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Characterization of banana starches obtained from cultivars grown in Brazil

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ABSTRACT

The starch market is constantly evolving and studies that provide information about the physical and rheological properties of native starches to meet the diverse demands of the sector are increasingly necessary. In this study starches obtained from five cultivars of banana were analyzed for size and shape of granules, crystallinity, chemical composition, resistant starch, swelling power, solubility, thermal and paste properties. The granules of starch were large (36.58–47.24 μm), oval, showed crystallinity pattern type B and the index of crystallinity ranged from 31.94 to 34.06%. The phosphorus content ranged from 0.003 to 0.011%, the amylose ranged from 25.13 to 29.01% and the resistant starch ranged from 65.70 to 80.28%. The starches showed high peak viscosity and breakdown, especially those obtained from 'Nanicão' and 'Grand Naine'. Peak temperature of gelatinization was around 71 °C, the enthalpy change (ΔH) ranged from 9.45 to 14.73 J g^{-1}. The starch from 'Grand Naine' showed higher swelling power (15.19 g g^{-1}) and the starch from 'Prata-Anã' higher solubility (11.61%). The starches studied are highlighted by their physical and chemical characteristics and may be used in several applications.

1. Introduction

The banana (*Musa* spp.) is one of the fruits with the greatest production and consumption worldwide, being the base of the economy of some countries because of their dietary characteristics, which imply a high consumption in the various sections of society, representing the fourth food commodity in trading volume [1].

According to data from the Food and Agriculture Organization [2], in 2012 Brazil was the world's fifth largest banana producer, with 6.90 million tons, behind India (24.87 million), China (10.55 million), Philippines (9.23 million) and Ecuador (7.01 million). The national average productivity is still low, 14.56 t ha^{-1}, below than performance of other countries leading the global market, such as Costa Rica, with production of 2.14 million tons and productivity of 54.1 t ha^{-1}.

Banana is produced in all Brazilian states, being the largest producers in 2014: São Paulo, Bahia, Minas Gerais, Santa Catarina and Pará with production of respectively 1,133,819, 1,088,647, 711,397, 701,501 and 588,655 tons and with a total production of 7.14 million tons [3]. However, the country, one of the major world producers, presents as one of the major problem in marketing high wastes in post-harvest [4].

The use of green bananas as a source of starch, since the pulp of the fruit in the ripening stage have 70–80% of starch in dry matter, decreases the wasted amount due to failures in the process of harvesting, storage and distribution.

Starch is a raw material abundant, renewable, biodegradable and non toxic which can be extracted with high purity by means of relatively simple industrial process and be easily converted into various products by chemical and biochemical processes. These factors, together, determine the agro-industrial potential immense of the starch.

About sixty million tones of starch are extracted annually worldwide from various cultures. About 60% of the produced starch is used in foods (bakery products, sauces, soups, candies, syrups, ice cream, chips, sausages, baby food, fat substitutes, specialty coffees, beers and other beverages) and 40% in pharmaceuticals and non-edible products purposes, such as fertilizers, seed coatings, paper,

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Table 1
Characteristics of banana cultivars.

Characters	Cultivars				
	Nanicão	Grand Naine	Prata Anã	Maçã	FHIA 18
Genomic group	AAA	AAA	AAB	AAB	AAAB
Genomic subgroup	Cavendish	Cavendish	Prata	Prata	Prata
Plant height	medium-low	medium-low	medium-low	medium-high	medium
Tillering	medium	medium	good	optimum	good
Growing season (days)	290	290	280	300	327
Bunch weight (kg)	30	30	14	15	24.5
N° fruits/bunch	220	200	100	86	135
N° hands/bunch	11	10	7.6	6.5	9
Fruit length (cm)	23	20	13	13	20
Fruit weight (g)	150	150	110	115	187
Yellow Sigatoka	S	S	S	MR	MR
Black Sigatoka	S	S	S	S	R
Fusarium wilt	R	R	MS	S	S

S = susceptible, MS = moderately susceptible, R = resistant, MR = moderately resistant.

cardboard, packaging materials, adhesives, textiles, diapers, bioplastics, building materials and oil drilling.

