

pH Affects Properties of Green Banana Starch¹

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ABSTRACT

The effect of pH on the pasting properties and swelling power of V-2390 and Montecristo green bananas (*Musa acuminata* × *M. balbisiana* AAB) cultivars was studied. Initial viscosity of starch slurries acidified at different pH levels with citric acid varied from 78° to 84° C. At pH 2.50 and 3.00 the starch gel lost much of its properties while being cooked at 95°C. However, at pH suitable for canning as acidified food (3.50 to 4.50) banana starch showed sufficient strength to maintain shape and texture as influenced by the starch. Starch was also relatively stable while submitted to prolonged periods of heating and when cooled and maintained at temperatures at which it might be regularly used. Swelling power increased as temperature increased, but was somewhat low for both cultivars. Banana starch granules were irregular in shape and size.

INTRODUCTION

Banana (*Musa accuminata* × *M. balbisiana* AAB) is an important food crop in tropical areas and is extensively cultivated in Puerto Rico. Montecristo is the most important banana cultivar grown in Puerto Rico, but it is susceptible to the leaf fungus known as sigatoka (black spot). However, cultivar V-2390 is not susceptible to this fungus.

In Puerto Rico bananas are consumed either as a fresh fruit when ripe or as a vegetable when green. When eaten green, they are boiled in salt water. This treatment changes the textural characteristics of green banana's most important constituent: the starch. These changes, presumably, are even greater when processed.

Study of the recorder rheological data gives valuable information on the physical changes that may be expected during the processing of products containing starch. The Amylograph-Viscograph has been the instrument most extensively used to measure the changes in consistency which occur when heating, cooking and cooling starch.

The rheological properties of starch can be modified by materials such as salt, fat, sugars, proteins and gums (8). Haydar et al. (6) found that a gradual substitution of hydrogen or alkaline cations in starch phosphate groups with Ca or Mg decreased starch swelling power, water binding capacity, viscosity, and solubilization. Other authors have described the effect of sugar, inorganic salts and other compounds on pasting properties of starch (2, 5, 7, 11, 13). According to Schoch (17) the viscosity of a

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starch paste may be reduced by blending at high speed, by applying high shear forces, by heating at high temperatures, by treatment with hot caustic alkali, and enzymes, and by treatment with acids.

Cowie and Greenwood (8) found that 0.2 M HCl at 45° C did not change the granular structure of potato starch, but that both the amylose and the amylopectin component were degraded. They also found that in spite of the fact that the potato starch did not change its granular structure it dispersed more readily to form a less viscous paste. Rodríguez Sosa et al. (15), working with the pasting properties of yam (*Dioscorea rotundata*) starch slurries at different pH levels, found that, except at pH 3.00, yam starch was stable when cooked at 50°C for 1 h. They also found that at pH 3.00 and after reaching 95° C the starch slurries thin down to zero viscosity losing all their gel properties and never retrograde.

When starch is heated in water, the granules swell and a portion of the starch substance dissolves in the surrounding aqueous medium. The degree of swelling and the amount of solubles will depend on the starch species, type and the degree of modification. Kasiyu et al. (9) found that at high concentrations banana (Valery var.) starch, as cereal starches, exhibits a two-stage swelling pattern, but that the second stage was not pronounced. Rodríguez-Sosa and Parsi-Ros (4) found that the swelling power of Habanero yam starch increased after 60° C being relatively high at 95° C.

Greenwood and Thomson (4) found that banana starch granules were oval with a granule size of 35 μm , but Kayisu (9) found that banana starch granules were irregular in shape with spheroids and elongated forms predominating. The granules varied from 15 to 40 μm for the spheroid type, the elongated granules were 7 to 25 μm wide and 20 to 50 μm long.

MATERIALS AND METHODS

Banana starch used in this experiment was extracted by the method described by Badenhuisen (1). The starch was dehydrated in a vacuum oven at 60°C for 24 hours and placed in a desiccator until used.

The consistency measurements of starch pastes, commonly referred to as viscosity, were obtained with an Amylograph-Viscograph. The starch slurries were prepared in the Amylograph bowl with 27 g of starch to 450 ml distilled water (6% aqueous solution) at pH 2.50, 3.00, 3.50, 4.00, 4.50, 5.00, 5.50 adjusted with citric acid. The mixtures thus obtained were stirred for 5 min at 200 r/min in the Amylograph for thorough mixing, and then stirred for 5 additional min at 75 r/min. The initial temperature for the heating-cooling cycle was 30° C; the 700 cm/g cartridge was used in all measurements. Temperature was increased at 1.5° C/min up to 95°

C and held constant for 1 h. Samples were then cooled at the same rate to 50° C and held at that temperature for another hour.

The swelling power of the granular starches was determined with the method described by Schoch (16), and granule size by the method of MacMasters (10).

