Starch Properties of Habanero Yam (*Dioscorea rotundata*)[1]

Edelmiro J. Rodríguez-Sosa and Orlando Parsi-Ros[2]

ABSTRACT

Some properties of the starch granules of Habanero yam (*Dioscorea rotundata*) were studied. These granules were oval shaped with an average diameter of 33 μ. Viscosity of the starch, as measured with the Amylograph-Viscograph, increased during cooking as starch concentration in the samples increased. The starch showed a moderate peak viscosity denoting its strength. Consistency measurements taken on the starch gel formed after amylography increased as starch concentration in the samples increased. Swelling power of the starch increased after 60° C, being relatively high at 95° C, the maximum temperature used. Light transmittance of a 1% starch solution decreased with the increase in heating temperature, while starch solubles increased.

INTRODUCTION

Vegetables containing starch are extensively used as staple foods in many tropical countries the world over. Among these, yam is one of the most important. Although considerable research is now being conducted on the yam tuber because of its potential for industrial purposes, comparatively little is known of the physical and chemical properties of its most important constituent: starch. This carbohydrate changes the textural characteristics of the starchy tuber when boiled for consumption as a fresh vegetable. These changes are enhanced when processed to produce elaborated products for which purpose they must be submitted to even harsher treatment.

To define the mechanics of the behavior of starch in foods requires an understanding of the basic physical and chemical properties of the starch molecules. The starch granule is composed of a linear and a branched fraction termed amylose and amylopectin, respectively. Chemically, the basic building blocks of the starch molecules are glucose units linked by alfa-1, 4 and alfa 1, 6 glycosidic bonds. The starch granules are arranged in the form of insoluble particles. The size and shape of the starch granule depend on the botanical source from which it is obtained. Microscopically, the granules appear to be made up of a series of concentric lamellations which are more pronounced in some starches than in others. The strength and nature of the micellar network within the granule is the most important factor that controls the swelling pattern of the starch.

[1] Manuscript submitted to Editorial Board July 24, 1980.

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

Most of the work previously performed in this Laboratory on the properties of yam starch concentrated on the Florido variety (*D. alata*) (3, 9, 10, 11). Nonetheless, Rodríguez-Sosa, et al. (12) studied the effect of pH on the pasting properties of Habanero yam (*D. rotundata*) starch slurries.

Rasper (7), examining the properties of starches from some West African yams, found considerable variations between the different *Dioscorea* spp. He found that the longitudinal diameter of the West African *D. rotundata* Poir (White Guinea Yam) starch varies from 35 to 40 μ and forms a gel of considerable strength. Cruz-Cay and González (3) found that Florido yam starch was oval shaped, 31 μ in diameter and that its viscosity, as measured with the Brabender Amylograph-Viscograph, increased throughout the cooking and cooling cycles and did not show a peak viscosity denoting its strength.

Knowledge of physical and chemical properties of starch is of vital importance to food technologists and processors. The present study examined various properties of Habanero yam starch.

MATERIALS AND METHODS

Yam starch used in this study was extracted with 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 desiccators until used.

The consistency measurements of the starch pastes, commonly referred to as viscosity, were obtained with the Brabener Amylograph Viscograph Research Model[3]. The starch slurries were prepared by mixing in the Amylograph bowl from 18 to 27 g of starch at 1 g intervals, each with 450 ml distilled water. The mixtures thus obtained were stirred for 5 min at 200 r/min in the Amylograph to mix them well, 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.

Consistency measurements were also taken on yam starch gel after amylography. Two instruments were used to perform these measurements: a Texture-Test System (shear press) and a CENCO Consistometer (Central Scientific Co., Chicago, Illinois). The shear press was provided with a universal cell and a snuggly fitted piston, and a bottom plate with

[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.

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 to 1 min and measurements were taken on 150 g samples at room temperature. The CENCO Consistometer consists of a rectangular trough divided in two sections by a gate assembly. The smaller of the two sections serves as a reservoir for the material to be tested. The larger section, which takes up most of the trough, serves as the track on which the product consistency is to be measured. It is divided into 0.5 cm divisions. For yam starch tests the reservoir was completely filled and the starch gel was permitted to flow under its own weight along 8 cm of the level surface. Time was recorded with a stopwatch.

