Effect of pH on Pasting Properties of Habanero (*Dioscorea rotundata*) Yam Starch[1]

Edelmiro J. Rodríguez-Sosa, Orlando Parsi-Ros, and Miguel A. González[2]

ABSTRACT

This paper describes the influence of pH on the viscosity or consistency properties of Habanero (*D. rotundata*) yam starch. Initial viscosity of starch slurries varied from 73.5° to 75.3° C. Except for a sample at pH 3.00, yam starch was stable when cooked at 50° C for 1 hour. The strength of the starch was lower when cooked at 95° C. At pH 3.00 and after reaching 95° C the starch thins down to zero viscosity and never retrogrades. The correlation coefficients between shear press of starch gels and amylographic measurements were high and significant at the 1% level.

INTRODUCTION

Yam (*Dioscorea* spp.) is one of the most important edible root crops grown in Puerto Rico. Commercial production of yam has been maintained stable for the last 17 years with an average production of 282,000 cwt, but its value at farm level has increased from $1.2 million in 1961–62 to $6.2 million in 1975–76 (5).

Aside from water, starch is the most abundant component of yam, comprising about 23% (14). The textural characteristics of many food systems depend greatly on the properties of their starch. Study of the recorded rheological data gives valuable information on what may be expected when the pH's of slurries are changed or different materials are added to products containing starch. Amylo-viscography is the technique most extensively used to study the changes which occur in starch slurries during heating, cooking and cooling.

The most important factor that controls the swelling pattern of starch is the strength and nature of the micellar network within the granule, which in turn is subjected to the degree and kind of association. The swelling and solubility pattern of starch is altered radically by chemical modification. Leach (9) mentioned that acid modification is one of the oldest and most widely used commercial processes for producing starches of reduced viscosity. When starch is treated with warm acidified water, hydrolytic cleavage presumably takes place in the more accessible intermicellar areas. As a consequence, the network within the granule is weakened. This results in a fragmentation of the starch granules on pasting, showing a greatly increased swelling and solubilization.

[1] Manuscript submitted to Editorial Board February 29, 1980.

[2] Associate Food Technologist, Research Assistant, and Technical Director, respectively, Food Technology Laboratory, Agricultural Experiment Station, Mayagüez Campus, University of Puerto Rico, Río Piedras, P.R.

Numerous authors have described the effect of sugars, inorganic salts, and other compounds on pasting properties of starch. Osman (11) and Hester et al. (7) found that sucrose retards the swelling of starch granules. Bean and Osman (3) showed that disaccharides have greater effect than monosaccharides on the gelatinization of starch. Harai et al. (6) found that lactose added to wheat starch pastes increases their viscosity. Triglycerides alone lower the gelatinization temperature or increase swelling (10). Rodríguez-Sosa and González (13) studied the influence of some food ingredients commonly used in breadmaking on the rheological properties of tanier (*Xanthosoma sagittifolium*) instant flakes, wheat flour, and a mixture of 15% tanier flakes and 85% wheat flour.

This research work was undertaken to study the effect of pH on the rheological properties of Habanero yam starch.

MATERIALS AND METHODS

The Habanero yam used in this study was obtained from a small size commercial farm on the eastern coast of Puerto Rico. Yam starch was extracted by the method described by Badenhuisen (2). The starch thus extracted was analyzed for moisture content with the vacuum-oven method (1) and was stored in plastic bottles at about 21° C and 60% relative humidity.

The consistency of starch pastes, referred to as "viscosity," was obtained with the Brabender Amylograph-Viscograph Research Model currently known as a Starch Tester.[3] The pH of the water used for the preparation of starch slurries was adjusted with citric acid to a range in pH between 3.00 and 7.00, with 0.50 unit increments. The starch slurries were prepared by mixing 25 g of starch with 450 ml of acidified water in the Amylograph bowl. The mixtures thus obtained were agitated for 5 min at 200 r/p in the Amylograph; they were then agitated at the recording speed (75 r/m) for 5 additional minutes. The initial temperature for the heating-cooling cycle was 30° C. Samples were heated to 95° C at a constant rate of 1.5° C/min and held at that temperature for 1 hour. They were then cooled to 50° C at the same rate and held there for another hour. The 700 cm/g sensitivity cartridge was used in all tests.

Consistency measurements were also taken on yam starch pastes after the amylographic determinations with a Texture Test System provided with a Universal Cell, a snuggly fitted piston and a bottom plate with an orifice of 0.062 inch (1.57 mm) together with a 300-lb (136.1 kg) proving ring with the range adjusted to 50%. The stroke of the ram was adjusted

[3] Trade names in this publication are used only to provide specific information. Mention of a trade name does not constitute a warranty of equipment or materials by the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other equipment or materials.

to 1 min. Measurements were taken on 150-g samples at room temperature.

Color of the starch pastes after amylography was also measured with a tristimulus instrument. A white tile (L = 92.8, a = −.5, and b = +2.5) was used as a standard.

