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ARTICLE *in* JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY · APRIL 1999

Impact Factor: 2.91 · DOI: 10.1021/jf980828t · Source: PubMed

Isolation and Partial Characterization of Banana Starches

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Two varieties of banana green fruit growing in Guerrero, Mexico, were used for starch isolation. Chemical analysis and physicochemical and functional properties were studied in these starches. The “macho” variety presented higher starch yield than “criollo”. In general, chemical compositions in both starches were similar, except in ash content, where the “criollo” variety showed a lower value than “macho”. The results of freeze−thaw stability suggested that banana starches cannot be used in frozen products. Both starches presented similar water retention capacity values that increased when temperature increased. Solubility profiles showed that at low temperature “criollo” had lower solubility than “macho”, but at higher temperature an inverse behavior was evident; also the solubility increased when temperature increased. Behavior similar to that for solubility was obtained in the swelling test. The banana starch studies indicate the “macho” and “criollo” varieties have different starch structures as evidenced by viscosity.

Keywords: *Starch; isolation; banana; functional properties; physicochemical properties*

INTRODUCTION

Starch is the major dietary component in all human populations. The consensus of recent opinion on healthy eating habits favors an increase in the proportion of polymeric plant carbohydrates (including starch) in the daily diet. However, in our culture, the main purpose of starch utilization in foods remain aesthetic rather than nutritional. This biopolymer constitutes 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 (Biliaderis, 1991).

Bananas are grown extensively in tropical and subtropical regions and are an important food crop. Although the composition of banana fruit has been defined, comparatively little work has been carried out on the starch (Kayisu et al., 1981; Lii et al., 1982). Banana is a climacteric fruit and in Mexico is consumed when the fruit is ripe. For this reason many fruits are lost during commercialization due to deficient postharvest handle. Starch is the principal component of green bananas, which undergoes important changes during ripening. Lii et al. (1982) investigated changes in physical and chemical properties of banana starch, as well as banana components, during ripening. It is well established that variable amounts of starch in food can escape digestion in the human small intestine and pass into the colon; this fraction is referred to as resistant starch (RS). Unripened banana starch is very resistant to digestion in the rat and man. Recently, Faisant et al. (1995a,b) studied the digestibility of banana starch granules in the human small intestine and reported the starch breakdown and also the structural features of RS; these studies are important in the digestibility and nutrition of banana starch. However, very few studies have been reported on the functional and physicochemical properties of banana starch. Banana could be an alternative source for starch isolation and for new applications of this polysaccharide.

Starch is deposited in the fruit in the form of granules, partially crystalline, whose morphology, chemical composition, and supermolecular 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 structure (French, 1984).

The purpose of the present study was to isolate banana starches, from two common varieties growing in Guerrero, Mexico, using a traditional wet-milling process, to determine their chemical composition and to investigate some chemical, physical, and functional properties of these starches isolated from this alternative source.

MATERIALS AND METHODS

Starch Isolation. Unripened bananas from two widespread varieties named “macho” and “criollo” were collected. The starch was isolated using a modification of the procedure of Kim et al. (1995). The fruits were peeled and cut into 5−6 cm cubes (500 g total weight) and immediately rinsed in sodium sulfite solution (1.22 g/L) and then macerated at low speed in a Waring blendor (500 g of fruit:500 g of solution) for 2 min. The homogenate was consecutively sieved through screens number 50 and 100 U.S. mesh, until the washing water was clean; then it was centrifuged at 10 800*g* for 30 min. The white-starch sediments were dried in a convection oven at 40 °C for 48 h, ground with a mortar and pestle to pass a U.S. No. 100 sieve. and stored at room temperature in a sealed container. In total 50 kg of banana fruit was used.

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10.1021/jf980828t CCC: $18.00
Published on Web 02/03/1999

Table 1. Chemical Analysis (%) of Banana Starches

content	"macho"	"criollo"
tot. starch[a]	97.2 ± 2.4	98.1 ± 1.8
moisture	12.9 ± 0.3	11.1 ± 0.4
protein[b]	2.03 ± 0.15	1.95 ± 0.2
fat[a]	2.2 ± 0.05	2.3 ± 0.07
ash[a]	1.3 ± 0.3	0.43 ± 0.06

[a] Means of 3 replicates ± standard error, dry basis. [b] Means of 3 replicates ± standard error, dry basis, N × 5.85.

