Characterization of flour and starch from guineo plantain AAAea (*Musa sapientum* L.)

Caracterización de harina y almidón obtenidos a partir de plátano guineo AAAea (*Musa sapientum* L.)

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Abstract

This study characterized guineo´s AAAea (*Musa sapientum* L.) flour and starch and their chemical, thermal, functional and morphological parameters. The results indicated a yield of 33.33% for flour and 3.61% for starch. The protein percentage for flour was 5.43% while for the starch was 2.17%, the analysis of soluble fiber to flour yielded a result of 19.85% and fat analysis in the starch was 4.11%. Thermal analysis shows that the flour stage of decomposition ranges from 141.33 °C to 388.30 °C where there is a weight loss of 55.85%. For the same starch sample stage is between 248 °C to 327 °C where weight loss is 74.15%. The gelatinization temperatures for flour and starch were 68 °C and 66.4 °C respectively, gelatinization enthalpies 2.38 J/g for flour and 6.06 J/g for starch. In the RVA analysis during the cooling period, the flour and starch had a good viscosity. Starch granules are irregularly shaped mostly, although some have spherical or oval forms. Sizes range from 4.17 µm to 42.11 µm.

Key words: Chemical, thermal, functional and morphological characterizations, guineo, flour, starch.

Resumen

En el estudio se caracterizaron las propiedades química, térmica, funcional y morfológica de la harina y el almidón de guineo AAAea (*Musa sapientum* L.). Los resultados mostraron un rendimiento de 33.33% para harina y 3.61% para almidón. El porcentaje de proteína en la harina fue de 5.43% y en almidón de 2.17%. La fibra soluble en harina fue de 19.85% y de grasa en el almidón de 4.11 %. El análisis térmico de la harina mostró que la etapa de descomposición varía desde 141.33 °C hasta 388.30 °C con una pérdida de peso de 55.85%. Para el almidón esta misma condición ocurrió entre los 248 °C y 327 °C con una pérdida de peso de 74.15%. Las temperaturas de gelatinización para harina y almidón fueron de 68 y 66.41 °C, respectivamente, con entalpías de gelatinización 2.38 J/g para harina y 6.06 J/g para almidón. En el análisis de RVA durante el período de enfriamiento, tanto la harina como el almidón presentaron buena viscosidad. La mayor parte de los gránulos de almidón mostraron formas irregulares, aunque algunos tienen forma esférica u oval. Los tamaños varían desde 4.17 µm hasta 42.11 µm.

Palabras clave: Almidón, caracterización química, térmica, funcional y morfológica, guineo, harina.

Introduction

Wheat flour is commonly used on the home daily market and in food industry as a base to prepare bakery products and instant soups. Flours from other raw materials like plantain, corn and rice are not used by the consumers because of lack of knowledge on their properties (Louis and Nwokocha, 2009). Starch is used in different industry sectors, mainly in food but also in textile, paper, plastics, dextrin and glue manufacturing, among others. Nowadays, there is a trend to search for new alternatives of native starches or modified ones in respect to their physical or chemical characteristics (Mohapatra *et al.*, 2009; Aurore *et al.*, 2009) in special the ones coming from tropical regions like mafafa, creole potato, parsnips, cassava, plantain and other musacea varieties, among others (Mohapatra *et al.,* 2010).

Guineo AAAea (*Musa sapientum*) is a musacea belonging to the group of cooking plantains no-Plantain, a poorly propagated crop in the world, although it is a common fruit in the tropics. In Colombia it is used as a fresh fruit for human consumption and animal feed. In several studies, it was demonstrated that guineo belongs to *Musa sapientum* and to the subgroup *Mutika-Lujugira*, which correspond to the genetic classification AAAea. (Gibert *et al.,* 2009; Dufour *et al.,* 2008 - 2009).

According to Dufour *et al.* (2008) in plots of small farmers the presence of different musaceas genetic groups is frequent; generally they are used for family consumption and are not found at local or national markets. In Colombia, with exception to the Plantain group, there is local production and consumption of around 400,000 t of cocking plantains, among them are highlighted AAB (guayabo), ABB (cachaco, pelipita), high plantain AAAea (guineo), among others.. Hybrids developed by the Fundación Hondureña para la Investigación Agrícola (FHIA) are productive and resistant to diseases; however, they have not been widely adopted because of their poor aroma and taste. On the other hand, the wide diversity of traditional products based on plantain and banana is recognized but, few authors state the consumer preference for some varieties according to their use, in particular on the less cultured varieties grown by small farmers (Dufour *et al.,* 2008). According to the above, it was required to determine the chemical, thermic, morphologic and functional characteristics of guineo and know its potential use as alternative raw material to make flour and starch for food industry.

Materials and methods

Flour and starch extraction and yield

The raw material used (guineo, *Musa sapientum*) was collected in La Esperanza farm, town of Calarcá, departament of Quindío, at 1400 MASL.

The yield percentage of guineo flour was determined by selecting three bunches of 500 g each. Each guineo fruit was weighted, peeled and sliced in slices before being taken to dry in the oven (Memmert UL40) at 40 °C for 48 h, then it was ground (IKA 2870900 MF 10.1 grinder, USA) in order to get flour with particle size < 100 µm (Mestres, 1993).

For starch extraction, water was added to the slices on a ratio 1:1 volume/volume (v/v) or weight/weight (w/w) and then it was homogenized at 6000 rpm for 1 min before the solution was sieved through a 100 µm mesh with constant addition of distilled water. Finally, the mix was centrifuged (J. P. Selecta - Medifriger BL-S, Spain) at 10,000 rpm for 1 min at 25 °C and the precipitate was filtered through a 100 µm mesh and then it was dried out on a recirculating oven at 40 °C for 48 h.

Chemical composition

In native and isolated flour and starch from guineo were determined by triplicate the raw protein (N x 6.25) by micro-Kjeldahl

(Method 46-13, AACC, 2000), humidity (Method 925.10, AOAC, 2000), fat (Method 30-25, AACC, 2000) and ashes (Method 08-01, AACC, 2000).

Thermal properties

Thermogravimetrical analysis (TGA). This analysis was performed using the TA Instruments TGA Q500 in presence of a nitrogen atmosphere for a temperature range from room temperature to 800 °C, with a heating speed of 5 °C/min in samples of 6 ± 0.50 mg (Pineda-Gómez *et al.,* 2011).