The amylographic determinations data were submitted to analysis of variance and the Duncan's multiple range test (4, 12). Correlation coefficients between shear press and amylographic determinations were calculated with the quick ranking procedure described by Kramer and Twigg (8).

RESULTS AND DISCUSSION

Figure 1 shows a typical amylogram of the Habanero yam starch slurry. After the gelatinization point, the curve rose to a peak viscosity. After

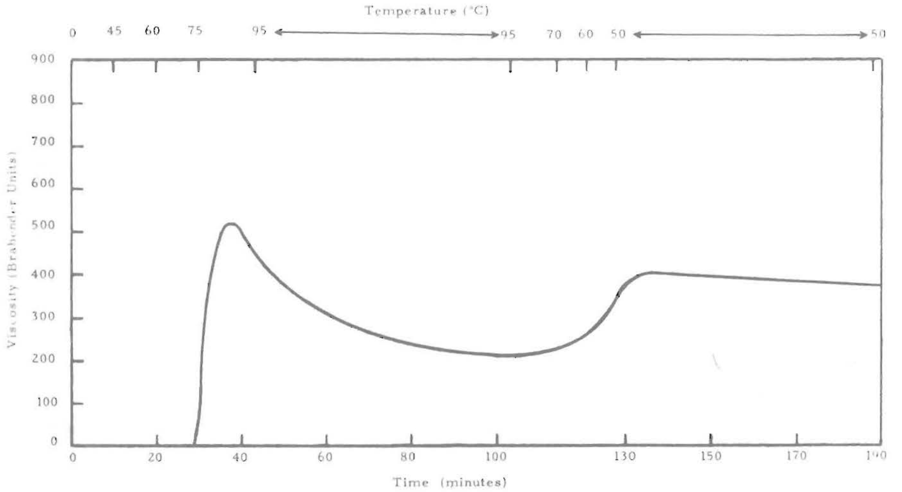

FIG. 1.—A typical amylogram of Habanero Yam (*D. rotundata*) starch slurry.

that point, a breakdown of starch granules occurred and viscosity decreased. Breakdown is due to a fragmentation and solubilization of the starch granules due to overswelling and to mechanical rupture caused by the agitation of the starch paste in the amylograph. Starch continued to thin down while cooking at 95° C. This process is an indication of the stability of the starch granules during cooking. Upon cooling to 50° C the hot paste tended to retrograde. This reassociation of the starch granules is shown by the increase in viscosity which results with the decrease in temperature. Yam starch, while cooking at 50° C tended to suffer a small decrease in viscosity possibly because of mechanical reasons.

Moisture of yam starch used in this experiment was around 12%. Tables 1 and 2 show the viscosity properties at the different pH levels and the color of the gel after amylography. Initial viscosity of starch slurries was the same for all samples when gelatinization or pasting temperatures varied from 73.5° C at pH 3.00 to 75.3° C at pH 6.50. Starch showed a moderate peak viscosity upon heating to 95° C, denoting the moderate fragility of the swollen starch granules. Peak viscosity was attained before reaching the maximum temperature, denoting certain degree of granule disintegration or cell rupture before reaching the maximum operating temperature.

TABLE 1.—*Consistency properties of Habanero yam starch on heating the slurries at different pH levels as measured with the Brabender Amylograph-Viscograph*

Consistency	pH levels								
	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00
Initial viscosity (BU)[1]	10	10	10	10	10	10	10	10	10
Gelatinization temperature (°C)	74.2	73.7	73.7	74.1	73.5	74.2	75.2	75.3	74.8
Peak viscosity	240	420	510	555	555	543	308	323	330
Viscosity at 95° C	40	310	433	450	460	455	250	263	268
Viscosity after 1 hour at 95° C	0	95	195	218	230	235	158	173	150
Viscosity at 50° C	0	165	378	463	475	503	293	340	265
Viscosity after 1 hour at 50° C	0	173	363	425	448	455	270	318	243

[1] Brabender units.

TABLE 2.—*Consistency properties and color measurements taken after amilography of Habanero yam starch at different pH levels as measured with the Texture Test System and the Color Hunter Difference Meter*

	Shear Press maximum force—lb	Color measurements[1]		
pH	50%	*L*	*a*	*b*
3.00	0	56.74	−.61	+.04
3.50	7.88	54.43	−.94	+.26
4.00	31.63	53.30	−.87	−.42
4.50	40.83	53.45	−.80	−.27
5.00	48.63	53.06	−.77	−.10
5.50	39.68	53.36	−.87	+.14
6.00	16.13	52.46	−.60	+.13
6.50	24.38	52.58	−.48	+1.29
7.00	15.75	51.44	−.75	+2.53

[1] Using the standard white tile $L = 92.8$, $a = -.5$, and $b = 2.5$.

Peak viscosity and viscosity at 95° C tended to increase from pH 3.00 up to pH 5.00 and then tended to decrease from pH 5.00 to 6.00, and again tended to increase from pH 6.50 to 7.00.

