Research Note

SUGARS IN TROPICAL-TYPE SWEET POTATO VARIETIES OF PUERTO RICO[1,2]

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Tropical-type sweet potato (*Ipomoea batatas*) describes varieties that combine white-, cream- or light yellow-fleshed roots with a sweetness between that of the non-sweet and the dessert (usually orange-fleshed) types. Because tropical-type sweet potato is usually less moist to the mouth than its dessert-type counterpart, this group has been referred to as dry-fleshed type or boniato-type sweet potato (Jackson and Bohac, 2006; Martin and Deshpande, 1985). Tropical-type varieties are the ones commonly grown and consumed in Puerto Rico and throughout the Antilles of the Caribbean Basin. This group is also common in Hawaii.

For sweet potato, sweetness is a key aspect of flavor and thus for acceptability in the market (Koehler and Kays, 1991). Characterizing sweetness for the selection of commercial varieties for fresh non-processed consumption is of paramount importance because this characteristic is entirely dependent on the sugar composition of the root. To develop effective selection criteria for sweetness in tropical-type sweet potato we need to obtain baseline information on sugar concentration from varieties predominant in the local market. That information is needed for establishing a standard for varietal evaluation and selection. The objectives were to assess the sugar concentrations in tropical-type varieties commonly grown and marketed in Puerto Rico, and to describe the methodology used for said assessment.

Traditional tropical-type varieties Miguela, Mina, and Dominicana (also known either as Canol or as Carlos-Hernández) were used in this study. Mina and Miguela were described by Badillo-Feliciano et al. (1976). Dominicana is a local landrace that currently dominates the market in Puerto Rico. We also included Viola, which has purple skin and white flesh, a variety released by USDA[7] and considered moderately sweet when compared with the other varieties included in this study (University of Puerto Rico, 1997).

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[7]Release of Viola Sweet potato Cultivar 9 November 1990. United States Department of Agriculture, Agricultural Research Service, Washington, D.C. 20250

To assure tuberous roots of uniform age, we made a field planting on the Agricultural Experiment Station farm at Juana Díaz, Puerto Rico. This facility is located in the southern coastal valley of Puerto Rico, which is the area where commercial production of sweet potato is concentrated. Each variety was grown in a bed 1.9 m wide and 9.1 m long. The soil was from a Mollisols series. Standard management practices and drip irrigation followed recommendations by University of Puerto Rico (1997). To assure enough roots for the analyses two replicates were planted. Harvest was 155 days after planting. Roots were selected at random from the field and cured for at least two days at room conditions before being analyzed for sugars. Average temperature and relative humidity in the storage room were 28° C and 90%, respectively.

Cured roots weighing from 150 to 400 g were selected for processing before sugar determinations. Roots were arbitrarily classified in sizes large, medium, and small and uniformly distributed among the processing treatments. For each variety, root samples were processed either raw, boiled or microwaved. For boiling, a group of roots weighing approximately 2,000 g were exposed to 4 L boiling distilled water for 30 minutes. For the microwaved treatment, a group of roots weighing about 900 g were wrapped individually in paper towels and placed at maximum energy in a 2450-MHz microwave oven for 12 to 15 minutes. The raw treatment consisted of neither boiling nor microwaving the roots; immediately after treatments, the flesh located at the center of the root was removed and combined with roots receiving the same treatment to form a composite sample. The composite was dried at 55° C and later ground to pass through a #20 mesh for preparing flour. The flour was placed in glass jars and frozen at -20° C for the extraction of sugars. Procedures for treatments were repeated to obtain the amount of flour needed for the analyses.

Sugars were extracted by mixing 20 g of the above mentioned flour with 100 ml of 80:20 ethanol-water. This combination was immediately placed in a water bath at 100° C, where it was kept for five minutes. The mixture was slowly agitated while in the bath. The solution was then vacuum-filtered by using Whatman No. 4[8] paper filters. The filtrate was then transferred to a 200-ml volumetric flask, and volume was adjusted with the 80:20 ethanol-water solution. Four milliliters of the latter solution was refiltered through a 0.45-µm nylon membrane polypropylene syringe filter and then quantitatively transferred into 4-ml HPLC vials. This doubly filtered solution was placed in a freezer at -20° C until the HPLC determination of sugars.

