Chemical and Geographical Assessment of the Sweetness of the Cultivated Sweetpotato Clones of the World

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ABSTRACT. Sweetness, which is known to vary significantly among clones, is the dominant sensory attribute characterizing the flavor of sweetpotatoes [*Ipomoea batatas* (L.) Lam.]. The relative sweetness of baked roots, expressed as sucrose equivalents, was determined for 272 clones from the U.S. Department of Agriculture National Plant Germplasm System collection. The clones were from 34 countries that collectively produced 93% of the world's sweetpotato production in 2002. Individual clones were separated into five categories based upon the concentration and relative sweetness of individual sugars, expressed numerically as sucrose equivalents per 100 g dry mass: very high ≥ 38 ; high 29–37; moderate 21–28; low 12–20; and nonsweet ≤ 12 . Based upon the mean sucrose equivalents of the clones for each country, only 9% of the countries, which accounted for only 2.1% of the total annual production of the countries surveyed, had sweetpotatoes that were classified as very high. While the majority (62%) of the countries surveyed had clones that were categorized as high, they represented only 4.4% of the total production of sweetpotatoes. None of the countries had mean sucrose equivalent values that were categorized as low or nonsweet, although a few individual clones were ranked as low and one as nonsweet. Countries that account for the majority (87%) of the sweetpotatoes grown worldwide had a mean sucrose equivalent ranking of moderate. Sweetness is derived from the composite of endogenous sugars (sucrose, glucose, fructose) and maltose formed via starch hydrolysis during baking. Maltose accounted for only 42% of the average contribution to the total sucrose equivalents. The range in the concentration of individual sugars among clones was substantial as was their contribution to sucrose equivalents. Sucrose equivalents due to maltose in individual clones ranged from 0.6 to 21.9 while endogenous sugars ranged from 6.4 to 46.9. The results indicate that essentially all of the sweetpotato clones tested from around the world were classified as equal to or greater than moderate in sucrose equivalents, and that there is substantial genetic diversity within the genepool such that the potential exists for tailoring the flavor of new cultivars, via significantly increasing or decreasing sugar content, to meet specific consumer preferences and/or product uses.

The sweetpotato is grown in more than 100 countries around the world and ranks fifth as a food crop in developing countries (Food and Agriculture Organization, 2002). Unlike virtually all other staples, the sweetpotato has an extremely dominant, distinct flavor. Flavor is a primary criterion in food selection, and flavor preference for the sweetpotato is known to vary with ethnic background and geographical location (Kays and Horvat, 1983). While used as a staple (i.e., a crop consumed frequently and as a significant portion of the diet) in many countries, it is rarely preferred even though it is more nutritious than most staple crops (Kays and Kays, 1998). The dominance of the flavor greatly minimizes the variation that can be achieved in the final flavor of the cooked product; hence the consistent strong flavor becomes readily tiresome if consumed daily in significant quantities. The sweet taste, due to sugars, is the central feature that significantly modulates the overall flavor through its direct impact on taste but also through the role of monosaccharides as precursors in the synthesis of several key aroma compounds (Kays and Wang, 2000; Wang and Kays, 2000, 2001, 2003).

There is substantial variation in flavor within the sweetpotato genepool (McLaurin and Kays, 1992) and in sweetness due to the endogenous sugars present in the raw roots (sucrose, glucose, and fructose) and the formation of maltose during cooking via the action of α -amylase (E.C. 3.2.1.1) and β -amylase (E.C. 3.2.1.2)

(Morrison et al., 1993; Sistrunk et al., 1954). Because individual sugars vary in their level of sweetness (Shallenberger, 1993) (e.g., fructose is 2.8 times sweeter than maltose), comparisons in the sweetness among clones require both quantification of individual sugars and adjustment for their relative sweetness [i.e., using the sweetness of sucrose as 1, sucrose equivalents (SE) are calculated]. In addition, not all sugars are equal in flavor quality. In the sweetpotato, the taste of maltose was preferred over the other sugars presented to sensory panelists in the United States (Koehler and Kays, 1991).

The advent of a nonsweet breeding line with the flavor, color, and texture of a white potato (*Solanum tuberosum* L.) has created the possibility of developing new, uniquely flavored cultivars to expand consumption (Kays et al., 2001). This potential leads to the question of what would constitute an improved flavor(s) for particular target populations of consumers.