Chemical Analysis. Moisture content was taken as weight loss after heating at 130 ± 2 °C for 2 h. Ash, protein, and fat were obtained according to AACC methods 08-01, 46-13, and 30-25 (AACC, 1983). Total starch was determined in triplicate samples using AOAC method 8.020 (AOAC, 1984).

Blue Value (BV). The blue value (absorbance at 680 nm) was obtained using Gilbert and Spragg method (1964). The maximum absorbance wavelength (λ_{max}) between 750 and 400 nm of starch−iodine complex was determined using a Genesys 5 spectrophotometer (Spectronic Instruments, Inc., Rochester, NY).

Clarity. Starch pastes (1%) were produced when 50 mg of sample was suspended in 5 mL of water in screwcap tubes and placed in a boiling water bath for 30 min. The tubes were thoroughly shaken every 5 min. After cooling of the samples to room temperature (15 min), transmittance (% *T*) at 650 nm was determined against a water blank.

Freeze−Thaw Stability. The 5% banana starch pastes (5 mL) were subjected to a one cycle freeze−thaw process of 18 h storage in a −20 °C freezer, followed by 6 h storage at room temperature. These samples were then centrifuged at 3000*g* for 10 min. The percentage of water separated after the freeze−thaw cycle was measured.

Water Retention Capacity. Water retention capacity was determined according to the method reported by Bryant and Hamaker (1997). Water was added to starch in preweighed centrifuge tubes at room temperature and then heated at 65, 70, 75, 80, 85, 90, and 95 °C for 15 min, with shaking at 5 and 10 min. The tubes were then centrifuged for 15 min at 1000*g*. The supernatant was decanted, and the tubes were allowed to drain for 10 min at a 45° angle. The tubes were then weighed, and the gain in weight was used to calculate the water retention capacity.

Swelling and Solubility. Starch solution (1% w/w) was prepared in a flask and then heated at 50, 70, and 90 °C for 30 min, with shaking each 5 min. The slurry was centrifuged for 10 min at 5000*g*. The supernatant was decanted, and the volume was measured; aliquots were used to estimate total carbohydrates (Dubois et al., 1956). The precipitate was used to determine the moisture content (2 h to 130 °C).

Apparent Viscosity. Apparent viscosity of starches was determined using a Brookfield viscometer (model RVF, Stoughton, MA). The starch slurry (5%, db) was cooked in a boiling bath for 15 min and then cooled to 25 °C. Cold paste viscosity was determined using spindle No. 3 at 25 °C, at four shear rate speeds: 2, 4, 10, and 20 rpm. The stability of the paste viscosity at 20 rpm was observed at 1, 2, 3, 4, 5, 10, 15, 20, and 30 min.

RESULTS AND DISCUSSION

The yield of starch from bananas "macho" and "criollo" were 43.8% and 11.8%, respectively. The higher yield value for the "macho" variety than "criollo" variety is likely due to the texture of the banana fruit, because both banana varieties presented different ripening stages. "Macho" bananas show higher firmness than "criollo" ones, and during the isolation procedure a significant amount of intermediate materials is lost. After drying, however, a powder with higher whiteness was obtained with "criollo" banana than "macho". Total starch in both samples was not different (Table 1). The wet-milling process is a good procedure for banana starch isolation with low levels of other components from the fruits.

Table 2. Functional Properties of Banana Starches[a]

starch	λ_{max} (%)	blue value	freeze−thaw stability (mL)	clarity (% *T*)
"macho"	583 ± 2.0	0.18 ± 0.006	2.4 ± 0.1	12.0 ± 1.1
"criollo"	589 ± 2.0	0.87 ± 0.003	2.5 ± 0.4	11.2 ± 0.1

[a] Means of 3 replicates ± standard error.

The chemical composition of banana starches is given in Table 1. The protein and fat contents of both starches were similar. The protein contents of "macho" and "criollo" banana starches were 2.03% and 1.95%, respectively. Lower protein values have been reported by other authors for different varieties of banana and ripeness grades (Kayisu et al., 1981; Lii et al., 1982). Our banana starches, at the same time, showed a high fat content. A fat content of 0.2% was reported by Kayisu et al. (1985) for green banana starch. Low fat values (between 0.11 and 0.37) were also found by Lii et al. (1982) for banana starches isolated at different stages of ripeness. In general normal maize (*Zea mays* L.) starches present higher fat levels than waxy starches. The higher fat content of banana starch might have technological and nutritional importance due to the amylose−lipid complexes formed during the processing of this starch. Perhaps this is the principal reason that banana starch is resistant to amylolysis (Asp and Björck, 1992).