Differential Scanning Calorimetry (DSC). Determination of temperature and enthalpy of gelatinization (T_p y ΔH_p) for flour and starch was done with TA Instruments DSC-Q100, in samples of (10.00 ± 0.50 mg) with 80% water content, for a heating speed of 5 °C/min, from room temperature till 100 ºC on a nitrogen atmosphere (Pineda-Gómez *et al.*, 2011).

Morphological analysis

Differential scanning microscopy. The morphology of the flour and starch was done with a scanning microscope (JEOL, Model JSM-6060LV, Japan) with high vacuum and 5 nm resolution in high tension mode. Analysis were done at 20 kV electron acceleration tension and 12 – 20 Pa pressure on the sampling chamber getting images of the fracture surfaces by the secondary electrons signal (Delpeuch and Favier, 1980; Jane *et al.,* 1994).

X-ray diffraction. Samples were reduced to a fine powder and sieved through a 150 µm mesh, then, they were densely packed on an aluminum container. X-ray diffraction patterns were obtained using a diffractometer Bruker D8 advance, with a Cu Kα (l = 1.5 5418 Å) radiation line, with a differential in potential of 30 kV and current density of 20 mA. Samples were registered between 5 and 40 degrees (2θ) with a pitch angle of 0.050 and counting time per pitch angle of 15 seg. Material was placed on aluminum sample slides with 30 x 30 mm area at room temperature and low humidity (Rojas-Molina *et al.,* 2007).

Functional analysis

Viscoamylograph. A Rapid Visco-Analyzer RVA-4 (Newport Scientific PTY LTD, Sydney, Australia, 1998) was used. For this analysis were prepared aqueous pastes, a solution containing 8% of flour with α-amylase inhibitor ($AgNO_3$ 0.002 mol/l) and, other with 7% starch without inhibitor. Each solution was heated with constant agitation from 50 ºC till 90 ºC with an increase in temperature of 6 °C per minute, followed by a constant temperature of 90 ºC for 5 min and finally reduced to 50 °C at a rate of 6 °C per minute (Dufour *et al.,* 2009).

Results and discussion

Chemical analysis

Average yield of guineo flour was 33.33% and the yield percentage of the starch extraction was 3.61%. The percentages of ashes in the guineo flour and starch were 2.76 ± 0.16 y 0.61 ± 0.06, respectively (Table 1), values that are close to the ones found by Yadav *et al.* (2005) in potato flour and by Gibert *et al.* (2009) in guineo flour. Percentages of protein were higher in flour (5.43%) than in starch (2.17%) and agree with the ones found by Gibert *et al.* (2009) for guineo starch, however, they were lower than the ones reported by Willard and Hix (1987) in potato flour (Willard and Hix, 1987). Humidity content, both in flour and in starch, was possibly affected by the environment in the laboratory where the analysis was performed; this explains the high SD values found. These contents are similar to the ones stated by Zakpaa *et al.*, (2010) for potato flour. The fat percentage was higher than the one found by Zakpaa *et al.*, (2010) for *Musa sapientum* L. starch and by Willard and Hix (1987) for potato flour; to the opposite, the carbohydrates present in the analyzed samples were lower than the

Table 1. Proximal analysis of flour and starch of guineo AAAea (*Musa sapientum*).

Component		Flour (%)	Starch (%)
Ashes		2.76 ± 0.16	0.61 ± 0.06
Protein		5.43 ± 0.00	2.17 ± 0.00
Fiber	Soluble	0.60 ± 0.00	0.12± 0.00
	Insoluble	18.48 ± 0.03	–
Moisture		4.92 ± 0.71	8.15 ± 2.35
Fat		1.05 ± 0.02	4.11± 0.81
Carbohydrates		66.76 ± 0.00	–

ones reported by the same authors in these crops.

When comparing the proximal composition of guineo flour that belongs to the group of cocking plantain no-Plantain, in which the varieties guayabo, hua moa, cachaco and pelipita also belong, together with other musa groups like dessert bananas (bocadillo, primitivo, Cavendish, Gros-Michel, rollizo, tafetán morado), dessert hybrids (FHIA 17, 1, 18 y 25), cocking hybrids (FHIA 20 y 21), plantains from the group Plantain (Africa, Dominico, Dominico Hartón, Hartón, Cubano blanco, Hartón Maqueño) (Dufour *et al.,* 2009; Gibert *et al.,* 2009), it was observed that in general the ashes content in all the groups varied between a range of 2.3% and 4.3%, which agrees with the results of the present study. Contents of crude fiber and total protein between the different musacea groups fluctuated between 1.8% and 5% and between 2.1% and 4.9%, respectively, which are values lower than the ones found in this study, specially the fiber that was > 18%.A similar behavior was observed by Da Mota *et al.* (2000) for the Mysore (AAB) variety, in which the fiber content was higher than 15%, mainly in the insoluble fraction, which was two times higher than in the Nanica and Nanicão (AAA) varieties that are widely consumed. It is important to notice that the insoluble fiber helps reducing the transit time in the gut and the interaction between mutagenic substances and the gut ephitelia; therefore, it helps to protect against colon diseases, while the soluble fiber has a hypocholesterolemic effect due to its capacity to absorb bile acids.The percentage of protein in guineo starch was > 2%, a high value for raw material with agroindustrial uses and similar to the one found by Olayide *et al.* (2008) and Núñez-Santiago *et al.* (2004). The content of ashes in guineo starch (0.61%) from this study was similar to the one revealed by Núñez-Santiago *et al.* (2004) for male plantain starch (0.54%) and higher than the ones found by Pacheco-Delahaye and Techeira (2009) for native starch of yam (0.43 %).

Finally, the humidity content in guineo starch in this study was similar to the one obtained in plantain and yam starches by the previous authors; whereas the fat contents were variable between studies.

Thermal properties

During the cocking and processing processes, flours and starches are affected by the heat changing their physical and chemical aspects that influence the quality of the final product. In general, the different transformations that happen are related to the water content present, the temperature and the rate of caloric flux given during the process.

