NOTE

Starch from Arrowroot (*Maranta arundinacea*) Grown at Tifton, Georgia

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Arrowroot (*Maranta arundinacea* L.) starch is produced primarily in the tropics, and historically St. Vincent, West Indies, produced over 98% of the supply of arrowroot starch for the United States, Canada, Britain, and Europe. The starch is used primarily in food although specialty uses in the paper, pharmaceutical, and cosmetic industries have been reported. Small production capabilities, competition from alternative crops, such as bananas, and high labor inputs have resulted in fluctuating supplies of starch in St. Vincent. Consequently, research was initially undertaken to evaluate alternative uses of the whole crop to increase economic returns (Erdman and Erdman 1984).

This note compares some of the characteristics of pilot plant isolated arrowroot starch from the Southeastern United States with arrowroot starch commercially isolated in St. Vincent, West Indies.

MATERIALS AND METHODS

Arrowroot plants were from rhizomes collected in St. Vincent, West Indies, and grown in Tifton, GA. A 0.186-ha plot of Tifton loamy sand was cultivated and fertilized with a mixture of N, P, and K in the ratio of 10:4.4:8.3 at the rate of 110 kg/ha immediately before transplanting cuttings that were maintained in the greenhouse over the winter months. Plants were spaced at 61-cm intervals within and between rows. Fertilizer (N, P, K 10:4.4:8.3) side dressing equivalent to 110 kg/ha was applied 54 days later. Irrigation water was applied twice daily as needed during weekdays (at 0700 and 1500 hr) so that soil conditions were noticeably damp at a depth of 1–2 cm. Rhizomes were mechanically harvested 236 days after transplanting. Harvested rhizomes were washed, chopped during two passes through a laboratory forage chopper (Silver Mfg. Co., Salem, OH), and then passed through a modified compost shredder. Starch extraction was performed by a wet milling procedure. The shredded material was continuously batch agitated in a 121-L rotating mixer under continuous water application (53.8 Liters/min). The starch-laden water slurry was passed over a screen (1-mm^2 pore size) to remove large particulate material and settled in a 60 m continuous plastic tube (26 cm diameter). The supernatant from the settling tube was discharged. Settled starch was collected, resuspended, and washed four times with clear water and filtered through a sieve (60 mesh) to remove extraneous material. The wet starch was dried at 50° C for 48 hr in a forced-air dryer and stored at −18° C until analyzed. Arrowroot starch collected from the Arrowroot Association Bellevue processing plant in St. Vincent, West Indies, in 1982 was used for comparative purposes. This starch was prepared by a wet milling procedure (Erdman and Erdman 1984), air dried at ambient temperature, and frozen at −18° C until analyzed.

Moisture was determined by drying 1 hr at 130° C (AACC 1976). Protein (total N × 6.25), fat, and gross ash content were determined by standard procedures (AOAC 1980). Gross energy content was determined by bomb calorimetry (Anonymous 1966). In vitro dry matter digestibility (IVDMD) was determined by the procedure of Tilley and Terry (1963). Total starch was estimated by the procedure of Thivend et al (1972) modified as described below. A 0.5-g sample was placed in a 125-ml Erlenmeyer flask, and 0.4 ml 95% ethanol was added to wet the surface. The starch was dissolved by adding 1 *M* NaOH (40 ml) and incubated for 3 min at 55° C. After incubation, 20 ml of 2.0 *M* acetic acid was added followed by 1.0 ml of glacial acetic acid. Glucoamylase (5.0 ml, Miles Laboratories, Inc., Elkart, IN) was added and the mixture incubated at 55° C for 1 hr with gentle agitation. The mixture was quantitatively transferred to a volumetric flask (250 ml), diluted to volume, and mixed and filtered through Whatman 2V filter paper. A 2.0-ml aliquot was diluted to 100 ml and assayed for glucose by the glucose oxidase procedure (AACC 1976). Control samples of wheat starch were analyzed with the arrowroot samples. Amylose was determined by potentiometric titration (Schoch 1964). Pasting properties were determined in a C. W. Brabender Viskograph-E (Hackensack, NJ; Shuey and Tipples 1980) using a counter balance spring of 700 cm-g maximum torque and a 5% starch suspension. The samples were heated from 30 to 95° C, held at 95° C for 30 min, cooled to 50° C, and held at 50° C for 30 min. Size-exclusion chromatography of the two starches was performed by the procedure of Kobayashi et al (1985). Differential scanning calorimetry was performed (Perkin-Elmer, DS2B) at an operating temperature range of 7–127° C, a 10° C/min scan rate, and with a water to starch ratio of 2:1. Scanning electron photomicrographs were prepared as previously described (Ghiasi et al 1982). Starch granular measurements of maximum and minimum diameters were taken from enlargements of the photomicrographs. Maximum diameter, width of starch granules, and other data were analyzed for differences by the *t* test (SAS Institute 1982) or K-ratio *t* test (Waller and Duncan 1969) using the Statistical Analysis System programming (SAS Institute 1982).