To better understand the existing flavor of sweetpotatoes around the world, we determined the sucrose equivalents of clones from a cross-section of countries/protectorates to determine if there are countries or regions that prefer sweetpotatoes with lower/higher levels of sugars.

Methods and Materials

CLONES. Two hundred and seventy-two clones (Table 1) from 34 countries obtained from the U.S. Department of Agriculture (USDA) National Plant Germplasm System (NPGS) repository in Griffin, Ga., were grown at the University of Georgia Horticulture Farm (Athens, Ga.) using standard sweetpotato production prac-

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Table 1. Sweetpotato clones analyzed for sucrose equivalents after baking, listed by country.

Argentina	531138
Australia	508511, 564160 ('Red Abundance'), 573335 ('Cape York'), 585060
Bangladesh	585065 ('Kamala Sundari')
Brazil	508513
Costa Rica	531139, 531140
Cuba	585085 ('Baracutey'), 585086 ('Regional De'), Grif 1068 ('Picadito')
Guatemala	376944 ('Extranjero'), 376945 ('Morado'), 452267, 508523, 531093, 531094, 531095, 531096, 531097, 531098, 531099, 531101, 538306, 538307, 538308, 538309, 585077, 585078, 585079, 585092, 585093
Honduras	556934 ('Cuitzeo')
India	585061 ('Kalmegh S-30')
Indonesia	585063, 585064
Japan	153905 ('Norin 2'), 153907 ('Norin 4'), 153909 ('Taihaku Saitama'), 508505 ('Kin-toki'), 508506 ('Koto-puki'), 508508 ('Kogane-sengan'), 508509, 585087 ('Kyukei'), Grif 1054
Korea	585062 ('Suwon 122'), 585067 ('Okinawa 100'), 585068 ('Suwon 147'), 585069 ('Eun-Mi'), 585070 ('Seon-Mi'), 585071 ('Won-Mi'), 585072 ('Saing-Mi'), 585073 ('Pung-Mi')
Mexico	267946, 304088 ('Morado de Yucatan'), 439749, 531136 ('Catemaco'), 585100 ('Tinto'), 585101
Myanmar	573297, 573298, 573334
New Caledonia	318848 ('Kumala Belep')
New Guinea	315347, 324885, 573287, 573288, 573301, 573302, 573303, 573304, 573305, 573307, 573308, 573309, 573310 ('Hadare'), 573311 ('Esdiei'), 573312 ('Gonime'), 573313 ('Munduen'), 573314 ('Naveto'), 573315 ('Ma' Alau'), 573325, 573326 ('Boianai'), 585057, 585058, 564133, 564134, 564138, 564142, 564143 ('Amasonto'), 564144 ('Wanmun small'), 564146 ('Wanmun Kabiufa'), 564149 ('Markham'), 564151 ('Tawa-1'), 564152 ('Talaaukwe'), 564153 ('Mbakoka'), 564154 ('Keanja'), 'Keango'), 564155 ('Unduandopa'), 564770 ('Wanmun large'), 585105, 585111 ('Merikan')
New Hebrides	324886
New Zealand	286619, 286621, 308196, 308201, 320446, 320448, 286623
Nigeria	508522, 531116, 564771, 564773, 585051, Grif 993, Grif 994, Grif 995
Peru	531121 ('Ihuanco'), 531131 ('Camote Morado-1'), 531123 ('Trujillano'), 'Huapachero'), 531151 ('Nino'), 531153 ('Chilingano'), 531154 ('Negro'), 'Corazon de Huarango'), 531155 ('Pedro Juan'), 531162 ('Sin Nombre'), 538285 ('Paramutay'), 538288 ('Eucaru'), 538292 ('Juancho'), 538297 ('Amarillo de Chilcalo'), 538298 ('Wennotz II'), 538300 ('Papino')
Philippines	315342 ('Qilin'), 315343, 344124 ('Lakwaw'), 564156, 564157, 564158, 564159, 573333
People's Republic of China	286629, 308198, 508514, 508515, 508516, 508517, 508518, 508519, 508520, 508521
Puerto Rico	208796, 208806, 208886, 508525 ('Blanquita'), 538342, 538343, 538345 ('Macana'), 538348 ('Viola'), 538350 ('Francia'), 538351 ('Mojave'), 538353 ('Amanecer'), 538354 ('Tapato'), 556942, 564162 ('Margarita') 573329 ('Wart'), 585109 ('Tapato'), 585110 ('Papato')
Ryukyu Islands	344123 ('Nanyo')
Solomon Islands	573292, 573330, 585053, 585056, 564128, 564129, 564130, 538347
Sri Lanka	585066
Taiwan	531141, 531145, 531146 ('Tainung 65'), 531147 ('Tainung 57'), 538284, 556940, 556941, 556943 ('Tainan 17'), 556944, 556945, 556946, 564116, 564117, 564118, 564119, 564120, 585088 ('Tainung 66')
Thailand	344120
Timor	318846, 312846-3
Tonga	308200, 564121, 573316 ('Hawaii'), 573318 ('Melika'), 573320, 573321, 573322, 585052, 585054 ('Halasika'), 585055, 585074, 585075, 585076, 585104
United States	566609 ('Acadian'), 566610 ('Allgood'), 566612 ('Baker'), 566613 ('Beauregard'), 566617 ('Caromex'), 566618 ('Carver'), 566619 ('Centennial'), 566622 ('Cordner'), 566623 ('Earlyport'), 566624 ('Eureka'), 566625 ('Excel'), 566627 ('Georgia Jet'), 566628 ('Georgia Red'), 508528 ('Gem'), 566630 ('Goldrush'), 566631 ('Heartogold'), 566632 ('Hernandez'), 566634 ('Hopi'), 566636 ('Jasper'), 566638 ('Jewel'), 566639 ('Julian'), 566640 ('Kandee'), 566641 ('Nancy Hall'), 566642 ('Nemagold'), 566644 ('Painter'), 566645 ('Pope'), 566646 ('Porto Rico'), 566647 ('Redcliff'), 566648 ('Red Jewel'), 566650 ('Regal'), 566651 ('Resisto'), 566652 ('Rojo Blanco'), 566653 ('Scarlet'), 566654 ('Shore Gold'), 566655 ('Southern Delite'), 566656 ('Sunnyside'), 566658 ('Sweet Red'), 566659 ('Topaz'), 566660 ('Travis'), 566661 ('Triumph'), 566662 ('Vardaman'), 566663 ('White Delite'), 566664 ('Whitestar'), Grif 1035 ('Haynes'), Grif 1065 ('Okamar'), Grif 1073 ('Red Resisto'), Grif 1162 ('White Bunch'), 595199 ('Darby'), Grif 1101 ('Tuskegee-100'), Grif 1067 ('Pelican Processor'), Grif 1152 ('Carolina Bunch')
Venezuela	508530 ('Batata Blanca'), 508531 ('Morada'), 'Sombica'), 508532 ('Wiripipi'), 'Itawa')
Vietnam	585059 ('Hung Loc 4')
Western Samoa	564125, 564106, 573291, 573323, 573324, 573327, 573328