Thermogravimetric analysis (TGA). The thermogram of guineo flour is displayed in Figure 1. The weight loss was 8.62% till

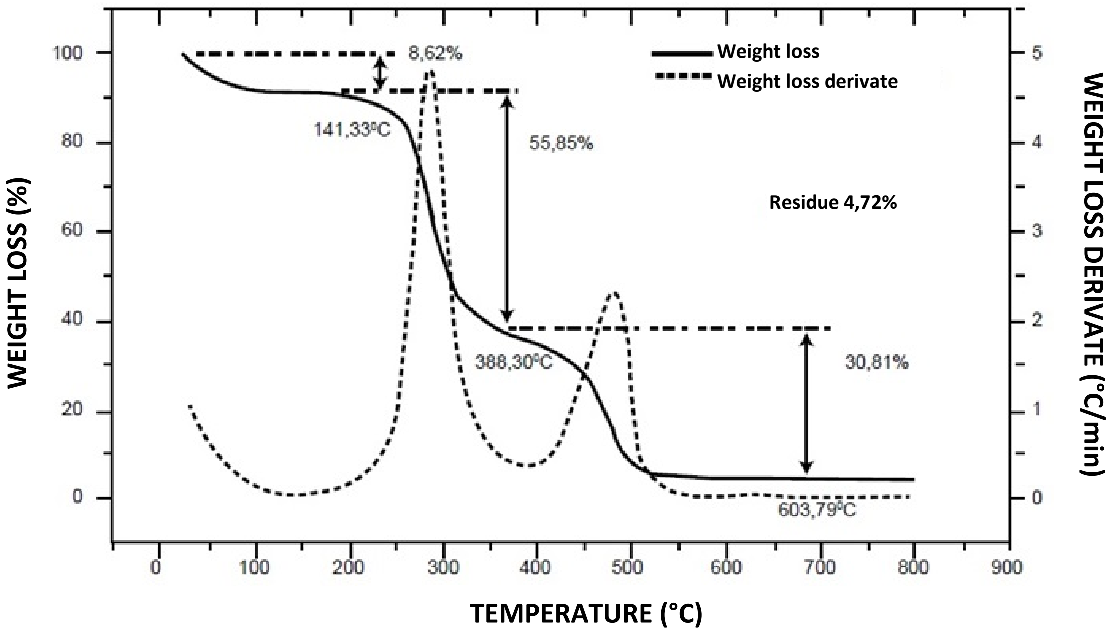


Figure 1. Thermogram of guineo flour.

141.33 °C related to the initial weight of the sample, which corresponds to the water content of the flour. From that point on there was another event of weight loss that finished at 388.30 °C with 55.85% decrease in weight, moment in which carbohydrates of low molecular weight and starch are eliminated. During the last phase, that finishes at 603.79 °C, is eliminated 30.81% that corresponds to fat, protein and the rest of the component with high molecular weight in the sample. From that point on there are no significant changes and the residue of 4.72% is obtained that contains the inorganic materials of the analyzed sample. With this technique it is possible to measure the content and speed of the changes in the mass of a material as a function of temperature or time on a controlled atmosphere, measurements that are mainly used to determine the composition of a material and, to predict its thermal stability at temperatures up to 1000 °C and to determine the starch percentage in flours (Pineda-Gómez *et al.*, 2011).

Ciesielski *et al.* (1998) found similar temperatures to the ones of this study for the dehydration (135 °C) and the decomposition (400 °C) phases in corn flour. Guineo flour is thermally stable and reaches a decomposition phase at a moderate temperature. The derivative weight loss curve in phase 1 (286.13 °C) presented a rate of 4.83%/min and, in phase 3 2.32%/min at 482.87 °C.

In the thermogravimetric curve (Figure 2) of guineo starch is observed that the sample in phase 1 at a temperature of 248.63 °C eliminates 12.99% of the initial weight that corresponds to the water in the sample. At this temperature, phase 2 or decomposition phase starts till reaching 327.88 °C where 74.15% is eliminated, which corresponds to carbohydrates that are the main component of the starch. Phase 3 is until 630.96 °C with 12.63% of weight loss and, finally, till 800 °C when no relevant changes in weight are noticed a 0.23% is obtained as residue which corresponds to inorganic materials (minerals). The derivative weight loss curve of the sample shows in phase 2 a maximum speed of 12.39%/min at 308.37 °C, which means a fast decomposition of carbohydrates in the sample.

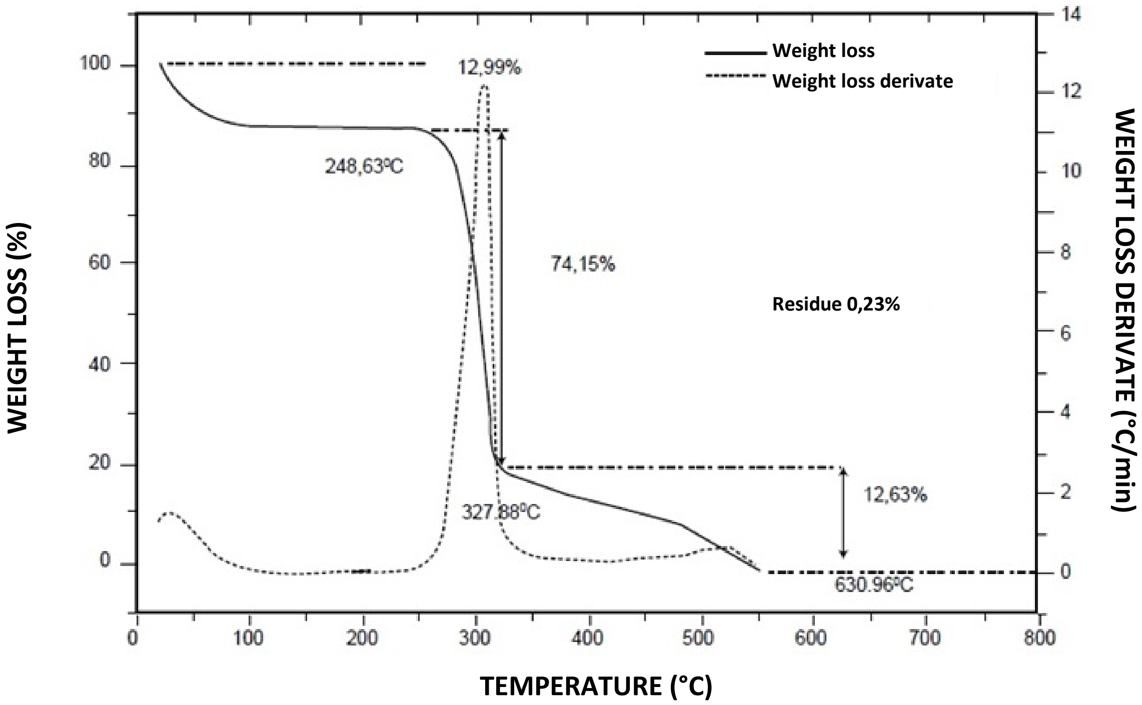


Figure 2. Thermogravimetric (TGA) and derivated DTG curve of guineo AAAea (*M. sapientum*) starch.