Prior to the analyses, HPLC-grade standards of sugar and ethanol were prepared for all sugars assayed: glucose, fructose, sucrose and maltose. Procedures to prepare the standards followed a modification of those described by Picha (1985). For the calibration curves, standards of concentrations 0.01, 0.05, 0.1, 0.5, 1.0, and 1.5% were prepared for each sugar. To inject along with samples, we prepared standards combining 1% glucose, 1% fructose, 2% sucrose and 5% maltose, and also combining 0.1% glucose, 0.1% fructose, 0.2% sucrose and 0.5% maltose. Sugars of analytical grade were used to prepare the solutions, all of which were transferred to individual 100-ml volumetric flasks to adjust the volume by using a 80:20 ethanol-water solution. All solutions were then filtrated by using 0.45-µm nylon-membrane polypropylene syringe filters. The filtrates were stored in a freezer at -10 to -20° C until the analyses.

As for the standards, procedures for sugar determinations followed those described by Picha (1985) as modified by Hernández-Carrión et al. (2003). Glucose, fructose, sucrose and maltose were determined by using a chromatograph system equipped with an

[8]Commercial names are given to provide specific information and do not represent endorsement by the University of Puerto Rico (UPR), the UPR-Mayagüez Campus, nor by the UPR- Agricultural Experiment Station nor the authors.

autosampler and a refractive index detector[9]. Sugar separation was accomplished by using two chromatographic columns. Glucose and fructose were separated by using Waters's Sugar PaK-1 cation exchange column heated to 90° C. For these sugars, mobile phase was HPLC-grade water with CaEDTA (50 mg/L) at a flow rate of 0.5 ml/min. In the latter column, sucrose and maltose, coeluted; thus an amino-bonded column, Supelco's Supelcosil Lc-NH_2 was used to assess these sugars. When separating sucrose and maltose, the column was heated to 25° C; the mobile phase was a 85:15 solution Acetonitrile:HPLC-grade water; the flow rate was 1.5 ml/min. Sugar concentration was obtained by comparing areas below the peaks of samples to those of the corresponding standards. These comparisons were made by using a computer program coupled to the HPLC system[10]. Sugar concentrations were expressed as percentages of the flour dry weight. Sucrose equivalents were calculated in order to compare varieties at the same level of sweetness (La Bonte et al., 2000). The formula to calculate sucrose equivalents (SE) was that given by Koehler and Kays (1991), where SE = 0.74 (% glucose) + 1.73 (% fructose) + 1.0 (% sucrose) + 0.33 (% maltose).

When submitted to heat, sweet potato starch is hydrolyzed into sugars primarily by enzymatic action. Sucrose, glucose and fructose were detected in raw samples, whereas maltose was not detected (Table 1). This observation is consistent with previous studies. Using varieties different from those included in this study, absence of maltose in raw samples has been reported by both Lewthwaite et al. (1997) and by Picha (1985). Sucrose was the main sugar in raw samples, and it tended to increase as a response to both boiling and microwaving (Table 1). A similar response was observed previously for orange-fleshed sweet potato (Picha, 1985).

Maltose appeared, and in relatively high concentrations, with boiling and microwaving (Table 1). This result conforms with results in previous studies which indicate that maltose is the main sugar in sweet potato after the flesh is subjected to heat (Lewthwaite et al., 1997; Babu, 1994; Picha, 1985). In this study, concentrations of maltose among boiled and microwaved samples of tropical-type varieties ranged from 11.5 to 18.9% of dry weight. For the moderately sweet variety Viola, however, concentrations of maltose ranged from 3.1 to 4.3% for the boiled and microwaved samples (Table 1). Methodology between studies varied, but percentage values of maltose obtained in this study for the tropical-type varieties were lower than those reported by Kays and Hovart (1984). The latter authors reported maltose concentrations from 19.0 to 27.1% on a dry weight basis. Overall, results of this study show that tropical-type sweet potato responded similarly to orange-fleshed sweet potato regarding increased concentrations of sucrose and maltose after boiling.

