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Chemical composition and functional properties of starch extracted from the pejibaye fruit (*Bactris gasepaes* Kunth.)

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ABSTRACT. This study aimed to establish the chemical composition and functional properties of the starch extracted from the pejibaye fruit (*Bactris gasepaes* Kunth.). The chemical characterization was evaluated from the determination of starch, amylose, amylopectin, total lipid, protein, ash, moisture and water activity. The water absorption index and the water solubility index were calculated for temperatures between 25 and 90ºC. Low contents of ash and protein were found. The studied starch has 14% moisture, according to the established by law. The water activity value was 0.55, which ensures its microbiological stability. A range of gelatinization between 65 to 70ºC was observed, close to the one of commercial starches. The solubility rate in water was 0.6119% and the absorption rate in water was 1.8252%. These results demonstrated that the starch from the pejibaye fruit has important characteristics for use in the food industry.

Keywords: gelatinization, water absorption, solubility.

Composição química e propriedades funcionais do amido extraído da fruta da pupunha (*Bactris gasepaes* Kunth.)

RESUMO. Este estudo tem como objetivo determinar a composição química e as propriedades funcionais do amido extraído do fruto da pupunha (*Bactris gasepaes* Kunth.). A caracterização química foi avaliada a partir da determinação do amido, amilose, amilopectina, lipídios, proteínas, cinzas, umidade e atividade de água. O índice de absorção de água e o índice de solubilidade em água foram realizados nas temperaturas entre 25 e 90ºC. Foram encontrados baixos teores de cinzas e proteínas. O amido estudado possui 14% de umidade, de acordo com o estabelecido pela legislação. O valor de atividade de água foi de 0,55, o que assegura a sua estabilidade microbiológica. Foi observada uma temperatura de gelatinização entre 65 e 70ºC, próximo ao do amido comercial. A taxa de solubilidade em água foi de 0,6119% e a taxa de absorção de água foi de 1,8252%. Estes resultados demonstram que o amido, a partir do fruto da pupunha, apresenta características importantes para a sua utilização na indústria de alimentos e na formulação de embalagens biodegradáveis.

Palavras-chave: gelatinização, absorção de água, solubilidade.

Introduction

Starch is an amylaceous product extracted from the edible parts of cereals, tubercles, roots and rhyzomes. Many authors consider starch as the main source for energy storage of superior vegetables, as well as the food responsible for 70 to 80% of the calories consumed by humans. The same presents a neutral homopolysaccharide structure, formed by chains of interlinked monosaccharide (glucose), composed by two fractions: amylose and amylopectin. The first consists of glucose units with glycosidic α-1, 4 , while the second, by glucose units linked in α-1, 4 with chains of glucose linked in α-1, 6 (LEONEL et al., 2003; CORRADINI et al., 2007).

The understanding of the structure of the starch granules is important in the comprehension of physical-chemical and functional properties, which determine the starch behavior. As the research and characterization of starch evolves, more diversified becomes its application, from human nourishment to biodegradable films and packaging (MALI et al., 2010). Currently, the literature offers several studies on extraction and characterization of starch and the relationship between these processes and the molecular structure of starch (APLEVICZ; DEMIATE, 2007; ROCHA et al., 2008; DENARDINI; SILVA, 2009; WANG; COPELAND, 2012). The physicochemical behavior exhibited by some starches suggests that several structural features, such as amylose, chain length distribution of amylopectin and degree of crystallinity in the granule, are closely related to the characteristics of the starch source and extraction method (LEONEL et al., 2003; DENARDINI; SILVA, 2009; ALDANA et al., 2011).

The pejibaye palm (*Bactris gasepaes* Kunth.) is a straight palm tree, with cylindrical trunks that can at adult phase reach a height of up to 20 meters. It produces fleshy fruit aligned in clusters with varying colors among red, yellow, orange, white and intermediary colors. These are rich in nutritional and energetic value, in carotene (pro-vitamin A), carbohydrates, oils and starch. The first Native American people used the pejibaye fruit mainly in the production of 'chicha' (a beverage made by the fermentation of the fruit) and of flour.

The region of the southern coast of Bahia State is one of the largest national producers of palm hearts and pejibaye fruit due to its favorable soil and climate conditions for the development of this crop. During the agro industrial exploitation of the pejibaye palm, huge amounts of residue are generated either in field or in factories. In the palm heart production, about 60% of the produced volumes are discarded. With regard to the fruit, despite the potential use, mainly in human nourishment, the production is totally directed to the obtainment of seeds. Therefore, the starch-rich pulp is totally discarded or underused. The great majority of the residues generated by the agribusiness of the pejibaye palm is discharged in the environment without previous treatment or destined to the production of fertilizers and/or animal feeding.