tices (Granberry et al., 1990). After harvest the roots were cured at 29 °C and 95% relative humidity (RH) for 7 d and stored at 15 °C and 85% RH until analysis. Clones are listed by country of origin as indicated by the USDA–NPGS passport data and by their individual plant introduction number (additional information on the clones can be found at USDA, 2005). When available, cultivar names are given in parentheses. The clones tested are diverse, as might be expected, with superior clones having been dispersed widely from their postulated center of origin in northwest South America over the past five centuries (Yen, 1982). During this interval they have been exposed to differing selection pressures for quality attributes by local growers/consumers.

Two nonsweet breeding lines from the University of Georgia (GA90-16, GA90-156) were also analyzed for comparison. Clones were not included when there was an obvious question about their origin (e.g., a clone assigned to a Spanish-speaking country with an Asian cultivar name).

The clones in the USDA–NPGS repository have been collected over a number of years for a wide range of reasons and, consequently, represent a much wider population than the most popular local cultivars currently grown in each location. The assumption we have made is that while the clones included in the test may not be the most popular cultivated for human consumption in each respective country, the mean of the clones from each country gives a general indication of the level of sweetness that is available locally, a relationship undoubtedly strengthened as the number of clones tested per country increases. The cultivars from the United States support this assumption in that the mean for all of the cultivars had the same SE ranking (very high) as two of the most popular cultivars grown at this time (i.e., ‘Beauregard’ and ‘Jewel’).

SAMPLE PREPARATION AND BAKING. Cured storage roots of the U.S. #1 grade or the closest approximation available were used for analysis. The proximal halves of three roots per clone were individually wrapped in aluminum foil, placed in a cold convection oven, and heated to 204 °C for a total baking time of 75 min. After removal from the oven, a 15- to 20-g sample of cooked tissue was collected from the fleshy interior to the cambium, composited, freeze dried, and stored at –30 °C until analysis.