The swelling power and solubility of the granular starches were determined with the method described by Schoch (13), and the photomicrography and granule size (diameter) by the method of MacMasters (6).

Paste clarity analyses were performed by pasting (for 30 min and stirring gently to keep the starch granules suspended) 1% aqueous dispersions of starch at 5° C intervals from 50 to 95° C in a thermostatically controlled water bath. The paste was aged for 24 hr at 10° C. An aliquot of 200 ml of the supernatant solution was taken, and 0.5 ml of 1% iodine solution was added to develop a blue color. The percentage of transmittance was measured after 5 min at 620 nm.

The data obtained on the amylographic determinations was submitted to analysis of variance and Duncan's multiple range test (4, 8). Correlation coefficients were calculated with the quick ranking procedure described by Kramer and Twigg (5).

RESULTS AND DISCUSSIONS

The average moisture content of yam starch was 8.00%. Table 1 shows the results of the amylographic determinations. Initial viscosities were about the same for all samples, and so were the gelatinization temperatures. All other viscosity measurements increased with an increase of the starch concentration of the sample. Contrary to that of Florido (3), Habanero yam starch showed a moderate peak viscosity which increased as the starch concentration increased. This behavior indicates that Habanero yam starch is relatively strong. Thinning down of the starch paste increased with an increase in starch concentration of the yam slurry (fig. 1). Mechanical disintegration of the swollen starch granule is probably the main reason of this decrease in viscosity, because rupture due to swelling occurred principally after reaching peak viscosity.

Upon cooling to 50°C, the viscosity of samples increased because of the retrogradation tendency. The reaggregration of the starch granules increased as the starch concentration in the samples increased (fig. 1). Habanero yam starch was stable while cooking at 50° C for 1 hour.

TABLE 1.—*Consistency properties of Habanero yam starch slurries as measured with the Brabender Amylograph-Viscograph, the shear press, and the CENCO Consistometer*

Measurements	Weight of starch (g/450 ml water)									
	18	19	20	21	22	23	24	25	26	27
Initial viscosity (BU)[1]	10	10	5	10	10	10	10	10	10	10
Gelatinization temperature (° C)	73.5	73.5	73.5	73.5	73.5	73.5	73.5	73.5	72	73.5
Peak viscosity	208	240	240	318	358	385	453	498	548	570
Viscosity at 95° C	205	240	235	313	343	360	403	433	450	460
Viscosity after 1 hour at 95° C	125	143	150	158	178	193	203	210	223	263
Viscosity at 50° C	223	253	268	290	323	385	393	433	463	480
Viscosity after 1 hour at 50° C	213	243	263	285	315	358	373	405	435	458
Shear press maximum force (lb)[2]	35.45	39.00	34.95	40.80	48.00	48.90	55.20	66.75	66.45	69.00
Consistency (Cm/s)[3]	5.96	3.99	2.72	2.30	2.80	1.48	1.14	0.67	0.57	0.31

[1] Brabender Units.

[2] Taken on starch gel after amylography. Ring = 300 lbs, stroke = 1 min, sample weight = 150 g, and range = 50%.

[3] Taken on starch gel after amylography.

There was an increase in viscosity and retrogradation as the starch concentration in the samples increased from 18 to a maximum of 27 g/ 450 ml water.

Yam starch after amylography is essentially a gel. As expected, shear press maximum force of gel and consistency measurements, taken with the Cenco Consistometer, increased with the increase in starch concentration (table 1). The correlation coefficients between weight and shear press and between weight and consistency, as measured with the CENCO