According to Liu *et al.* (2008) the temperature at the dehydration phase for corn starch is between 60 and 100°C which increases as the water content is higher. The maximum points in these curves allow the identification of the start and end of the thermic degradation event. Liu *et al.* (2008) considered that in these stages the main chains are broken when C-C-H, C-O and C-C bonds are broken and the reaction of combustion H_20, CO and CO_2 happens. TGA curves show only a peak indicating the presence of a unique mechanism of degradation, which involves the loss of the polymer structure of the starch (amylase and amylopectine). A sharp and long peak indicates a fast amylase degradation process; whereas a wide and small peak at temperatures higher than 200 °C shows amylopectine degradation. For guineo a sharp and long peak is observed indicating a larger proportion of amylase, parameter that can be compared with the XRD analysis.

Differential Scanning Calorimetry (DSC). When knowing the gelatinization process, it was possible to determine the content of available starch for human consumption since the gelatinized starch has a higher digestibility percentage (Pineda-Gómez *et al.*, 2011). In Figure 3 is displayed a DSC thermogram for guineo flour that shows gelatinization as a sharp endothermic peak on the thermogram basal line and initial temperature T_o de 58.8 °C where the phase transition process starts and the sample has a change that can result imperceptible. In this first phase transition, water acts as plasticizer. At this temperature, low molecular weight polymers, particularly amylose molecules begin to separate from the starch granule. As temperature increases the starch granules collapse till the amorphous part (amylose) is totally solubilize, while the crystalline part of the starch stays in the aqueous solution (Pineda-Gómez *et al.*, 2011). The peak temperature T_p was 67.48 °C and is in this point is where the highest values for heat absorption are recorded and where the sample changes from a rubbery state thanks to the onset of granule rupture. When the process is finished it comes back to a state where no changes of phase or sample composition

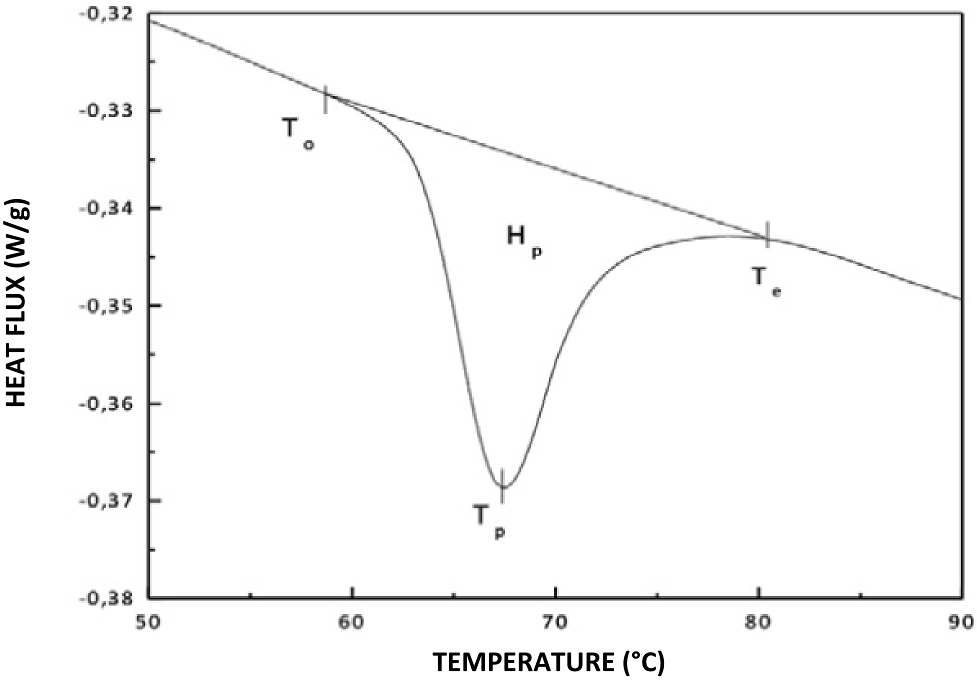


Figure 3. DSC thermogram of guineo flour.

occur. The enthalpy of gelatinization H_p is the energy absorbed during the process, its value was 2.38 J/g, which is calculated as the area under the gelatinization peak and, the final temperature of the process T_e was 80.41 °C.

This transformation is accompanied by irreversible structural changes, induced by thermic treatments in the starch, among them: water absorption, granule swelling, fusion of the crystalline part, birefringence lost and, increase in viscosity and solubility of the granule. The initial phase of the gelatinization process and the range during which it happens are mainly ruled by the starch concentration in the solution, method of observation, granule origin a shape, and homogeneity inside the grain (Rodríguez *et al.*, 2009). Dufour *et al.* (2008) found that the T_o for guineo flour was 64.40 °C; however Nimsung *et al.* (2007) found an average of 74 °C for musaceas, Nimsung *et al.* (2007) and Yadav *et al.* (2005) revealed values of 78 °C for musaceas flour and 82 °C for potato flours and values for gelatinization enthalpy between 15 and 16 J/g for musaceas and 13.70 J/g for potato flour.

Guineo starch also showed an endothermic behavior (Figure 4). Similarly to what happened with the flour, T_o was 45.53 °C, a lower value than 68.08 °C found by Nwokocha and Williams (2008) in other works with musaceas but, similar to what was reported by Rodríguez *et al.* (2005) in yellow yam (49.26%). When the gelatinization process happens there is a transition that depends on temperature and time but no on the calorific capacity, therefore there is not a significant change on the basal line once the transition ends. This is a characteristic that identifies the first order transitions. On the other hand, the gelatinized starch is predominantly an amorphous material, with a possible physical intercross among the granule components. This intercross gives rigidity to the amorphous regions and has a similar effect than the chemical intercross (Pineda *et al.*, 2011).