On the other hand, the starch present in residues has a potential use in several industrial applications, including food, cosmetics and biopolymers. However, in order to evaluate the applicability of the pejibaye fruit starch in food or packing industries, the understanding of its chemical composition and functional properties is of paramount importance since they heavily depends on the amylaceous source (PELISSARI et al., 2012). There are a plenty of studies addressing the characterization of starch from different sources (FABIAN et al., 2010; HERNANDEZ-URIBE et al., 2011), but to the authors knowledge there is no attempt yet to characterize the starch from the pejibaye fruit. In this context, the aim of this study is to determine the chemical composition and functional properties of the starch extracted from the pejibaye fruit. Therefore, the contribution of this work is to indicate that a polluting waste generated by palm industry may be used in food formulations and biodegradable films, i.e., an added-value product.

Material and methods

Obtainment of starch

The starch was obtained from the pejibaye fruit according to the methodology described by Leonel et al. (2003), modifying the mesh sieves, based on the characteristic of the starch source. Figure 1 depicts the procedure of processing the pejibaye fruit starch in laboratory. Fruit were peeled, shredded and put into plastic containers. The grinding was made in a knife mill of the 'Croton' type with a screen of 10 mesh, separating the mulch from the starch milk which is purified in sieves of 100 and 200 mesh. It is then successively washed with running water for the separation of the starch by decanting into plastic containers. The decanted starch is purified in absolute alcohol, filtered and dehydrated at 35°C for 12h in a dryer containing silica gel. The obtained starch is then reduced to powder and passed through a sieve of 48 mesh, thus obtaining the sample for analysis. Attempting to increase the yield of the process, the mulch obtained in the first extraction is further purified in the 10 mesh sieve.

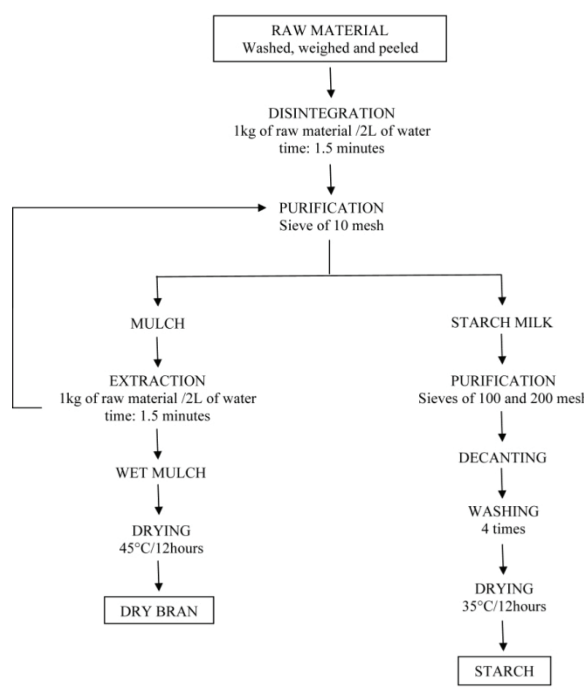

Figure 1. Flowchart of the processing of the pejibaye fruit starch in laboratory.

Chemical composition

The chemical composition was determined according to the Association of Official Analytical Chemists (AOAC, 2002): humidity in oven at 105°C, procedure no. 925.09 (32.1.03); ashes in muffle 550°C, procedure no. 923.03 (32.1.05);

protein by Kjeldahl, using a conversion factor of 6.25, procedure no. 991.20 (33.2.11). The content of total lipids was determined by the method from Bligh and Dyer (1959). The starch content was evaluated according to the methodology proposed by the Adolf Lutz Institute (IAL, 2004), which has as a principle the detection of glucose by the Lane-Eynon method, produced by the hydrolysis of the starch molecule. The amylose was quantified by spectrometry according to the methodology proposed by Gilbert and Spragg (1964) and the amylopectin, by difference. The water activity was measured in a digital instrument Aqua-Lab, model CX-2, made by Decagon Devices Inc., EUA.