EXTRACTION OF SUGARS. The freeze-dried samples were milled into flour using a Cyclotec 1093 sample mill (Rose Scientific Ltd., Edmonton, Alberta, Canada). A total of 100 mg of flour was homogenized in 10 mL of 80% methanol containing 2.2 mg phenyl-β-D-glucopyranose as an internal standard for 1 min at 17,000 rpm using a Handishear AC hand-held homogenizer (Virtis, Gardiner, N.Y.). The resulting slurry was centrifuged 5 min at 17,000 g_n. Ten milliliters of supernatant was pipetted into a vial and stored at 4 °C until analysis.

DERIVATIZATION. Extracts were prepared via oxime-trimethylsilyl derivatization according to Chapman and Horvat (1989) with minor modification. Fifty microliters of sample was pipetted into a vial, placed on a heating block at 40 °C, and dried with nitrogen gas. Twenty-five microliters of hydroxylamine-HCl (25 mg·mL⁻¹ in pyridine) was added to each vial and heated at 75 °C for 30 min. The oximes of sugars were then derivatized by injecting 70 μL BSTFA + 1% TMCS and heated at 75 °C for 20 min. After cooling, a 1 μL injection was made into the gas chromatograph using an autoinjector. A mixture containing known amounts of the internal standard and pure reference sugars (fructose, galactose, glucose, inositol, sucrose, maltose) was analyzed every

10 samples to obtain correction factors.

GAS CHROMATOGRAPHY. Chromatography analyses were performed using a Hewlett-Packard 5890A gas chromatograph (Agilent, Palo Alto, Calif.) equipped with a flame ionization detector. The GC column was a 30 m × 0.32 mm (i.d.) fused silica, DB-5, 0.25 μL film thickness capillary column (J&W Scientific, Folsom, Calif.). Injector and detector temperatures were 250 and 300 °C, respectively. Oven temperature was initially held at 150 °C for 1 min and then programmed from 150 to 210 °C at 4 °C·min⁻¹ and held at 210 °C for 30 s and then to 250 °C at 7 °C·min⁻¹ and held at 250 °C for 30 s and finally to 280 °C at 4 °C·min⁻¹ and held for 5 min. Helium was used as the carrier gas at a flow rate of 53 mL·min⁻¹. The splitless injection mode was used. Air and hydrogen flow rates to the detector were 370–380 mL·min⁻¹ and 28 mL·min⁻¹, respectively. Nitrogen was used as a make-up gas at a flow rate of 30 mL·min⁻¹. An HP 3392A integrator was connected to the GC for peak area determination. Identification of each sugar was based upon retention times using authentic standards and by adding standards to samples before extraction to verify retention times of individual peaks. Recovery tests were carried out using standard addition methods. The technique was found to be quantitative (i.e., >96% recovery). Standards for sugars exhibited less than 3% cv among triplicate injections of the same sample.

CALCULATION OF SUCROSE EQUIVALENTS. Because individual sugars vary in their sweetness, to obtain a relative measure of sweetness that would allow for comparison among clones, sucrose equivalents (SE) were calculated using the equation: sucrose equivalents = 1.2 fructose + 1 sucrose + 0.64 glucose + 0.43 maltose (Shallenberger, 1993) and were expressed as grams per 100 g dry mass (DM). An SE of 30 g/100 g DM indicates that the combined sweetness of the sugars present is equal to that of 30 g sucrose/100 g DM. Galactose and inositol were not included due to their relatively low sweetness and extremely low concentrations. Clones were separated into five sucrose equivalent categories based on sensory panelist assessments of the threshold for the very high (SE ≥38 g/100 g DM) and nonsweet (SE ≤12 g/100 g DM) categories. Three individual categories (high, moderate, low) were assigned in comparable increments between the very high and nonsweet categories (Table 2). Previously we utilized four categories in screening germplasm; however, since taste panels can discriminate between relatively small increments in sweetness (Koehler and Kays, 1991), an additional category was added for increased precision.

Sucrose equivalents were also calculated for endogenous sugars (sucrose, fructose, and glucose) vs. sugar derived from baking (maltose) to assess the relative contribution of each.

Table 2. Categories based on sucrose equivalents (SE), number of clones per category, percentage of countries surveyed per category, and percentage of annual total production of countries surveyed per category (Food and Agriculture Organization, 2002).