When the guineo starch temperatures are compared in peaks T_p (66.41 °C) and in T_e (85.53 °C) and the energy absorbed

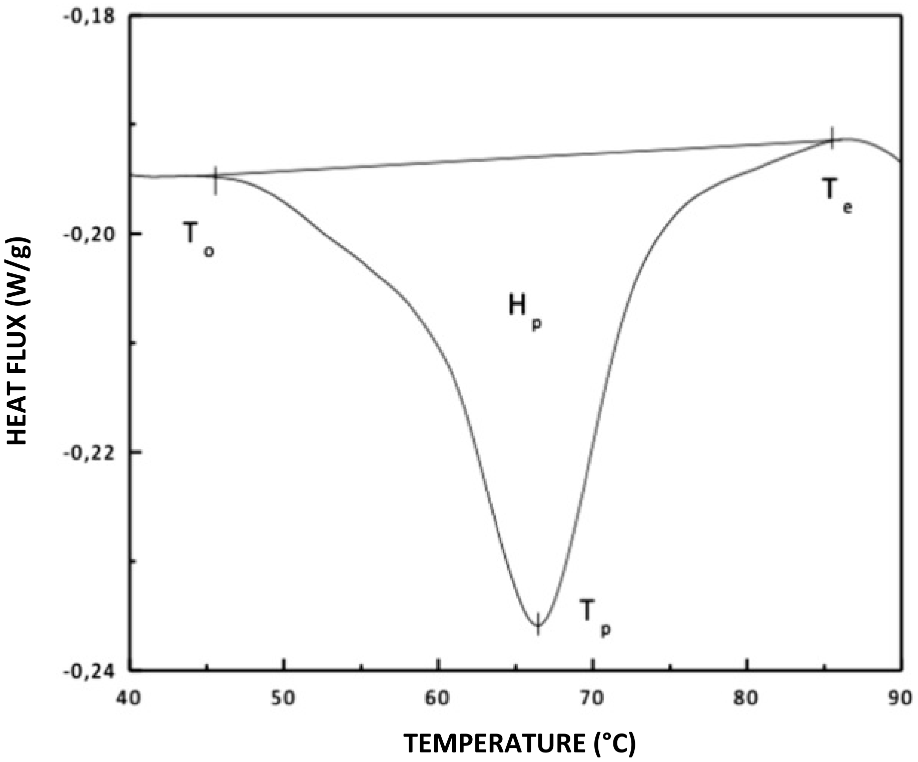


Figure 4. DSC thermogram of guineo starch.

(6.06 J/g) with the findings of Nwokocha and Williams (2008) in yellow plantain (T_p= 68.68 °C and T_e = 73.90) and in white plantain (T_p = 71.88 °C and T_e = 77.15 °C) it is observed that the temperatures of the first one are in the same range that the one found by the researchers for yellow plantain starch. These temperatures indicate the transition between the flour and starch phases at the beginning of the gelatinization of the samples when are subjected to cocking temperatures, which facilitates the understanding of the changes during the different processes to which both products are subjected at the food and non-food industry (Dufour *et al.*, 2008, 2009). The low enthalpy levels found in the guineo flour and starch are possibly due to the lack of homogeneity of the structures in the granules.

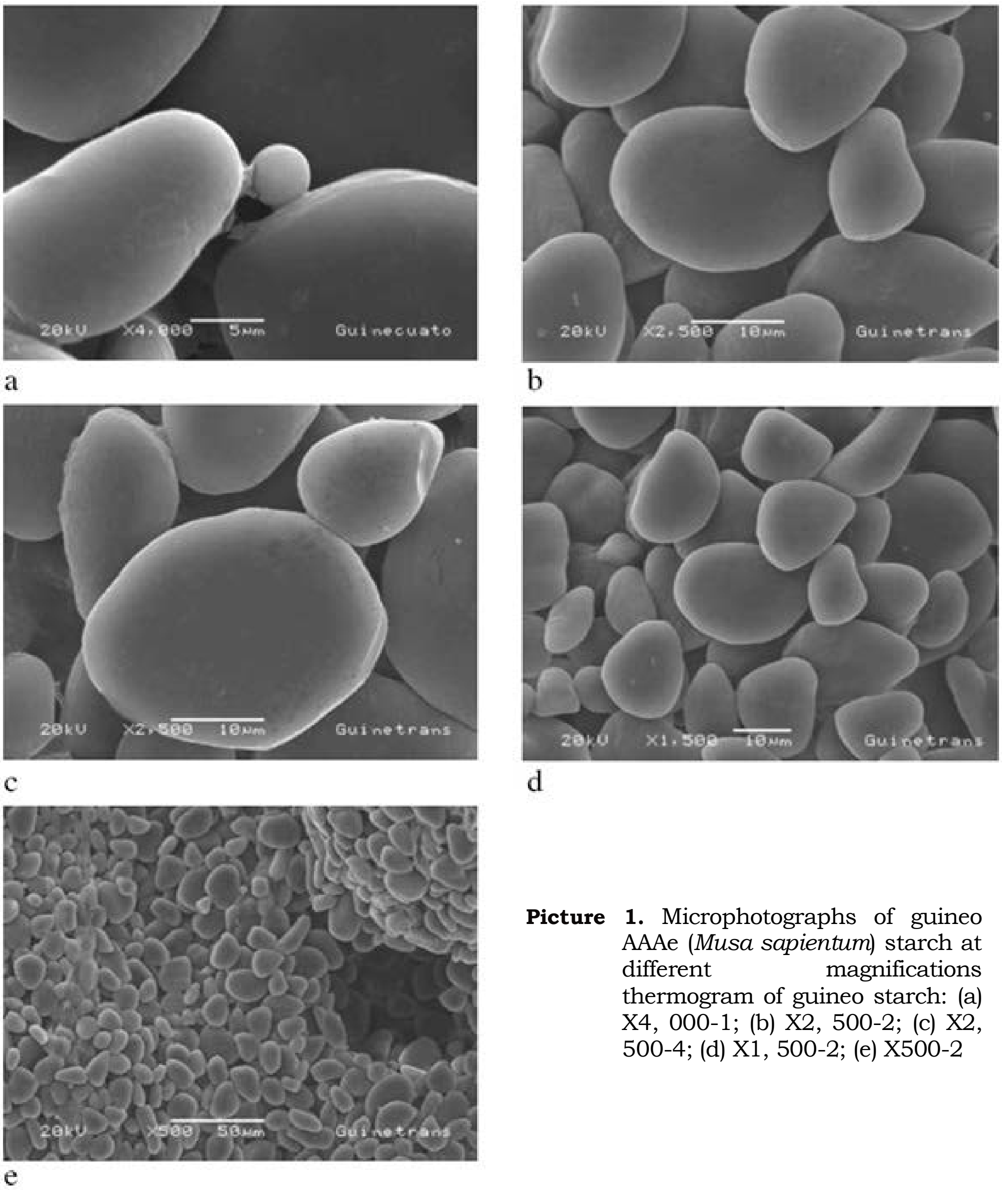
DSC analysis shows the phase transitions for starch. In this case it happens at 75.4 °C, in which the water acts as a plasticizer and the low molecular weight polymers, particularly the amylose molecules, start their separation from the starch granule. As temperature increases, the granules collapse till the amorphous part (amylose) is totally soluble while the crystalline part remains in the aqueous solution. Starch has a lower initial temperature than the flour, which is due to the presence of different components in the last one. With the final temperature the opposite happens, it is higher for starch due to the rubberiness of the sample after heat absorption.