RESULTS AND DISCUSSION

Proximate analyses, gross energy content, and IVDMD of arrowroot starches produced in the southeastern United States and St. Vincent are presented in Table I. Protein, gross energy, and IVDMD of starch produced in Tifton was lower ($P<0.05$) than West Indies starch. The ash content, however, was higher ($P<0.05$) in Tifton starch. The greater ash content in Tifton starch, possibly

TABLE I
Proximate Analyses, Gross Energy, and IVDMD of Arrowroot Starch[a]

Measurements	Starch Origin[b]	
	Tifton, GA	St. Vincent, W.I.
Protein,[c] %	0.12 d ± 0.01	0.27 c ± 0.01
Fat, %	0.36 c ± 0.05	0.28 c ± 0.03
Ash, %	5.20 c ± 0.56	2.41 d ± 0.57
Gross energy, cal/g	4,026.63 d ± 3.22	4,148.31 c ± 14.80
IVDMD, %	55.55 d ± 0.38	60.33 c ± 0.13

[a] Mean ± SEM, reported on dry basis. Comparisons in the same row followed by different letters are significantly different ($P<0.05$) using a *t* test. IVDMD defined as in vitro dry matter digestibility, $n = 2$.
[b] Mean comparisons in each line followed by a different letter are significantly different ($P<0.05$).
[c] Nitrogen × 6.25.

[1] U.S. Department of Agriculture, Agriculture Research Service, Tifton, GA 31793-0748.

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caused by variations in processing techniques, may account in part for the significant differences in the starch samples. Geographic location or variety may also have contributed to these differences. The starch extraction yield was 9.4% in Tifton and reported to be 8–16% in St. Vincent.

Comparisons of starch and amylose are presented in Table II. Starch and amylose contents were comparable for both locations.

TABLE II
Starch and Amylose Content of Arrowroot from Two Locations

Origin	Moisture (%)	Starch[a] (%)	Iodine Affinity (mg I_2/100 mg starch)	Amylose[b] (%)
Tifton, GA	14.9	96.7	3.78	19.0
St. Vincent, W.I.	8.6	94.4	3.97	19.9

[a] Starch content reported on dry-weight basis. $n = 2$.
[b] Amylose determined on defatted samples. Amylose content calculated assuming iodine affinity of amylose is 19.9 mg of I_2/100 mg.

TABLE III
Pasting Characteristics of Arrowroot Starch from Two Locations[a]

Origin	Pasting Temperature (° C)	Peak	Final (95° C)	Break-down[b]	Cooled Down (50° C)	Setback[c]	Final (50° C)
Tifton, GA	72.7	410	373	37	625	215	598
St. Vincent, W.I.	75.9	337	240	97	393	56	397

[a] Values are reported in Brabender units. $n = 2$.
[b] Breakdown = consistency at 95° C after holding 30 min.
[c] Setback = consistency at peak after cooling to 50° C.

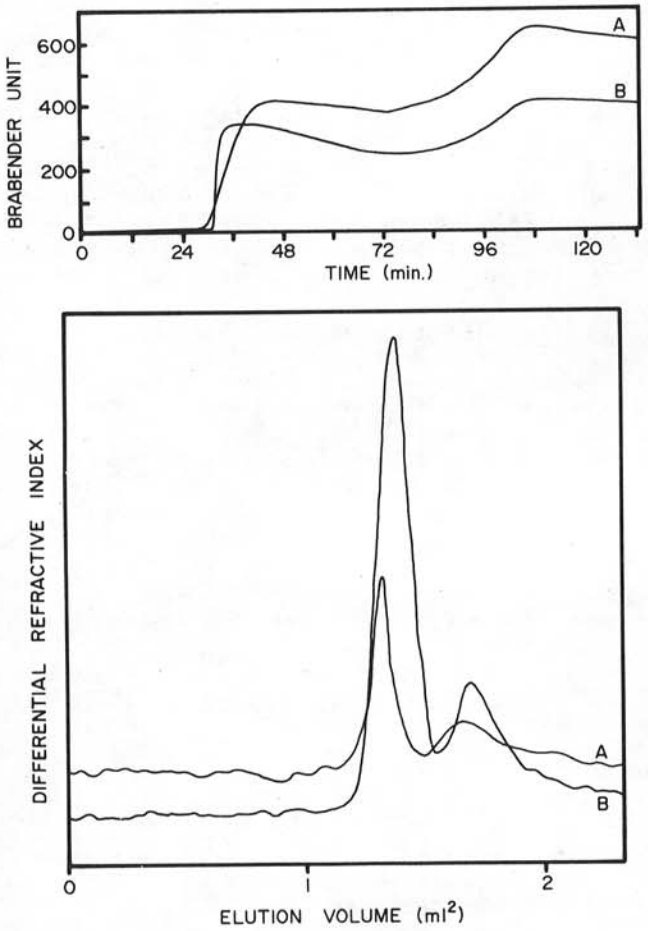

Fig. 1. Pasting characteristics and size exclusion chromatography of arrowroot starch produced in Tifton **(A)** and St. Vincent **(B)**.