Categories	SE (g per 100 g dry mass)	Clones (no. per category)	Proportion in countries surveyed (% per category)	Proportion of annual production (% per category)
Nonsweet	≤12	1	0	0
Low	13–20	7	0	0
Moderate	21–28	91	29	93.5
High	29–37	124	62	4.4
Very high	≥38	49	9	2.1

Results and Discussion

Five SE categories were established for baked sweetpotatoes based upon the range in sugars found within the germplasm as assessed (Table 2). The majority of the clones (124) were in the high SE category (29–37 g/100 g DM). The second greatest number (91) were classified as moderate followed by very high (49). Only seven clones were low and one was nonsweet. Several nonsweet clones have been reported (e.g., GA90-16 is potato-like in flavor and has a SE value of only 11.3 g/100 g DM) (Kays et al., 2001). The SE of individual clones ranged from 12 to 56 g/100 g DM. It should be noted that in addition to a genetic component, the sugar content and sucrose equivalents of the cooked product is also a function of the method of cooking (Sun et al., 1994), which in turn impacts the product's aroma and overall flavor (Wang and Kays, 2001). Test samples were baked in a convection oven, which gives substantially higher SE values than, for example, microwave cooking (Sun et al., 1994), due to the increased starch hydrolysis and maltose formation.

A mean SE value was calculated for the clones from each country (Table 3) to obtain a general estimate of the typical sugar level to which consumers have access. Numerically the majority of the countries had clones that were classified as having high SE. The second largest number of countries had clones with a mean classification of moderate. Only three countries had mean values in the very high category (i.e., Bangladesh, Indonesia, U.S.). Of the countries in which sweetpotato clones were assessed, 29.4% of the countries had mean values within the moderate category, 61.8% high, and 8.8% very high (Table 2). In a few instances a country's classification is based on a very small number of clones and may, therefore, not give a good estimate of the SE level available to the consumers there.

The geographical distribution of the clones by countries, expressed as the mean SE value, did not present a distinct pattern (Fig. 1). Countries in which the mean SE value for the clones was classified as moderate were found in South America, Asia, the Caribbean, and Melanesia. Likewise, countries with a mean SE ranking of very high were also relatively widely dispersed (i.e., U.S., Bangladesh, Indonesia). Based upon the clones surveyed, there did not appear to be a geographical region in which one level of SE is preferred over another; rather, essentially all of the sweetpotatoes are relatively sweet (i.e., $\geq$ moderate SE).

The countries from which clones were tested produced 93% of the world's sweetpotatoes in 2002 (Table 3). When SE categories were assessed relative to the annual production, countries that had a mean classification of high, which represented the greatest number of countries, comprised only 2.1% of the total production of the countries tested (Table 2). The majority of the sweetpotatoes (93.2%) was classed as moderate, and 4.4% were very high. Therefore, while 62% of the countries surveyed had sweetpotatoes categorized as high, the majority of the sweetpotatoes produced in the countries surveyed were classified as moderate, one category lower. Assessing the percentage of the world's total production that fell into the various sweetness categories was strongly influenced by China, the world's leading producer of the crop (Food and Agriculture Organization, 2002). While the mean SE category for the Chinese clones tested was moderate, a significant portion of the sweetpotatoes grown there are processed to starch, during which the water-soluble mono- and disaccharides are lost. SE level, therefore, is not a critical selection trait and as a consequence, the presence of starch types in the clones tested could bias the mean toward a

Table 3. Countries ranked by the mean^z sucrose equivalents (SE) of baked sweetpotato clones within sucrose equivalent categories (see Table 2), with production statistics by country for 2001 (Food and Agriculture Organization, 2002).

Sucrose equivalent category and country	Mean SE g per 100 g dry mass	Production (kt)
Very high		
Bangladesh	49.2	346
Indonesia	44.8	1746
United States	37.9	567
Total		2659
High		
Philippines	36.5	549
New Caledonia	36.0	3
Venezuela	34.8	12
Vietnam	34.4	1725
Australia	34.1	6
Mexico	33.2	60
Timor	31.3	---
Costa Rica	32.8	---
Puerto Rico	32.8	2
New Zealand	32.0	16
Guatemala	30.9	---
Solomon Islands	30.9	84
Nigeria	30.4	2503
Western Samoa	30.3	---
Taiwan	30.3	---
Tonga	30.0	6
Peru	29.6	224
Myanmar	29.5	57
Korea	29.5	250
Ryukyu Islands	29.3	---
Sri Lanka	29.2	49
Total		5546
Moderate		
Japan	28.7	1030
Brazil	28.7	483
Papua New Guinea	27.7	490
New Hebrides	27.6	---
Argentina	27.4	310
India	27.2	1200
Cuba	27.0	270
Honduras	26.4	2
People's Republic of China	25.4	114289
Thailand	23.2	97
Total		118171
Low		
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Nonsweet		
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^zMeans represent the average SE of all clones tested within a country.