Gelatinization temperature (GT)

The gelatinization temperature was established as proposed by Souza and Andrade (2000), which considers the rupture of 70% of granules as the gelatinization point. The temperature range around this value was considered a GT interval. About 5 grams of starch were weighed and diluted in a 100 mL - volumetric flask with distilled water. The sample was then put in a beaker and heated up in a water bath on a heater with a plate at 100°C. Samples were collected every 5°C from 40 up to 90°C. These samples were then diluted (0.1 g of sample for 9.9 g of distilled water) and analyzed under an optical microscope (Olympus BX50, Tokyo).

Functional properties

Water absorption rate (WAR)

The WAR was established as described by Anderson et al. (1969). In a test tube with a lid, 1.5 g of sample were weighed, added to 15 mL of water and stirred for 30 min. The solution was then transferred to a centrifuge tube Excelso II model 206 MP, and centrifuged at 3000 rpm for 10 min. The floating liquid was collected, transferred to a Petri dish and evaporated in a water bath at 100°C and, right afterwards, in an oven at 105°C for 3h. The remaining gel in the tube of the centrifuge was weighed. The WAR expressed in gram of gel per gram of gel of dry material (g g^{-1}) was determined starting from the residue of the evaporation of the floating liquid according to:

$$WAR(g.g^{-1}) = \frac{PRC}{PA\text{-}PRE} \tag{1}$$

where:

PRC is the mass of residue from the centrifugation (g),

PA is the mass of the sample (g),

PRE is the mass of the evaporation residue (g).

Rate of solubility in water (RSW)

The RSW value is calculated by the ratio between the mass of the evaporation residue (PRE), obtained from the procedures described above, and the mass of the sample (PA) according to:

$$\%\ RSW = \frac{PRE}{PA} \star 100 \tag{2}$$

Data analysis

The experiments were conducted using an Completely Randomized Design (CRD), with three replications. We determined the average and their standard deviation using the statistical program Statistical Analysis System (SAS, 2004).

Results and discussion

Chemical composition

Table 1 shows that the starch from the pejibaye fruit is basically formed by carbohydrate, starch, lipid, protein and ash.

Table 1. Chemical composition of the starch from the pejibaye fruit.

Component (%)	Average[1]	Deviation
Starch	79.00	± 0.12
- Amylose	12.40	± 0.18
- Amylopectin	66.60	± 0.01
Total lipids	0.93	± 0.01
Protein	0.54	± 0.07
Ash	0.18	± 0.008
Moisture	14.00	± 0.15
Water activity	0.55	± 0.001

[1]Results expressed on a wet basis.

The amylose content was lower than found by Rocha et al. (2008) in cassava-salsa (21.67%) and Weber et al. (2009) in normal corn (27.80%), but higher than registered for waxy maize (1.8%). According to Weber et al. (2009), the content of amylose in starch granules varies according to the plant source, but is generally found in the interval of 20-30%. However, low amylose contents indicate that the studied starch needs less energy for its gelatinization, and that the formed paste has a higher maximum viscosity with fewer tendencies to a retrogradation, when compared with starch from cassava, potato and normal corn (ASCHERI et al., 2010).

The content of lipids was higher than verified for corn starch, 0.69%, wheat, 0.69% and banana, 0.02% (NAGULESWARAN et al., 2012; PELISSARI et al., 2012). According to Ascheri et al. (2010), it is recommended that the amount of lipids in starch is lower than 1%, like in the case of the starch from pejibaye fruit, because this makes the starch more neutral and less prone to complexation.

In relation to the percentage of protein, the pejibaye fruit starch has low protein contents when compared to corn starch, 0.65% (BATISTA et al., 2010) and 0.86%, (NAGULESWARAN et al., 2012), rice bran, 0.66% (FABIAN et al., 2010), wheat starch, 0.57% (BATISTA et al., 2010) and banana, 0.97% (PELISSARI et al., 2012). However the contents were higher than found in yam bean starch, 0.10% (LEONEL et al., 2003), and parsley manioc, 0.12% (ROCHA et al., 2008). The content of ash found (0.18%) was lower than the one of apples, 2.49% (DEMIATE et al., 2003), corn, 0.21%, and wheat, 0.20% (NAGULESWARAN et al., 2012), and higher than in banana, 0.04% (TEIXEIRA et al., 1998) and cassava, 0.17% (DEMIATE et al., 2003). According to Rocha et al. (2008), the lower the amount of protein and ash, the higher is the quality of the starch indicating that the starch presented a high degree of purity and the extraction process in the laboratory was efficient, similarly to the studied pejibaye fruit starch.