Morphological analysis

The morphology of the starch granules could be attributed to the botanical origin, to the amyloplast biochemistry, the degree of fruit maturity and the plant physiology. Starch granule size affects its functional properties, the smaller they are the higher is their digestibility; additionally, they are resistant to processes with high temperatures such as sterilization. In some starches their granule size shows is associated with the amylose/amylopectine ratio (Delpeuch and Favier, 1980).

Microphotographs in Picture 1 show the morphology of the native starch of guineo AAAea (*M. sapientum*) without gelatinization, where granules with irregular shape, in some cases spherical or ovals, can be observed. There are different granule sizes, the smallest ones were 4.17 µm in average, middle ones with 16.52 µm and the largest ones 42.11 µm. these values are in the range found by Coulibaly *et al.* (2006) for three granule sizes. Granule size affects the physic-chemical, functional and nutritional aspects, the larger ones developed high viscosity in the paste and the smallest ones are more digestible (Espinoza *et al.*, 2009).

Granule surface presented a soft texture without pores which indicates high purity degree and excellent quality without apparent damage. The microphotographs show granules free of contaminants, this indicates an efficient extraction process and the characteristics of the material and its nature were not affected (Picture 1a, b, c). It has been observed that the small granules can absorb higher amounts of water that the larger granules due to a higher contact area (Millán-Testa *et al.*, 2005).



Picture 1. Microphotographs of guineo AAAe (*Musa sapientum*) starch at different magnifications thermogram of guineo starch: (a) X4, 000-1; (b) X2, 500-2; (c) X2, 500-4; (d) X1, 500-2; (e) X500-2

Starch is composed of two macromolecules, amylose and amylopectine, the lineal chains of these polymers can form helices with six glucose molecules per cycle. In the case of amylopectine, the α-D-(1→6) are breaking points for the formation of the helices; the short ones are only formed with the lineal parts of the molecule, instead those composed of 120 glucose molecules can be formed with the amylose. The way the double helices are packed in the amylopectine molecule and the water content are determinant parameters for the polymorphism type. Double helices with type A crystals are packed in a monoclynic way and show between 4 and 8 molecules of water; while the type B crystals show double helices arranged hexagonally and with a water content of 36 molecules indicating that, for example, the chachafruto starch conserve a less compact structure than the type A and B because it belongs to the type C, in which there is a higher packing of the amylopectine double helices (Duprat *et al.*, 1980).

In this study, the guineo flour presented a semicrystalline structure possibly due to its different components. Type B patterns have been reported for banana flours (Pingyi *et al.*, 2004), a pattern that do not have double helices as the type A but, there is a water column that is replaced with a longer amylopectine chain than the one of the type A. In Figure 5 is observed that the flour of this study showed intensity peaks for angles (2 Theta) at 12°, 14°, 17°, 18°, 19°, 20°, 22°, 24° and 25°, approximately.

Guineo starch (Figure 6), as the flour, presented a type B pattern but, its structure is crystalline, as it is characteristic in polymers. It can be observed, as well, that the intensity peaks are presented at 14°, 15°, 17°, 18°, 20°, 23°, 24° and 25°, similar to the flour sample analyzed.

Functional analysis

In Figure 7 is observed the rheological behavior of guineo flour. Pasting temperature was 69.28 °C after 4.22 min. Maximum