^yNone of the countries had clones with an average SE in this category.

lower average SE value. Relatively sweet baked sweetpotatoes, purchased from street vendors in Beijing and Qufu in Fall 2000, appeared to be preferred as a snack food over less sweet cultivars (personal observation).

The majority of the clones from the U.S. that have been released as named cultivars were classified either as high or very high in SE. The U.S. cultivars were also grouped (Table 4) by the state in which they were released to determine if a pattern

Fig. 1. Geographical distribution of the sucrose equivalents (SE) of baked sweetpotato storage roots of clones from 34 countries, expressed as the mean SE of the clones from each country. Countries in which the clonal means were categorized very high and moderate SE are highlighted.

indicative of the importance of sweetness in the selection criteria could be ascertained. Oklahoma and Louisiana had the highest mean SE values for the cultivars developed. In general, all of the states that had relatively large sweetpotato breeding programs consistently had cultivars that were in the high to very high categories.

The distribution of SE was plotted as SE derived from the hydrolysis of starch during baking vs. total SE (endogenous sugars + maltose) with the figure separated into the five SE categories (Fig. 2). The majority of the clones cluster in the high to moderate categories. Relatively few were found in the low and nonsweet categories, indicating that either the clones assessed were selected for sugar content or that the lack of sugars is a trait that seldom emerges in cultivars selected. Figure 3 illustrates the relationship between SE derived from maltose and SE from the endogenous sugars

Table 4. Sucrose equivalents (SE) of U.S. cultivars by state of origin and mean per state.

State of origin of cultivar	SE (g per 100 g dry mass)	State of origin of cultivar	SE (g per 100 g dry mass)	State of origin of cultivar	SE (g per 100 g dry mass)
Alabama		Maryland		South Carolina	
Carver	40.3	Sunnyside ^y	35.6	Excel ^u	36.3
Rijo Blanco	<u>25.5</u>	Whitestar ^y	<u>25.3</u>	Redcliff	42.6
$\bar{x}$	32.8	$\bar{x}$	30.5	Regal ^u	40.5
Georgia		Mississippi		Resisto ^u	34.7
Coastal Red	36.6	Verdaman	24.6	Southern Delite ^u	<u>37.2</u>
Georgia Jet	<u>40.0</u>	North Carolina		$\bar{x}$	38.3
$\bar{x}$	38.3	Caromex ^x	34.1	Texas	
Kansas		Gem	35.7	Topaz	31.1
Kandee	38.0	Jewel	42.8	Virginia	
Louisiana		Pope	41.8	Painter	35.7
Arcadian	46.7	Red Jewel	37.9	Shore Gold	<u>38.7</u>
Beauregard	43.5	Scarlet	40.1	$\bar{x}$	37.2
Centennial	38.2	Sweet Red	30.8		
Darby	47.2	White Delite	<u>32.4</u>		
Eureka ^z	35.7	$\bar{x}$	37.0		
Goldrush	46.3	New Mexico			
Heartogold	47.9	Hopi ^w	33.9		
Hernandez	41.5	Oklahoma			
Jasper	42.8	Allgold	47.5		
Julian	38.3	Nemagold	33.9		
Travis	<u>42.7</u>	Oklamar	52.5		
$\bar{x}$	42.8	Cordner ^v	<u>38.4</u>		
		$\bar{x}$	43.1		

Released jointly by:

^zLouisiana State University and University of California–Davis.

^yUSDA–Beltsville and the University of Maryland.

^wNorth Carolina State University and New Mexico State University.

^vUSDA Mississippi State University and New Mexico State University.

^uOklahoma State University and Texas A&M University.

^xUSDA Charleston and Clemson University.