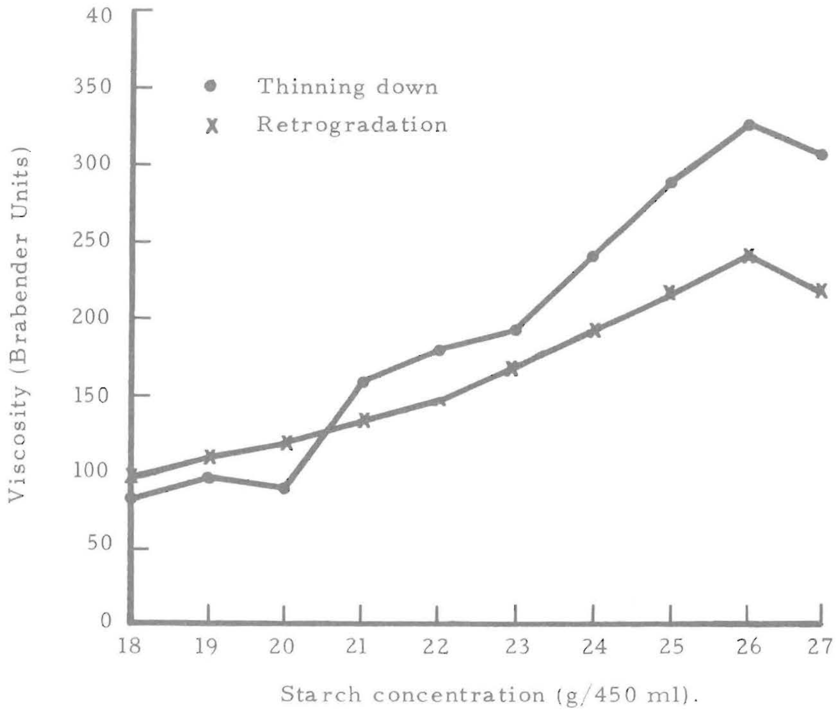

FIG. 1.—Total thinning down (peak viscosity less viscosity after one hour at 95° C) and retrogradation (viscosity after 1 hour at 50° C less viscosity after 1 hour at 95° C) of Habanero yam (*D. rotundata*) starch slurries.

Consistometer, were very high: 0.95 and −0.95, respectively, As the shear press values increased, the samples were more viscous as measured with the CENCO Consistometer ($r = -0.97$). Also, the correlation coefficients between shear press and amylography and between consistency and amylography were very high (above 0.90).

Since these correlations are so high, it is recommended that for quality control the CENCO Consistometer be used to measure consistency of starchy pastes because it is less expensive and easy to use. However, for research and development purposes it is better to use the Brabender Amylograph and/or the Texture-Test System (shear press) since they give more complete data.

Figure 2 is a photomicrograph of Habanero yam starch granules as observed under a microscope (450×). As Florido, Habanero yam starch granules were oval shaped (3). However, the average diameter of the Habanero yam starch granules was 33 μ ranging from 13 to 52 μ. Both mode and median were 31 μ. The average dimaeter reported by Cruz-Cay and González (3) for Florido yam starch was 31 μ.

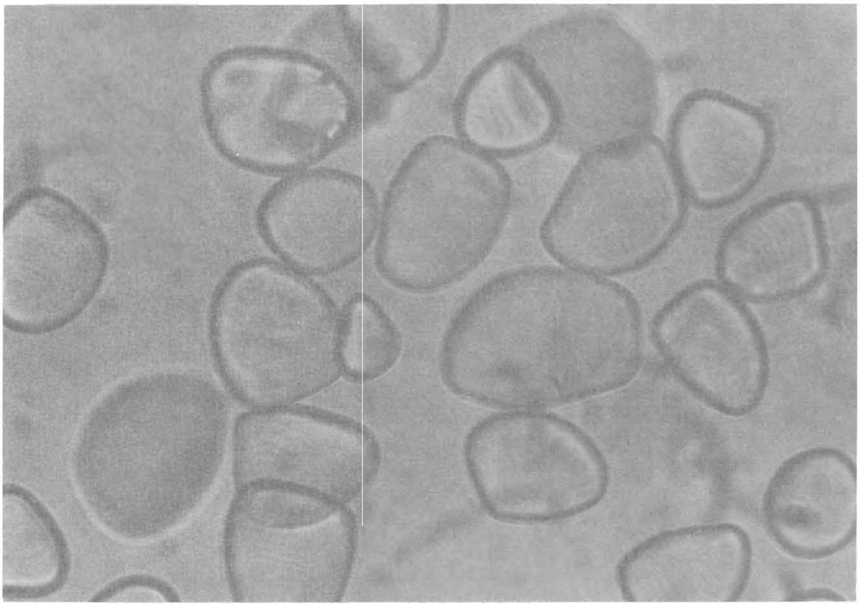

FIG. 2.—Photomicrograph of Habanero yam starch granules (450 ×).