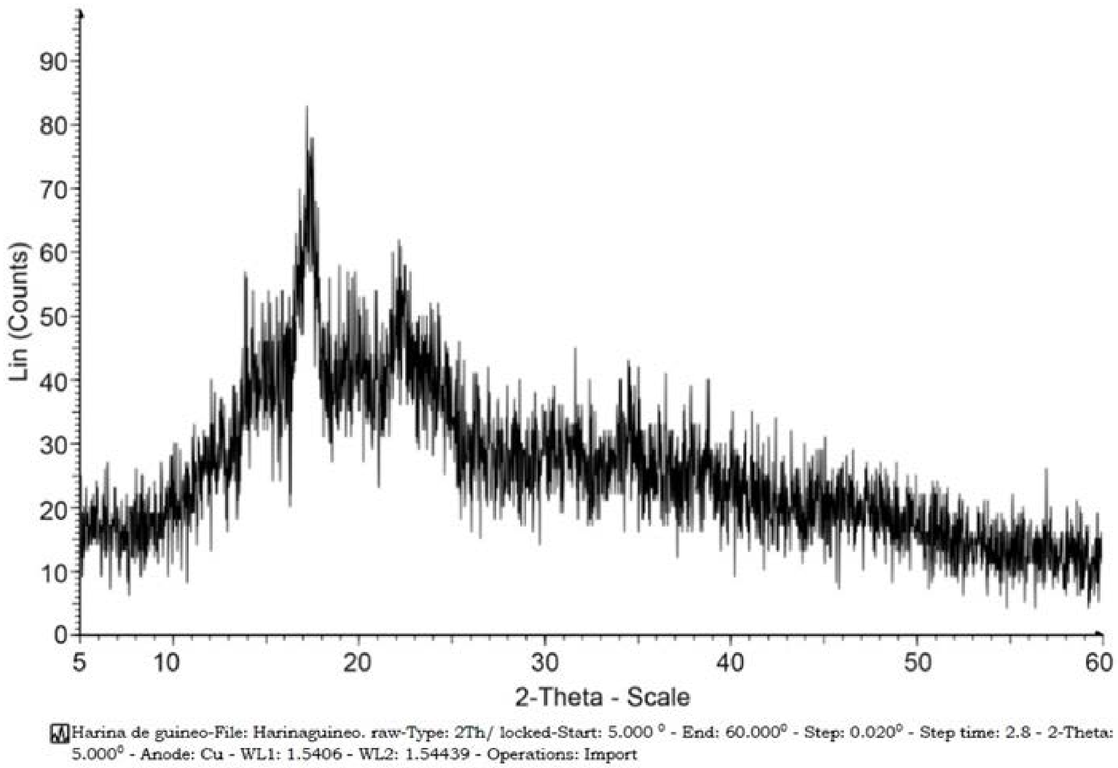


Figure 5. X ray diffraction pattern of guineo flour.

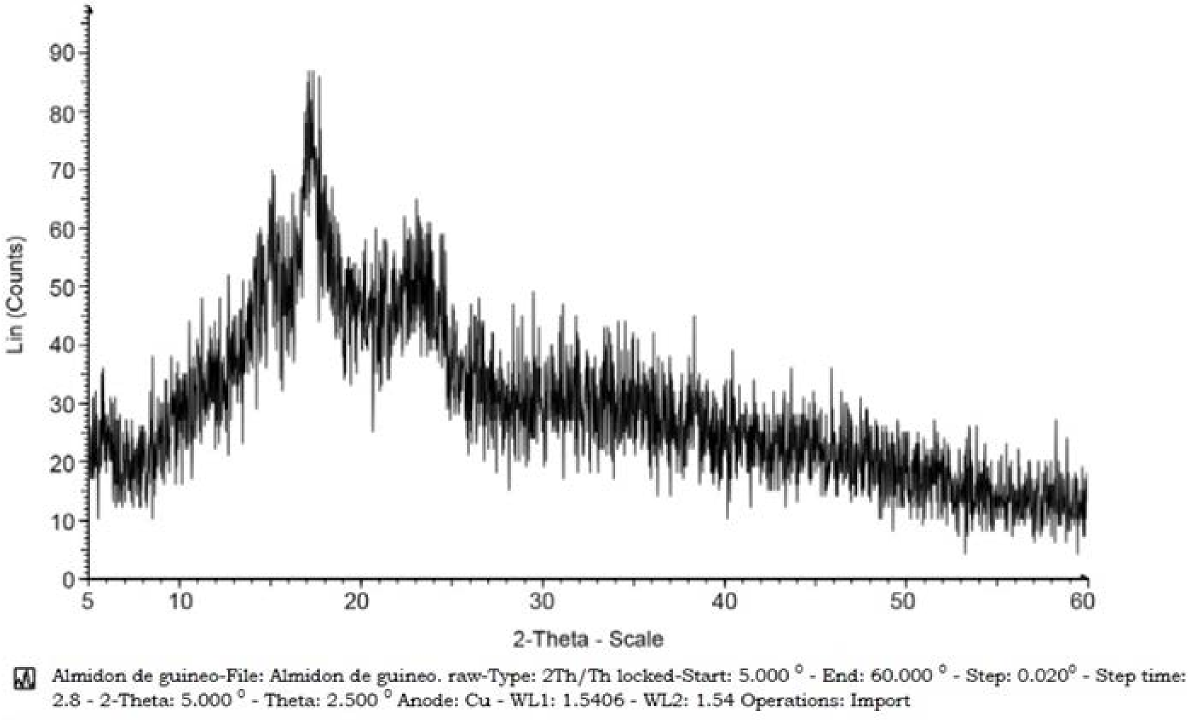


Figure 6. X ray diffraction pattern of guineo starch.

viscosity was 877 cP with temperature of 90.05 °C and 10.20 min. of time. The peak of viscosity showed a fall till 860 cP, the breakdown or difference between the maximum and minimum peaks for viscosity was 17 cP. The viscosity of the hot paste was found at 872 cP. When temperature was reduced to 50 °C a final viscosity of 1028 cP and a setback or difference between minimum and maximum viscosities of 168 cP was achieved with a consistency of 151 cP and cocking easiness of 5.98 min.

Dufour *et al.* (2008, 2009) found in

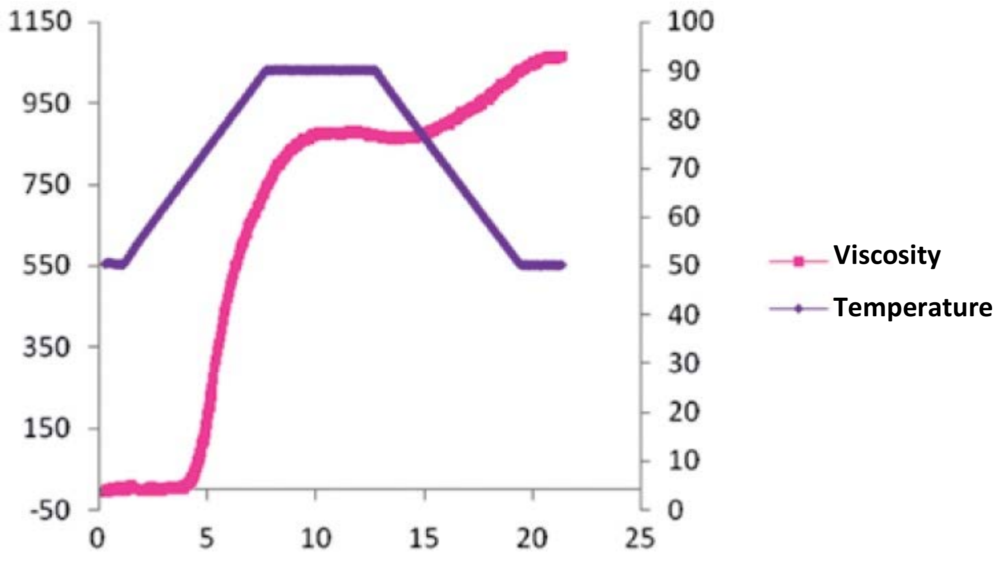


Figure 7. RVA viscosity curve of guineo flour.

guineo flour a pasting temperature or granule swelling of 71.60 °C, a maximum viscosity of 1622 cP and final viscosity of 2128 cP. Cocking easiness was optimal at 3.73 min. Da Mota *et al.* (2000) in flour from different banana varieties found average maximum viscosities of 330 cP and final viscosity of 423 cP. The pasting temperature was 51 °C, approximately.