"Macho" banana starch was considerably higher in its ash content (1.3%) than "criollo" (0.43%); lower ash contents (between 0.02 and 0.06%) were found in banana starches analyzed by other authors (Kayisu et al., 1981; Lii et al., 1982). The high potasium content present in banana fruit might be partially responsible for this high ash level.

The blue values of "macho" (0.18) and "criollo" (0.87) banana starches suggest differences in the level of amylose and amylopectin in these starches (Table 2); however, both blue values indicate that they were within those of normal maize starches. The blue values agree with λ_{max} values obtained, because "macho" has a λ_{max} of 583 nm and "criollo" a value of 589 nm.

The two varieties of "macho" and "criollo" banana starches presented the same freeze−thaw stability (Table 2). Both starches drained 50% of water incorporated during the experiment. In general, it has been reported that normal maize starches show poor freeze−thaw stability and waxy starches have high stability to freeze−thaw cycles (Singhal and Kulkarni, 1990; Baker and Rayas-Duarte, 1998). Our results suggest that banana starch is not desirable for frozen products. No previous results had been reported on freeze−thaw stability for banana starch.

The banana starches showed similar % *T* values (Table 2). These values are lower than those reported for normal maize starch (Bello-Pérez and Paredes-López, 1996; Craig et al., 1989). The difference could be due to the fact that during the isolation of banana starches some enzymatic browning takes place. Banana starches with this whiteness may be used in spoonable salad dressing (Singhal and Kulkarni, 1990).

The water retention capacity profiles of banana starches are presented in Figure 1. The water retention capacity of "macho" banana starch was similar to that of "criollo". Slight differences in amorphous and crystal-

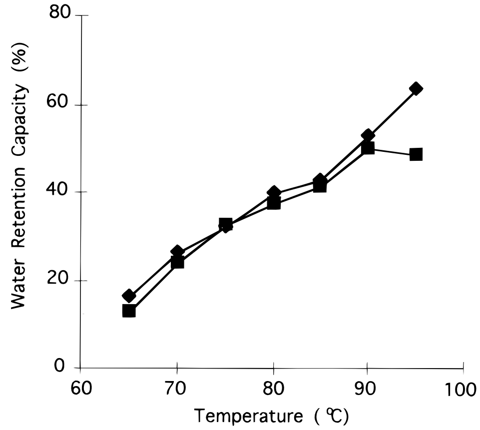

Figure 1. Water retention capacity profiles of banana starches: (■) "macho"; (◆) "criollo".

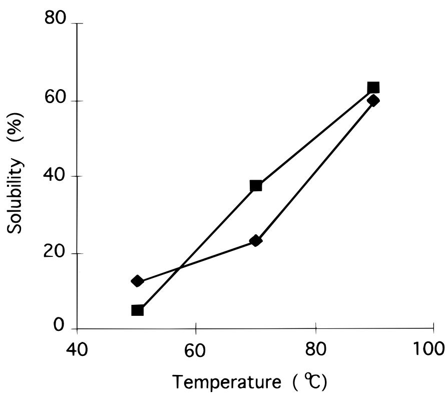

Figure 2. Solubility profiles of banana starches: (■) "macho"; (◆) "criollo".

line regions of amylopectin may be present in the granules of both starches.

Solubility profiles of banana starches at different temperatures are presented in Figure 2. Higher solubility values were found for both starches when the temperature increased. "Macho" banana starch at 50 °C has lower solubility value than "criollo", but when temperature increased (70 °C) "macho" banana starch presented higher values. Nonetheless, at the highest temperature of the experiment, there are no major differences in the solubility behavior of both banana starches. This pattern is likely due to the minor differences in amylose/amylopectin content or chain length distribution in the starches studied. However, structural studies of banana starches are required. Low solubility values have been reported for banana (Kayisu et al., 1981), sorghum (Pérez et al., 1997), and plantain (Pérez-Sira, 1997) starches.

A similar pattern for solubility of banana starches was found for swelling (Figure 3). When the temperature increased to 90 °C "macho" banana starch presented the highest swelling value; at this temperature remarkable differences between the two starches were found. As expected, increments in the pasting temperature increased swelling, but differences are present in the two banana samples. Amylose solubilized during starch gelatinization at high temperature contributes to swelling of starch granules. Lii et al. (1982) reported the same behavior and similar values of swelling for banana starch compared to those found in this work.