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, on starch type and the degree of modification. Swelling power of Habanero yam starch was the same for temperatures from 50 to 60° C but beyond that point it increased with the increase in temperature (table 2). At pasting or gelatinization temperature (+70° C) swelling power was moderately low, but at maximum Brabender cooking temperature (95° C) it was relatively high. According to Schoch (10), for practical purposes the optimum single-point characterization for determining swelling power and solubility of starches is 85° C.

Light transmittance (paste clarity) was 100% on temperatures from 50° to 65° C (table 2). The supernatant liquid at these temperatures did not contain soluble starch. On the other hand, paste clarity from 70° to 95°C decreased with the increase in heating temperatures indicating an increase of starch solubles with the increase in temperature. At these temperatures, solubles percentage increased, and the blue color developed was more intense.

TABLE 2.—*Swelling power, percent soluble and paste clarity of Habanero yam starch*

Temperature of heating water	Swelling power	Starch solubles	Paste clarity % transmittance
°*C*		%	
50	2.21	0	100
55	2.22	0	100
60	2.22	0	100
65	2.42	0	100
70	12.21	17.40	66
75	44.46	60.32	66
80	174.10	87.68	67
85	175.26	86.40	61
90	223.06	87.66	59
95	361.82	91.84	57

RESUMEN

Varias características del almidón del ñame Habanero (*Dioscorea rotundata*), se estudiaron. Los gránulos del almidón son ovalados y tienen un diámetro medio de 33 μ. La viscosidad del almidón, según se midió con el amiloviscógrafo Brabender, aumentó durante las etapas de cocción según aumentó la concentración del almidón en la muestra. El almidón mostró un pico máximo de viscosidad moderado lo cual indica la fortaleza de dicho almidón. Las medidas de consistencia tomadas al gel de almidón formado luego de la amilografía aumentó según aumentó la concentración de almidón en la muestra. El poder de hinchazón (swelling power) del almidón aumentó pasados los 60° C, siendo relativamente alto a los 95° C, que fue la temperatura máxima usada. La transmitancia de una solución de almidón al 1% disminuyó con el aumento en temperatura, mientras que el almidón soluble aumentó.

LITERATURE CITED

1. Association of Official Agricultural Chemists, 1970. Official Methods of Analyses, 11th ed, Washington, D.C.
2. Badenhuisen, N. P., 1964. Methods in Carbohydrates Chemistry, Vol. IV: 14–15, Academic Press, New York, N. Y.
3. Cruz Cay, J. R. and González, M. A., 1974. Properties of Starch from Florido Yam (*Dioscorea alata* L.), J. Agri. Univ. P. R. 58 (3): 312–6.

4. Duncan, D. B., 1955. Multiple range and multiple F tests, Biometrics, Vol. 2: 1-42.
5. Kramer A. and Twigg, B. A., 1966. Fundamentals of Quality Control for the Food Industry, The AVI Publishing Co., Conn.
6. MacMasters, M. M., 1964. Methods in Carbohydrates Chemistry, Vol. IV: 233-40, Academic Press, New York, N. Y.
7. Rasper V., 1967. Investigations in Starches from some West African Root Crops, Proc. Int. Symp. Trop. Root Crops, Univ. West Indies, St. Augustine, Trinidad, Vol. 2, Sec. VI: 48-59.
8. Robinson, P., 1955. Test of significance, Bull. of Statistical Res. Ser., Canada Dep. Agric.
9. Rodríguez Sosa, E. J. and González, M. A., 1972. Preparation of yam (*Discorea alata* L.) Flakes, J. Agri. Univ. P. R. 56 (1): 39-45.
10. —— and ——, 1974. Effect of flake size on pasting characteristics of instant Florido yam (*Dioscorea alata*) flake slurries, J. Agri. Univ. P. R. 58 (2): 219-24.
11. ——, ——, and Parsi Ros, O., 1974. Effect of precooking on the quality of instant flakes from Florido yam (*Dioscorea alata* L.), J. Agri. Univ. P. R. 58 (3): 317-21.
12. ——, Parsi Ros, O. and González, M. A., 1981. The effect of pH on the pasting properties of Habanero (*D. rotundata*) yam starch slurries, J. Agri. Univ. P. R. 65 (a): 154-59.
13. Schoch, T. J., 1964. Methods in Carbohydrates Chemistry, Vol. IV: 106-8, Academic Press, New York, N. Y.