In relation to moisture a percentage of 14% was found. The measured water activity was 0.55. The Brazilian legislation specifies that the maximum moisture of starch should not exceed 18%, thus the pejibaye fruit starch complies with the legislation (BRASIL, 2005). There are no legal parameters for water activity measurement, but the value found assures the product stability, hindering that several groups of deteriorative and pathogenic microorganisms may develop and spoil the starch and limit its potential applications (GUTKOSKI et al., 2007).

Functional properties

Gelatinization temperature (GT)

The temperature increase resulted in the growth of the pejibaye fruit starch granules. In the temperature range from 65 to 70ºC, the occurrence of an excessive swelling was verified, with structural disorganization of the granules, being this one considered the GT of the pejibaye fruit starch.

The GT of the starch extracted from pejibaye fruit is considered equivalent to other starch sources, such as corn, with a GT varying from 70 to 75°C (SOUZA; ANDRADE, 2000), potato, 65-70°C, and wheat, 70-75°C (RATNAYAKE; JACKSON, 2007), and pond lily, 73.10-78.70ºC (ASCHERI et al., 2010). Therefore the pejibaye fruit starch has a GT close to the abovementioned raw materials, allowing their substitution in food industries.

The GT of starch occurs in general at temperatures above 60°C. The properties of gelatinization are controlled, in part, by the structure of the amylopectin. Since the crystalline regions of the starch granule are generally made of amylopectin and not of amylose, starches with high amylose content present lower gelatinization temperatures (YONEMOTO et al., 2007).

Water absorption rate (WAR)

Table 2 summarizes results of WAR for temperatures in the range of 25 to 90°C. The granules presented no high resistance to temperature increase, being subjected to rupture with prolonged heating. Below the gelatinization temperature range (65-70ºC), the starch granule presented low swelling power. As the temperature increases, the swelling power of pejibaye fruit starch also increases.

Table 2. WAR values of the starch from the pejibaye fruit as a function of temperature.

Temp. (°C)	WAR (%)	Deviation
25	1.8252	± 0.0160
50	2.4373	± 0.0257
60	4.5547	± 0.0228
70	5.5141	± 0.0226
80	6.3985	± 0.0476
90	8.6587	± 0.0349

At 90°C the WAR was 8.6587%. When compared with the WAR at room temperature (1.8252%), an increase of 374.42% was observed. Studies by Yuan et al. (2007), establishing the swelling power for cassava and potato starch at 90°C, found that WAR was 5.5 g g^{-1} and 8.7 g g^{-1}, respectively, being the WAR of potato starch equivalent to the WAR of pejibaye fruit starch.

The WAR is related with the viscosity of the cold paste, since only the damaged starch granules absorb water at room temperature, resulting in a viscosity increase (CARVALHO et al., 2002). The higher the temperature, the higher the vibration of molecules of starch granule. As a consequence, there is a rupture of intermolecular links, which may then form hydrogen bonds with the water molecule (FENNEMA, 2000). According to Ciacco and Cruz (1982), the direct consequence of the heating of a starch suspension is the increase of solubility, clarity and viscosity of the paste.

Rate of solubility in water (RSW)

Table 3 lists the RSW of pejibaye fruit starch at temperatures from 25 to 90ºC. At room temperature, RSW was 0.6119%, presenting a slight increase (2.799%) up to 80°C. However, between 80 to 90°C, an increase of 18.5507% was detected.

Table 3. RSW values of the pejibaye fruit as a function of temperature.

Temp. (°C)	RSW (%)	Deviation
25	0.6119	± 0.0004
50	0.7937	± 0.0007
60	0.9149	± 0.0002
70	1.4867	± 0.0004
80	2.7996	± 0.0001
90	18.5507	± 0.0009

The RSW is related to the amount of soluble solids in a dry sample, allowing verifying the degree of the severity in the treatment, as a function of the degradation, gelatinization, dextrinization and consequent solubilization of the starch (CARVALHO et al., 2002). When the starch is heated with excess water, above the gelatinization temperature, the crystalline structure is ruptured due to the relaxation of hydrogen bonds and so, the water molecules interact with the hydroxyl groups of amylose and amylopectin causing an increase of the size of granules due to swelling, with a consequent partial solubilization (HOOVER, 2001).

Conclusion

In summary, starch granules presented low solubility in water and low resistance to temperature elevation and a temperature range for gelatinization similar to other sources of starch. This study provided a better understanding of the properties of the pejibaye fruit starch, indicating that this starch is compatible with several applications, from food industry to production of biodegradable packaging. Therefore, the polluting waste generated by pejibaye fruit industry may be converted into a more valuable product.

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