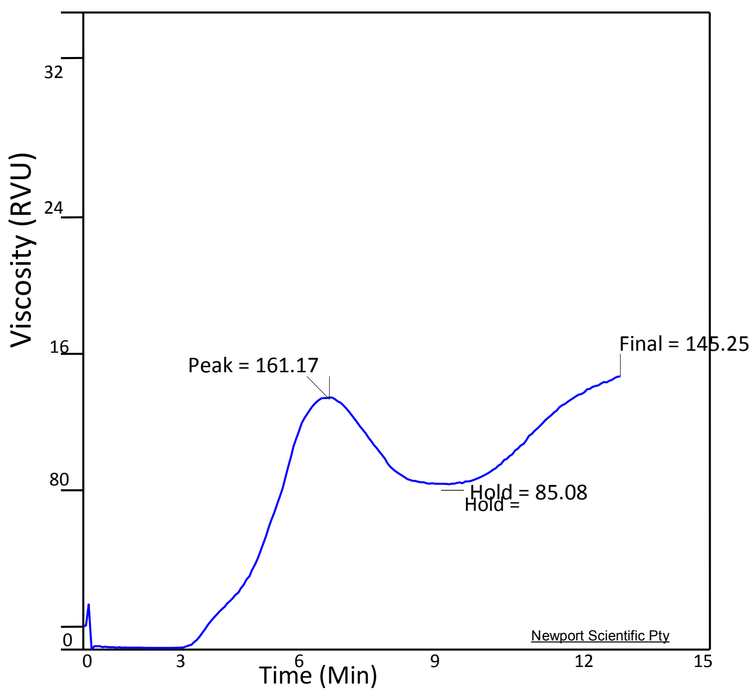

Figure 2. Pasting curve for agbagba plantain starch.

is subjected to a period of constant high temperature and mechanical shear stress, this hold period is often accompanied by a breakdown in viscosity. The breakdown was highest in Agbagba (48.42RVU) and least in French horn (28.17RUV). Adewole et al. (2012) reported values of 24.45 RVU for plantain and 29.42 RVU for banana

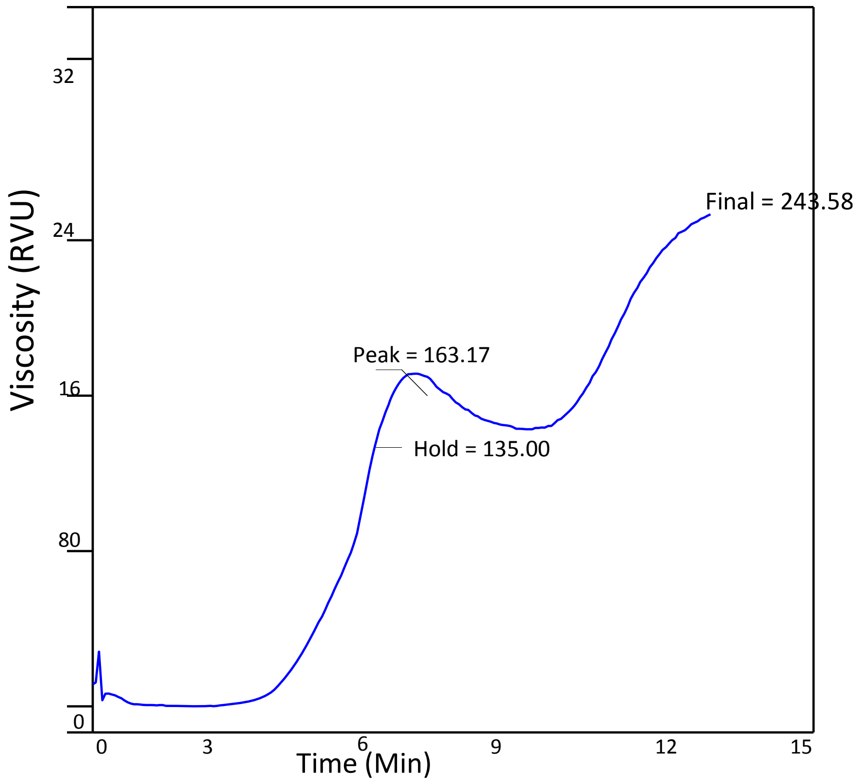

Figure 3. Pasting curve of french horn plantain starch.

starches.

The ability of starch to withstand shear thinning or breakdown in viscosity (that is high breakdown value) is of high industrial significance in starches (I.I.T.A, 2011), thus all the starches obtained in this study will be useful in industrial food applications. The final viscosity ranged from 145.25 RVU in Agbagba to 247.33 RVU in cadaba. These values are lower than the value of 298.67 RVU reported for plantain starch by Adewole et al. (2012). Values for setback viscosity ranged from 60.17 RVU in Agbagba to 124.08 RVU in Cadaba. Final viscosity is an important parameter in predicting and defining the final and textural quality of foods (Kramer and Twigg, 1970). High set back viscosity is associated with a cohesive paste, while a low setback viscosity is indicative of a non-cohesive paste (IITA, 2011). This shows that starches from cadaba and French horn will produce a more cohesive paste, these values correlate with values for final viscosity which was also higher in cadaba and French horn indicating that the two starches will be more useful industrially as compared to Agbagba. Bihaderis et al. (1993) and Brooks and Schiltach (1999) reported the use of starches with high viscosity value as tablet binders in pharmaceutical companies. The time to attain peak viscosity ranged from 5.35 min in French horn to 5.68 min in cadaba.

Conclusion

The starches extracted from the cultivars possess good physico-chemical and pasting properties and could be utilized in plantain based food and pharmaceutical products. Starch from French horn cultivar had a better yield and lower value of breakdown viscosity indicating a more stable paste formation.

Conflict of Interests

The author(s) did not declare any conflict of interests.

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