In this study, increase in sucrose equivalents as a response to boiling and microwaving was associated with the increased concentration of maltose (Table 1). Across varieties, sucrose equivalents for boiled and microwaved samples were between 9.7 and 11.8, whereas in raw samples sucrose equivalents were from 1.9 to 6.1. We wanted to determine whether the traditional tropical-type varieties Miguela and Mina show sucrose equivalents higher than those of Viola, the latter being a moderately sweet variety. On average, sucrose equivalents for Mina were less than those of Viola independently of the type of processing (Table 1). Mina, however, is known to be sweeter-to-taste than Viola

[9]HLPC equipment was MODULES of the Waters Corp, Milford MA (USA). HPLC Automatic autosampler was Model Waters717 plus; Refractive index detector was Model Waters 410; Solvent distribution system was Model Waters 600E., Temperature control system was Waters TCM.

[10]The HPLC equipment used in this study was coupled to a Waters Millennium Chromatography Workstation, Ver. 3.0.

TABLE 1. *Percentages of sugar on a dry weight basis for sweet potato varieties of common use in Puerto Rico.*

Variety	Type of Processing	Sugar				Sucrose equivalents
		Glucose	Fructose	Sucrose	Maltose	
		%				
Dominicana	Raw	0.3 ± 0.1[1]	Undetected	1.7 ± 0.1	Undetected	1.9 ± 0.1
	Boiled	0.5 ± 0.1	0.1 ± 0.1	2.9 ± 0.1	18.9 ± 0.3	9.7 ± 0.1
	Microwaved	0.4 ± 0.1	0.1 ± 0.1	4.0 ± 0.1	17.5 ± 0.3	10.4 ± 0.1
Miguela	Raw	1.3 ± 0.1	1.6 ± 0.1	2.2 ± 0.1	Undetected	6.1 ± 0.1
	Boiled	1.6 ± 0.1	1.1 ± 0.1	2.9 ± 0.1	12.6 ± 0.2	10.3 ± 0.2
	Microwaved	2.0 ± 0.1	1.4 ± 0.1	3.4 ± 0.1	13.3 ± 0.3	11.8 ± 0.2
Mina	Raw	0.4 ± 0.1	0.1 ± 0.1	2.1 ± 0.1	Undetected	2.8 ± 0.1
	Boiled	0.3 ± 0.1	0.2 ± 0.1	2.6 ± 0.1	11.5 ± 0.2	7.1 ± 0.1
	Microwaved	0.5 ± 0.1	0.2 ± 0.1	3.2 ± 0.1	12.1 ± 0.1	8.0 ± 0.1
Viola	Raw	0.5 ± 0.1	0.4 ± 0.1	4.1 ± 0.5	Undetected	5.2 ± 0.5
	Boiled	0.8 ± 0.1	0.3 ± 0.1	4.6 ± 0.1	4.3 ± 0.8	10.6 ±0.2
	Microwaved	0.8 ± 0.1	0.3 ± 0.1	4.7 ± 0.2	3.1 ± 0.3	10.3 ±0.2

[1]Means for three extractions per sample. Numbers after the mean percentage value correspond to the standard error.

(University of Puerto Rico, 1997). Sucrose equivalents for Viola look similar to those of Miguela (Table 1). These findings suggest that establishing selection criteria for sweetness of sweet potato only upon the basis of sucrose equivalents does not assure acceptable sweetness-to-taste. Sweetness-to-taste is an arbitrary and complex trait to work with because it depends on particular preferences of persons or groups of persons. Sweetness is also part of flavor, which appears to be highly influenced by volatile constituents of the root (Dumas and Ortiz, 2006; Sun et al., 1995; Kays and Hovart, 1984). For effective selection in breeding programs, quantitative measurements of chemical components in sweet potato, such as sugars, must be complemented with qualitative assessment of prospective consumers.

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