The data obtained on the amylographic and swelling power were submitted to analysis of variance and Duncan's multiple range test (12).

RESULTS AND DISCUSSION

Table 1 shows the pasting properties of V-2390 and Montecristo banana starch slurries. Initial viscosity of the starch slurries for both

TABLE 1.—Consistency properties of green V-2390 and Montecristo banana starch slurries on heating at different pH levels as measured with the Brabender Amylograph-Viscograph

| Properties | pH levels | | | | | | |
|-------------------------------------|--------------------|------|------|------|------|------|------|
| | 2.50 | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 | 5.50 |
| | <i>V-2390</i> | | | | | | |
| Initial viscosity (BU) ¹ | 10 | 8 | 10 | 10 | 10 | 10 | 10 |
| Gelatinization temperature (°C) | 78 | 78 | 79.5 | 79.5 | 79.5 | 78 | 81 |
| Viscosity at 95°C | 118 | 290 | 405 | 380 | 445 | 438 | 265 |
| Maximum viscosity at 95°C | 220 | 303 | 425 | 425 | 483 | 495 | 478 |
| Viscosity after 1 h at 95°C | 0 | 33 | 223 | 293 | 413 | 450 | 455 |
| Viscosity at 50°C | 0 | 33 | 290 | 360 | 560 | 623 | 658 |
| Viscosity after 1 h at 50°C | 0 | 35 | 275 | 385 | 518 | 520 | 585 |
| | <i>Montecristo</i> | | | | | | |
| Initial velocity | 10 | 10 | 10 | 10 | 10 | 5 | 10 |
| Gelatinization temperature (°C) | 78 | 79.5 | 79.5 | 82.5 | 82.5 | 82.5 | 84 |
| Viscosity at 95°C | 220 | 255 | 253 | 240 | 220 | 225 | 220 |
| Maximum viscosity at 95°C | 243 | 310 | 353 | 390 | 435 | 458 | 478 |
| Viscosity after 1 h at 95°C | 8 | 55 | 193 | 293 | 390 | 438 | 470 |
| Viscosity at 50°C | 8 | 60 | 230 | 368 | 513 | 593 | 648 |
| Viscosity after 1 h at 50°C | 5 | 63 | 210 | 328 | 445 | 513 | 573 |

¹ Brabender Units.

cultivars was about the same. Gelatinization temperatures from pH 4.00 to 5.50 of Montecristo cultivar were somewhat higher, indicating a degree of resistance to swelling at these pH levels.

Viscosity measurements of V-2390 banana were only slightly higher than those of cultivar Montecristo indicating that the susceptibility to acid treatment is about the same for both cultivars. Except for "Viscosity at 95° C" (table 1), viscosity measurements of starch of both cultivars increased as pH increased, showing that swelling capacity was higher at higher pH levels.

Maximum viscosity or swelling capacity was attained after 95° C, but

this maximum was not a viscosity peak. At the concentration used in this experiment, banana starch granules swelled very little. Low swelling indicates a strong internal bonding. Banana starch also resisted mechanical disintegration at intermediate pH levels. This resistance could explain the absence of peak viscosity and the slight increase in viscosity during cooking (fig. 1). Generally speaking, the swelling capacity of V-2390 cultivar was somewhat higher than that of Montecristo.

At pH 2.50 and 3.00 viscosity measurements of starch of both banana cultivars decreased substantially when heated at 95° C denoting that the starch molecules suffered a great solubilization. At these pH levels banana starch slurries lost practically all their gel properties. The degree of solubilization (maximum viscosity minus viscosity after 1 h at 95° C)

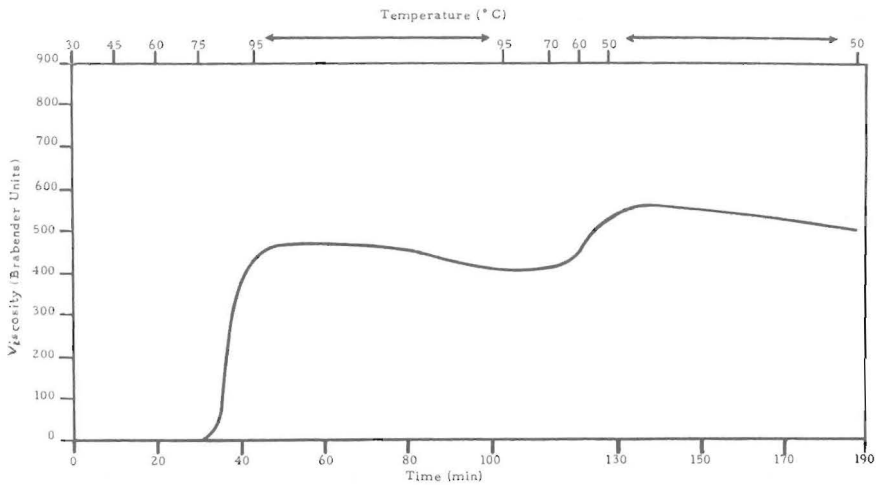


FIG. 1.—A typical amylogram of green banana (*Musa acuminata* × *balbisiana* AAB).

increased as pH decreased. This can be explained in terms of hydrolytic or oxidative cleavage that probably takes place in the more accessible intermicellar areas when granular starch is treated with acid. Acid treatment causes a weakening of the network within the granule. Thus, the granules fragmented and showed an increase in solubilization during pasting.