Iodine affinity and amylose contents were lower, but comparable to previously reported values (Anderson and Greenwood 1955). These data suggest that the starches were similar, irrespective of origin of production, and demonstrated that a quality arrowroot starch could be produced in the United States.

Pasting characteristics of arrowroot starches are shown in Table III. Small differences were observed in initial pasting temperature. However, peak height, final cooled, and setback consistencies were higher and breakdown lower in Tifton starch. Starches from Tifton and St. Vincent were both higher in initial pasting temperature when compared to Brazilian arrowroot starch (Ciacco and D'Appolonia 1977). The Brabender pasting curves (Fig. 1a) indicated potential differences in starch granule properties of the arrowroot starches. These differences could result from variation in the amounts of impurities in the starch samples. However, size exclusion chromatography (Fig. 1b) indicated that the molecular weights were similar, as determined by elution times and peak shapes. The difference in peak heights is attributed to sample concentration differences.

Differential scanning calorimetry characteristics of arrowroot starches are presented in Table IV. Curve initiation and peak of curves were higher ($P<0.05$) for St. Vincent starch than for Tifton starch. No difference ($P>0.05$) was detected for the end of the

TABLE IV
Differential Scanning Calorimetry of Arrowroot Starch[a]

Origin	Moisture (%)	H (cal/g)	T_o^b	T_p^b	T_m
Tifton, GA	8.56	4.49	334.0 c	338 c	358.8
St. Vincent, W.I.	14.85	4.64	338.0 b	347 b	359.0

[a] T_o, T_p, and T_m defined as initiation of curve, peak of curve, and end of curve, respectively, expressed in °K.
[b] Mean comparisons in the same column followed by different letters are significantly different ($P<0.05$) using t test.

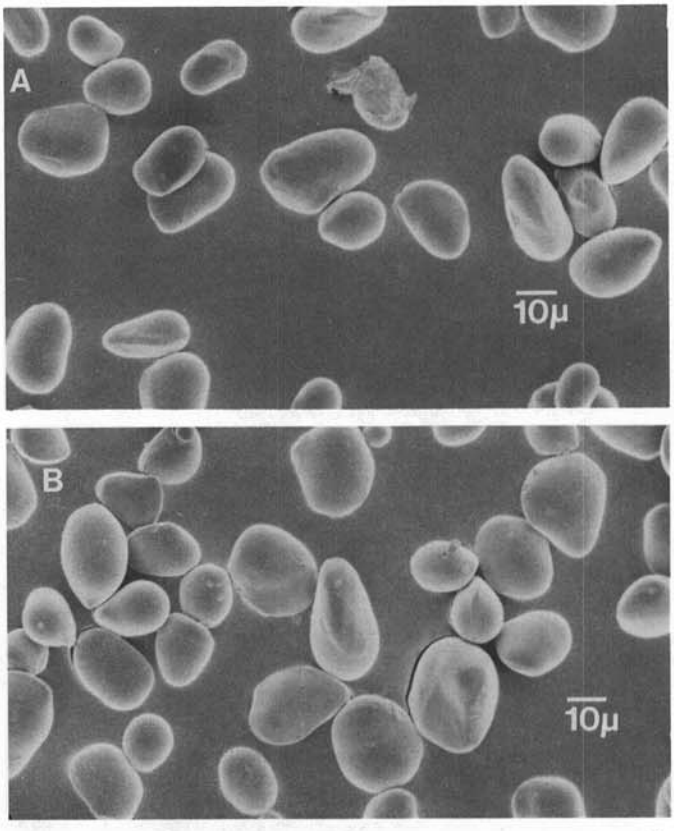

Fig. 2. Scanning electron micrographs of arrowroot starch produced in Tifton **(A)** and St. Vincent **(B)**.

scanning curve. The relatively high level of ash in starch from Tifton could have interfered with the pasting and differential scanning calorimetry characteristics of the Tifton grown starch.

Scanning electron photomicrographs of Tifton and St. Vincent produced starch are presented in Figure 2. Photomicrographs of both starches appear similar; however, measurements showed Tifton starch to be smaller ($P < 0.05$, $n = 62$). The mean and standard error of the mean (SEM) measurements for Tifton starch maximum and minimum granule diameters were 14.52 ± 0.56 and 10.05 ± 0.32 μm, respectively ($n = 39$). The mean maximum and minimum granule diameters and SEM of St. Vincent isolated starch were 16.62 ($\pm$ 0.78) and 12.42 ($\pm$ 0.62) μm, respectively ($n = 23$). The reduced size of Tifton starch may result from the shorter growing season compared to St. Vincent.

Differences and similarities were found for arrowroot starches isolated in Tifton and St. Vincent. Although statistical differences could be demonstrated in this study, it is difficult to compare starch prepared at a pilot plant with commercially prepared starch. Therefore, extreme caution should be exercised when interpreting these data. The data do, however, indicate that arrowroot starch can be produced in the southeastern United States. Because starch yield in Tifton is comparable to yields in St. Vincent, commercial production of a high quality arrowroot starch in the U.S. appears feasible, although improvements in processing techniques are needed to obtain a high-quality product.

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