According to the report of Dufour et al. (2008, 2009) gelatinization temperature between different musaceas types varied between 59.7 and 67.8 °C, values observed in Tafetán morado and Dominico, respectively. The analysis showed differences (P < 0.01) for the gelatinization temperature of dessert bananas and FHIA hybrids, with the Plantain subgroup and the cocking plantains different to Plantain (guinea). The gelatinization temperatures observed were: dessert banana (63.2 °C), cocking plantains different to Plantain (65.7 °C), FHIA hybrids (66.6 °C), Plantains (67.1 °C). This difference in starch gelatinization behavior reflects the differences in cocking behavior and contributes to explain the differences between varieties and genetic groups (Da Mota *et al.*; 2000), (Zhang *et al.*; 2005). Therefore the Plantains need more energy for gelatinization and take longer to cock and soften.

The values for guineo gelatinization reported in this study were similar to the ones obtained by Yadav *et al.* (2005) for potato flour, which correspond to a viscosity peak of 803 cP and a final viscosity of 826 cP. In Figure 8 is included a viscoamylogram of guineo starch where is observed that the pasting temperature 72.35 °C, at 4.73 min. The maximum viscosity (2191 cP) was reached at 89.95 °C in 8.07 min. time and decreased at 1797 cP producing a breakdown at 394 cP. The hot paste viscosity was1812 cP and the final was 2194 cP with a setback of 397 cP. Yadav *et al.* (2005) for potato flour indicated that the paste consistency was 3 cP and the cocking easiness was found at 3.34 min. The guineo starch viscosity was higher than its flour due to its crystallinity and the different component that make their behaviors different.

The pasting temperature for starch was high, indicating a high association degree between the macromolecules at the interior of the starch granule; however, the flour presented a higher time and temperatures at the peak phase, due to the presence of

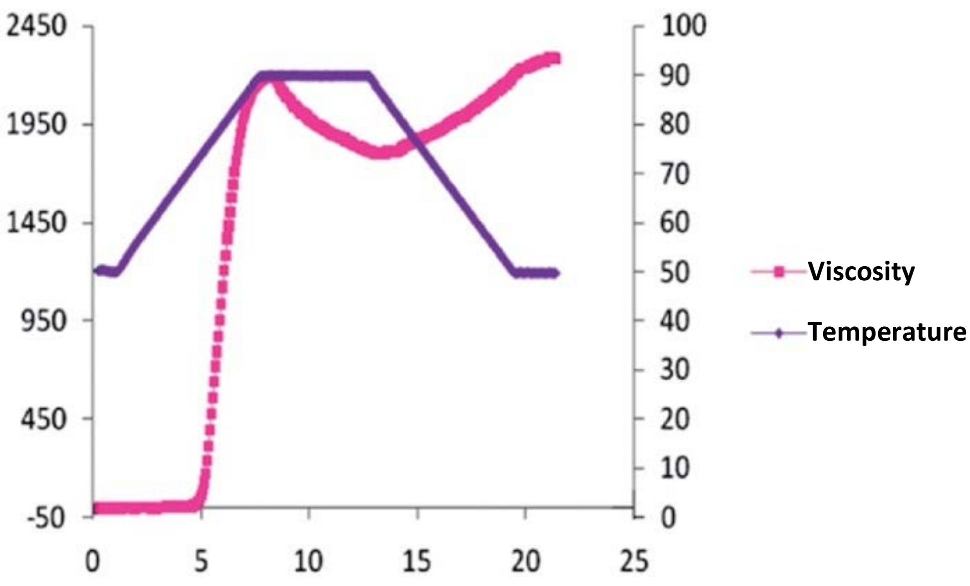


Figure 8. RVA viscosity curve of guineo starch.

components different than starch. When the temperature was kept at 90 °C by 5 min, the starch viscosity revealed a higher reduction than the one of flour, this phenomenon happens thanks to the swelling capacity of the granules of the first one and the marked reduction of the viscosity reflected in its lower stability during the cocking.

In the cooling period, both the flour and starch showed a normal retrogradation, which can be associated with the components of the swelled granules and the disperse molecules of starch in the hot paste. It is possible that the starch has a higher amylose content causing a faster retrogradation. The flour consistency showed a higher value meaning a higher viscosity variation, although the starch reports a higher cocking easiness.

Conclusions

- Apparently, the guineo is not a good source to extract starch since its yield is low (3.61%), however, it has a good protein percentage (2.17%), and could be used in the industry as additive to elaborate different food.

- The chemical analysis of guineo showed a fat percentage of 4.11% and an acceptable viscosity (RVA) in flour, reason why this product has higher stability in the cocking process than the starch. Both have a good retrogradation, being higher the one of the starch and therefore can be used to make other products such as soups, sauces, creams, baked, food pastes, puddings, among others.

- The X ray analysis showed that the diffraction patterns for guineo starch are characteristics for soluble starches like the ones of cassava and potato, so it is possible to use it as additive to increase viscosity in water systems like sauces and compotes. The differential scanning microscopy confirmed the obtained results by diffraction and viscoamylography since larger in size, the starches have a better water retention capacity.

- For its thermal properties and specially for its temperatures of phase transition (DSC), guineo flour and starch should not be subjected to aggressive thermal treatments like baking or frying, since these products retrograde at low temperatures, producing structural changes that are not reversible and do not allow a physic-chemical stable product.

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