After 95° C, samples at pH 3.00 started to thin down until reaching zero viscosity and never retrograded. The starch gel was completely destroyed and apparently the same happened to starch granules. From pH 3.50 to 5.50 all other viscosity measurements tended to increase with an increase in pH. They decreased at pH 6.00, increased at pH 6.50 and again decreased at pH 7.00. The higher thinning down while cooking at 95° C was obtained in samples at pH from 3.50 to 5.50. The higher degree of retrogradation was observed in samples at pH 5.50 followed by the samples at 4.50 and 5.00. However, in spite of the changes noticed there were not significant differences among viscosity measurements at pH 4.00, 4.50, 5.00, and 5.50, but these were significantly different in measurements at pHs 3.00, 3.50, 6.00, 6.50 and 7.00. In pasting measurements at pHs 3.50, 6.00, 6.50 and 7.00 there were significant differences with measurements at pH 3.00. There were no significant differences among samples 3.50, 6.00, 6.50 and 7.00.

Yam starch slurries after amylography are essentially gels. Shear press maximum force (gel strength) tended to increase from 0 at pH 3.00 to 48.63 lb at pH 5.00, then tended to decrease (table 2). At pH 3.00 there was no gel formed at the end of the amylographic cycle. The correlation coefficient between shear press maximum force and peak viscosity was 0.85, while between maximum force and viscosity at 95° C it was 0.84. On the other hand, the correlation coefficients between maximum force and each of the other amylographic measurements was 0.95. All these correlation coefficients were significant at the 1% level.

Lightness of the starch paste after amylography tended to decrease with the increase in pH, while no definite trend was observed regarding greenness ($-a$) (table 2). Redness ($+b$) tended to increase from pH 5.50 to 7.00. Samples of pH from 4.00 to 5.00 showed a decrease in the blue ($-b$) component.

In conclusion, if Habanero yam starch is used as a thickening agent in a given food preparation or any other mixture the pH should be above 3.50 and should be cooked with gentle stirring to avoid cell rupture. If a higher degree of gelatinization is desired, the pH of the solution should be between 4.50 and 5.50.

RESUMEN

Se describe la influencia del pH en la viscosidad o consistencia de varias mezclas acuosas de almidón de ñame Habanero (*D. rotundata*). Para las pruebas se utilizaron niveles de pH de 3.00 a 7.00 en incrementos de 0.50 unidades. La viscosidad o consistencia de las mezclas se midió utilizando un amiloviscógrafo Brabender y el sistema de medir la textura (prueba de dureza) conocido como "Shear Press". La viscosidad inicial de las mezclas de almidón varió a medida que la temper-

atura subió de 73.5° a 75.3° C. Con excepción de la muestra a pH 3.00, el almidón de ñame Habanero resultó ser bastante fuerte y estable al cocerse a 50° C por una hora. La fortaleza del almidón fue menor cuando se coció a 95° C. En el caso de la muestra a pH 3.00 hubo una ruptura total del gel, bajando la viscosidad a cero cuando se coció a 95° C y no hubo retrogradación alguna cuando la muestra se enfrió a 50° C. Las viscosidades más altas obtenidas fueron con las muestras a pH 4.50, 5.00 y 5.50. Los coeficientes de correlación entre las medidas de viscosidad del amiloviscógrafo y el "Shear Press" fueron altos y significativos al 1%.

LITERATURE CITED

1. Association of Official Agricultural Chemists, Official Methods of Analyses, 1970, 11th ed, Washington, D.C.
2. Badenhuisen, N. P., 1964. Methods in Carbohydrates Chemistry, IV: 14–15, Academic Press, New York, N.Y.
3. Bean, M. L. and Osman, E. M., 1959. Behavior of starch during food preparation, II. Effects of different sugars on the viscosity and gel strength of starch pastes, Food Res. 24: 265.
4. Duncan, D. B., 1955. Multiple range and multiple F tests, Biometrics, 2: 1–42.
5. Facts and Figures of Puerto Rico Agriculture, 1977. Department of Agriculture, Santurce, P.R.
6. Harai, J., Zaehringer, M. V., and Weise, A. C., 1970. Properties of wheat starch pastes containing components of cheddar cheese whey, Food Technol. 24 (7): 803–5.
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. Kramer, A. and Twigg, B. A., 1966. Fundamentals of Quality Control for the Food Industry, The AVI Publishing Co., Conn.
9. Leach, H. W., 1955. Starch: Chemistry and Technology, Ed. by R. L. Whistler and E. F. Paschall, Vol. 1, Fundamentals Aspects, Academic Press, New York, N.Y.
10. Osman, E. M. and Dix, M. R., 1960. Effects of fats and non ionic surface-active agents on starch pastes, Cereal Chem. 37: 464.
11. ——, 1975. Interaction of starch with other components of food systems, Food Technol. 29 (4): 30–5, and 44.
12. Robinson, P., 1959. Test of significance, Bull. Stat. Res. Ser., Canada Dep. Agri.
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. Agri. Univ. P.R. 61 (2): 234–41.
14. Watt, B. K. and A. L. Merrill, 1963. Composition of Foods, Agri. Handbook No. 8, USDA, Washington, D.C.