In view of the large application market of this polymer, investments in the areas of identifying new sources, cultural management, and also chemical, physical and biological modifications in order to obtain starches with a wide range of functional properties are needed to ensure compliance with such varied applicability purposes.

In a market in constant evolution and with an ever-stronger competition, the differentiating factor of an industry is the creation of new products and/or the production of products with improved characteristics. Thus, the search for native starches with properties that meet the different requirements of the consumer market has been one of the focuses of research in recent decades.

The banana is presented as a potential source of native starches with special properties. The starch of this fruit has shown interesting characteristics for industrial applicability as significant levels of amylose, high peak viscosity and final viscosity [5] and high levels of resistant starch [5–7].

Given the importance of new starchy raw materials, this study aimed to evaluate the physical, chemical, thermal and paste properties of starches extracted from five banana cultivars grown in Brazil.

2. Materials and methods

Five cultivars of banana were performed: 'Nanicão', 'Grand Naine', 'Maçã', 'Prata-Anã' and 'FHIA 18' (Table 1).

The cultivation of banana was conducted in São Manuel, São Paulo, Brazil (22°46′S latitude, 48°34′W longitude and altitude 740 m) during the agricultural cycle 2014/2015. The predominant climate type is temperate mesothermal, with rains in summer and dry in winter, with average temperature of the warmest month above 22 °C and the average annual rainfall of 1377 mm. The soil of the area is classified as Red-Yellow Dystrophic Latosol.

Soil analysis and the application of lime to raise the soil base saturation to 70% were conducted prior to orchard establishment. Seedling planting was held at 4 m spacing between rows and 2.5 m between plants in an area equivalent to 10 m^2 by plant.

In the course of the experiment were performed: irrigation, weed control, thinning, removal of dried leaves, fertilization, pest control and disease, elimination of banana heart, removal of pistils and cutting pseudostem after harvesting.

Ten bunches from each cultivar were used to obtain the starches. The harvest of bunches occurred during the stage 1 of maturation of fruits, ie with fully green peel. The fruits were peeled, sliced and crumbled in an industrial blender in chilled water (4 °C) and ascorbic acid (1%) for the extraction of starches. Then, the material was centrifuged on a rotating sieve with a mesh of 0.25 mm. The "starch milk" was purified in a centrifuge, and the pre-drying and drying steps performed in the vacuum filter and flash dryer.

2.1. Morphology and size of granules

The morphology of starches was observed by a scanning electron microscope (model Quanta 200, FEI Company). The samples were placed on stubs with double sided adhesive tape where the starches were fixed and covered with a gold layer of 20 nm sputter Balzers. The images were viewed, selected and saved by the software coupled to the equipment.

The granule size distribution was determined with laser diffraction using a Mastersizer 2000 (Malvern Instruments Ltd., Malvern, Worcestershire, UK), with the help of a Scirocco dry disperser unit used for dispersing the powders at a feed pressure of 2 bars and a feed rate of 40%. The obscuration was in the interval of 0.5–5%. The Fraunhofer approximation was used for calculation of the starch granules size distribution and the corresponding volume fraction-length mean diameter ($D_{4,3}$) [8].

2.2. Crystallinity

Samples of starch were kept in a desiccator containing saturated $BaCl_2$ solution (25 °C, wa = 0.9) for 10 days for moisture balance. Samples were packed in an aluminum holder and analyzed at room temperature by X-ray diffractometer (Rigaku Rotaflex, model RU 200 B, Tokyo, Japan) operating with monochromatic filter copper, Kα radiation, power of 0.8 kW, current of 100 mA, voltage of 50 kV and rotating anode. The wavelength used was 1.542 Å and a scan rate of 1 min^{-1}. Analyses were performed between 3° and 40° in 2θ. The peak intensity was expressed in counts per second (cps). Relative crystallinity was determined by the relationship between the peak area and the total area using software Origin version 7.5 (Microcal Inc., USA) [9].

2.3. Physical and chemical composition of starches

The starches were analyzed for moisture, ash, fiber, lipids, protein, starch, pH, titratable acidity [10], amylose apparent [11], resistant starch [12] and phosphorus [13].

2.4. Pasting properties

Pasting properties of banana starches were determined in a rapid visco analyzer (RVA 4, Newport Scientific, Australia) using 10% starch suspensions with a total mass of 27.5 g. The program