Apparent viscosity of banana starches decreased when shear rate increased (Figure 4). This typical

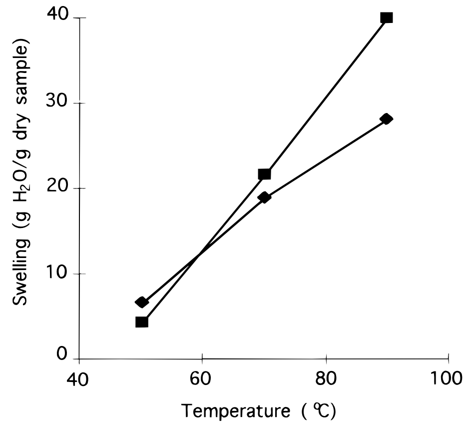

Figure 3. Swelling profiles of banana starches: (■) "macho"; (◆) "criollo".

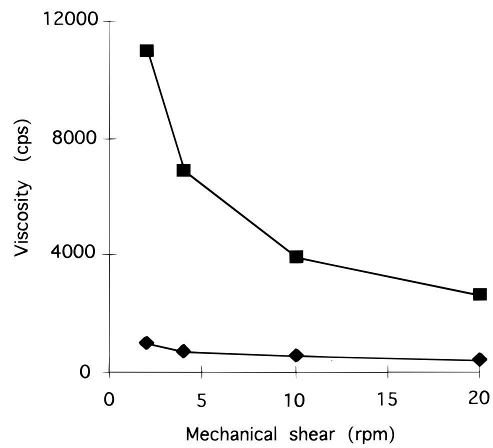

Figure 4. Effect of mechanical shear on paste viscosity of 5% (db) for banana starches determined using a Brookfield viscometer at 25 °C with the spindle No. 3: (■) "macho"; (◆) "criollo".

decrease in viscosity with an increase in rotational speed indicates shear-thinning behavior. "Macho" banana starch presented higher values of apparent viscosity. This difference between both starches was remarkable. These results suggest that "macho" banana starch could be used in food products which require high viscosity or used to adjust textures. The low apparent viscosities found for "criollo" banana starch are similar to those reported for waxy starch using the same spindle (Uriyapongson and Rayas-Duarte, 1994). It is evident from these results that the molecular structure of the banana starches plays an important role in this viscosity behavior. Other food applications for "criollo" banana starch need to be found.

The viscosity profiles of banana starch pastes at constant rate (20 rpm) and temperature (25 °C) are given in Figure 5. The apparent viscosity of "macho" banana starch slightly decreases with time. However, the apparent viscosity of "criollo" banana starch was lower than "macho" banana starch. "Criollo" banana starch was more stable during the 30-min test.

CONCLUSIONS

The two varieties of banana starches studied, "macho" and "criollo", presented some similarities in chemical characteristics and physicochemical properties (blue values). Water retention capacity was similar for both starches. However, other functional properties such as

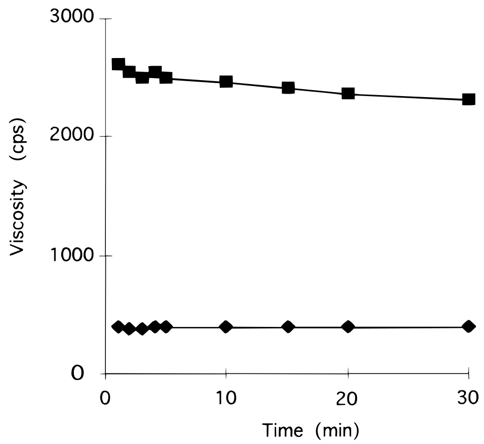

Figure 5. Paste viscosity of 5% (db) for banana starches determined using a Brookfield viscometer at 25 °C with the spindle No. 3: (■) "macho"; (◆) "criollo".

swelling, apparent viscosity, and freeze−thaw stability were different. "Macho" banana starch showed higher apparent viscosity than "criollo", but the former had lower paste stability. These results suggest some food applications of banana starches.

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Received for review July 28, 1998. Accepted November 25, 1998. Financial support from the Consejo Nacional de Ciencia y Tecnología/SIBEJ-México and Consejo Nacional de Educación Tecnológica-México is gratefully acknowledged.

JF980828T