The retrogradation or reaggregation tendency (viscosity at 50° C minus viscosity after 1 h at 95° C) of starch granules of both banana cultivars increased with the increase in pH. The starch of both cultivars was relatively stable while being cooked at 95° C and at 50° C. This indicates that at pH levels suitable for canning acidified green bananas (3.50 to 4.00) starch showed sufficient strength to maintain the characteristic banana texture as influenced by starch.

Viscosity measurements of starch slurries at pH 2.50 were the lowest in both banana cultivars and were significantly different ($P = .05$) from all others except from that at pH 3.00. There were no significant differences in starch slurries of the two cultivars among samples at pH levels 4.50, 5.00, and 5.50. Also, no significant differences were found in viscosity measurements of samples at pH levels 3.50, 4.00, and 4.50 in cultivar V-2390 nor between samples at pH levels 3.50 and 4.00 in cultivar Montecristo, but in Montecristo a significant difference was observed between starch slurries at pH 3.50 and 4.50.

Swelling power of starch of both cultivars increased as temperature increased (table 2). However, within the limits of this study, it seems

TABLE 2.—Swelling power of green V-2390 and Montecristo banana starch at different pH levels and temperature

| Temperatures | pH levels | | | | | | |
|--------------|--------------------|-------|-------|-------|-------|-------|-------|
| | 2.50 | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 | 5.50 |
| °C | <i>V-2390</i> | | | | | | |
| 60 | 2.61 | 2.32 | 2.92 | 2.52 | 2.71 | 2.58 | 2.47 |
| 65 | 2.85 | 2.36 | 2.92 | 2.88 | 2.94 | 3.13 | 3.37 |
| 70 | 5.82 | 4.12 | 5.58 | 6.54 | 5.61 | 5.31 | 5.70 |
| 75 | 8.79 | 7.01 | 7.09 | 7.68 | 7.44 | 7.13 | 7.17 |
| 80 | 9.32 | 7.93 | 8.79 | 8.65 | 8.28 | 8.85 | 8.09 |
| 85 | 11.89 | 9.09 | 9.32 | 9.21 | 9.88 | 10.01 | 9.24 |
| 90 | 13.20 | 9.58 | 11.87 | 11.17 | 11.47 | 11.49 | 10.42 |
| 95 | 20.86 | 11.68 | 13.71 | 14.44 | 11.73 | 13.70 | 12.56 |
| | <i>Montecristo</i> | | | | | | |
| 60 | 6.85 | 4.25 | 4.51 | 2.81 | 3.63 | 3.17 | 3.30 |
| 65 | 8.04 | 7.14 | 7.04 | 5.33 | 6.11 | 6.15 | 6.60 |
| 70 | 9.71 | 8.46 | 7.80 | 7.17 | 7.76 | 8.28 | 7.76 |
| 75 | 14.16 | 8.68 | 13.81 | 8.95 | 9.68 | 9.06 | 9.54 |
| 80 | 16.77 | 10.50 | 11.30 | 10.48 | 10.73 | 10.14 | 10.50 |
| 85 | 24.34 | 12.51 | 12.67 | 12.01 | 12.52 | 12.19 | 11.67 |
| 90 | 27.96 | 14.86 | 15.88 | 13.92 | 13.14 | 14.06 | 14.55 |
| 95 | 37.21 | 24.26 | 21.93 | 16.27 | 16.90 | 17.36 | 18.61 |

that swelling power depends on temperature but not on pH. Thus, no definite trend was observed regarding the relationship between pH and swelling power.

Swelling power at pH 2.50 was the highest and significantly different from that of all other pH levels. However, no significant differences were found among samples at other pH levels. At pasting or gelatinization temperature of banana starch ($\pm 80^\circ \text{C}$) and at 95°C (maximum cooking temperature) swelling power for both cultivars was somewhat low. Swelling power at 90 and 95°C for both cultivars was significantly different between the two and significantly different from that of other tempera-

tures. According to Schoch (7), 85° C is the optimum single-point characterization for determining swelling power of starches. In Montecristo cultivar, swelling power at 85° C was significantly different from that at all other temperatures. In cultivar V-2390, no significant difference was observed between samples at 80° and 85° C. In the two cultivars there were no significant differences between samples at 75° and 80° C.