Fig. 2. Total sucrose equivalents (SE) in grams per 100 g dry mass (DM) of baked sweetpotato storage roots from various countries plotted against SE derived from maltose and separated into the SE categories presented in Table 2 (NS = nonsweet, L = low, M = moderate, H = high, VH = very high). Stars (★) indicate the position of the maximum and minimum SE levels that could theoretically be attained if a clone possessed the highest and lowest maltose and endogenous sugar values in the current study. Diamonds (◆) indicate the position of two nonsweet breeding lines developed at the University of Georgia.

Fig. 3. Distribution of the sucrose equivalents (SE) in grams per 100 g dry mass (DM) of baked sweetpotato clones from various countries plotted as SE derived from maltose formed during cooking vs. SE derived from endogenous sugars (glucose, fructose, and sucrose). The clones are separated into four categories [low sugars/low starch hydrolysis (-/-); low sugars/high starch hydrolysis (-/+); high sugars/low starch hydrolysis (+/-); and high sugars/high starch hydrolysis (+/+)] based upon the level of hydrolysis of starch during cooking and the level of endogenous sugars present in the roots (Morrison et al., 1993). Diamonds (◆) indicate the position of two nonsweet breeding lines developed at the University of Georgia.

(i.e., sugar formed during cooking vs. sugars present prior to cooking). Endogenous sugars comprised a higher average percentage of the total SE across all clones (58%) than did maltose (42%); the former ranging from 25% to 98% and the latter 2% to 75%. The average percentage of the SE value across all clones contributed by each sugar was: sucrose 44%, fructose 8%, glucose 6%, and maltose 42%; and the range: sucrose 6% to 77%, fructose 1% to 36%, glucose 0% to 23%, and maltose 2% to 75%. It had been previously proposed (Morrison et al., 1993) that sweetpotato germ-plasm could be separated into four general classes based on initial sugar concentration and changes during cooking: 1) low sugars/low starch hydrolysis (-/-); 2) low sugars/high starch hydrolysis (-/+); 3) high sugars/low starch hydrolysis (+/-); and 4) high sugars/high starch hydrolysis (+/+). Only one clone in the collection surveyed fell into the -/- classification, indicating decidedly nonsweet clones either seldom occur or are routinely discarded. Likewise, a relatively small number of clones were found in the +/- and +/+ categories with the majority classified as +/+ (Fig. 3).

The contribution of maltose ranged in SE from 0.58 to 21.92 g/100 g DM while the contribution from the endogenous sugars ranged from 6.44 to 46.94 g/100 g DM. This indicates that it may be possible to select for cultivars with distinctly higher SE than the highest existing clones if exceptionally high maltose formation potential can be combined with high endogenous sugars [e.g., potentially giving a total SE of approximately 69 or 19% higher than the highest clone tested (Fig. 2)]. Such a combination assumes that there would be no fatal deficits (e.g., yield, storage disease susceptibility) that would eliminate such clones. Likewise, it may also be possible to select clones that are exceptionally nonsweet [e.g., approximately 7 SE (Fig. 2)] for uses in which they would be advantageous. One mechanism conferring a low SE value involves the gene for β -amylase (Kumagai et al., 1990) in which a functional gene product does not appear to be formed. It is controlled by one recessive allele (β -amy) that appears in a reasonably high frequency. Plotted on Fig. 3 (◆) are two nonsweet breed-

ing lines selected at the University of Georgia, indicating that exceptionally nonsweet cultivars are readily attainable. The fact that more nonsweet cultivars were not in the samples tested and presumably not among the cultivars utilized around the world, could be due to several possible reasons: 1) the nonsweet trait(s) is seldom present in breeding populations; 2) the population of clones in the U.S. germplasm collection is biased toward sweet clones; or 3) the nonsweet trait occurs but the clones are discarded as unacceptable.

Increasing or decreasing sweetness in future clones involves altering two groups of genes: genes controlling the formation of starch, which influences latent pools of mono- and disaccharides within the storage roots, and genes controlling starch hydrolysis and maltose formation. Existing evidence from the germplasm surveyed indicates that there is sufficient variation in both traits present to allow significant increases or decreases in sweetness.

Evidence presented indicates that sweetpotatoes grown worldwide are all moderate to high in their SE values. Clones are present within the genepool that will allow selecting new cultivars that are significantly higher or lower in SE than existing cultivars. Due to the dominance and importance of sweetness in the overall flavor of the cooked product, the potential exists for tailoring the flavor for specific consumer preferences and product uses, increasing the utilization of the crop worldwide.

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