Starch granules of both cultivars were irregular in shape; at the same time oval, spherical and elongated granules appeared. Granules were also of irregular sizes; the average granule size of V-2390 was 33.4 μm ; of Montecristo it was 28 μm . The range in size in both cultivars was from 10 to 85 μm .

RESUMEN

Se estudió el efecto del pH sobre la pastosidad y la hinchazón del almidón de guineo verde (*Musa acuminata* \times *M. balbisiana* AAB) de las cultivares V-2390 y Montecristo. Las medidas de pastosidad se tomaron con un amiloviscógrafo. Las mezclas acuosas de almidón se prepararon añadiendo a 450 ml de agua destilada 27g de almidón y ajustando el pH con ácido cítrico a 2.50, 3.00, 3.50, 4.00, 4.50, 5.00 y 5.50. La viscosidad inicial de las muestras varió de 78° a 84° C. A los niveles de pH 2.50 y 3.00 el gel de almidón perdió casi todas sus propiedades al calentarlo prolongadamente a 95° C. Sin embargo, a los niveles adecuados para enlazar el guineo verde como un producto acidificado (3.50 y 4.50), el almidón mostró suficiente fortaleza para mantener la forma y textura del guineo según las influye el almidón. El almidón también fue relativamente estable cuando se sometió a períodos prolongados de calentamiento y enfriamiento y también se mantuvo a las temperaturas en que regularmente se utiliza. El poder de hinchazón del gránulo de almidón aumentó según aumentó la temperatura, pero esta medida fue bastante baja en ambas cultivares. Los gránulos del almidón de guineo son irregulares en forma y tamaño. El tamaño medio fue de 33.44 μm y 28 μm en las cultivares V-2390 y Montecristo, respectivamente.

LITERATURE CITED

1. Badenhuisen, N. P., 1964. Methods in Carbohydrates Chemistry, Vol IV: 14-15, Academic Press, New York, N. Y.
2. Bean, M. L. and Osman, E. M., 1959. Behavior of starch during food preparation. II. Effect of different sugars on the viscosity and gel strength of starch pastes, Food Res. 24: 265.
3. Cowie, J. M. G. and Greenwood, C. T., 1957. Physico-chemical Studies on Starches. Part V. The effect of acid on potato starch granules, J. Chem. Soc. Part III. 2658.
4. Greenwood, C. T. and Thomson, J., 1962. Physico-chemical Studies on Starches. Part XXIV. The fractionation and characterization of starches of various plant origins, J. Chem. Soc. 222-9.

5. Harai, J., Zaehringer, M. V. and Weise, A. C., 1970. Properties of wheat starch pastes containing components of cheddar whey, *Food Technol.* 24 (7): 803-5.
6. Haydar, M., Moledina, K., Ooraikul, B. and Hadziyev, D., 1980. Effect of calcium and magnesium on cell wall and starch of dehydrated potato granules, *J. Agric. Food Chem.* 28 (2): 383-91.
7. Hester, E. E., Briant, A. M. and Personius, C. J., 1956. The effect of sucrose on the properties of some starches and flours, *Cereal Chem.* 33: 91-101.
8. Howling, D., 1980. The influence of the structure of starch on its rheological properties, *Food Chem.* 6 (1): 51-61.
9. Kayisu, K., Hood, L. F. and Vansoed, P. R., 1981. Characterization of starch and fiber of banana fruit, *J. Food Sci.* 46 (6): 1885-90.
10. MacMasters, M. M., 1964. *Methods in Carbohydrates Chemistry*, Vol IV: 233-40, Academic Press, New York, N. Y.
11. Osman, E. M., 1975. Interaction of starch with other components of food systems, *Food Technol.* 29 (4): 30-5 and 44.
12. Robinson, P., 1955. Test of significance, *Bull. of Statistical Res. Ser., Canada Dep. Agric.*
13. Rodríguez-Sosa, E. J. and González, M. A., 1977. Effect of some food ingredients on various characteristics of instant tanier flakes and wheat flour, *J. Agric. Univ. P.R.* 61 (2): 234-41.
14. —, and Parsi-Ros, O., 1982. Starch properties of Habanero yam (*Dioscorea rotundata*), *J. Agr. Univ. P.R.* 66 (1): 27-34.
15. —, — and González, M. A., 1981. Effect of pH on pasting properties of Habanero (*Dioscorea rotunda*) yam starch, *J. Agri. Univ. P.R.* 65 (2): 154-9.
16. Schoch, T. J., 1964. *Methods in Carbohydrates Chemistry*, Vol. IV. 106-8, Academic Press, New York, N. Y.
17. —, 1969. Mechano-chemistry of starch, *Wallerstein Laboratories Communications*, 32 (9): 149-71, Wallerstein Laboratories, 125 Lake Avenue, Staten Island, N. Y.