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# Sweet Potato Variability in Boiled Slices and Fried Chips[1]

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**ABSTRACT**

**Roots of thirty cultivars, breeding lines, and of 310 unselected seedlings of sweet potato were evaluated as boiled slices. Then slices of seventy five selections of these were deep fried in soybean oil and evaluated as chips. On the basis of color, sweetness, and mouthfeel, seedlings were classified into 25 of 27 theoretical classes. Low sweetness was associated with dry mouthfeel. The frequency of defects in the boiled slice was determined. Two types of chips were distinguished, a sweet cookie-type chip, and a nonsweet chip. Quality characteristics were more or less independent of each other and of other characteristics measured. Ratings of chips were closely correlated to judgment of flavor, and to a lesser extent, crispness, lack of oil residue, and attractiveness. High ratings were not associated with degree of sweetness. Sweet potatoes are suitable for cookie-type as well as conventional chips. However, their properties before frying are not reliable guides to quality when fried.**

## INTRODUCTION

The sweet potato (*Ipomoea batatas*) is a starchy root crop used by diverse cultures for different purposes. In the United States the sweet potato is best described as a dessert vegetable, for the most common varieties are very sweet, moist in the mouth, and are cooked to enhance these characteristics. By tradition the deeply orange varieties are preferred. The concept of what a sweet potato should be is exemplified by the publication "Sweet Potato Quality" (10). On the other hand, in Puerto Rico and the Caribbean where sweet potatoes are often used as a dietary staple the so-called white-fleshed type is preferred. On cooking, such sweet potatoes are somewhat dry to the mouth, are not very sweet, and when cooked vary in color from white to light gray, pale green, cream, or yellow.

It appears that different combinations of color, mouthfeel (whether the cooked sweet potato is moist or dry in the mouth) and sweetness are closely related to the potential uses of the sweet potato. In addition, other

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culinary traits such as softness on cooking, polyphenolic oxidation, and fiber content also influence potential use.

The internal color in sweet potato is due to the interaction of two kinds of pigments, anthocyanins and carotenoids. Combinations of these pigments are common in seedlings, and some of these are not attractive. Common colors after cooking of previously white sweet potatoes such as light green, gray, or khaki, probably are the result of low quantities of both major kinds of pigments, and probably of oxidized polyphenols and epoxy carotenoids as well (10).

Mouthfeel has been thoroughly investigated in the sweet potato. A dry sensation when the cooked root is masticated, correlated with viscosity, may be due to relatively high contents of calgon-soluble pectin and hemicellulose. Although easily estimated subjectively, mouthfeel can be measured as viscosity of cooked sweet potatoes (8, 9). Strong personal preferences exist with respect to mouthfeel. "Moistness" is considered desirable in the United States (10) but a dryish feel is very acceptable or preferred in the Caribbean (4).

Sweetness of sweet potato varies not only with variety but also with storage, curing, and with cooking method. There are sweet potato varieties that are not noticeably sweet. These varieties appear to be much more suitable for making French fries, potato chips, and flour than are normally sweet sweet potatoes. However, in some sweet potatoes, sugar content increases with storage and curing (10). On the other hand, cooking definitely increases sugar content as starch is broken down enzymatically (12).

As a first step in knowing what the sweet potato is and can be, it is very important to characterize the variation of the sweet potato in the tropics. The present study was made to define more carefully the variation seen in relation to boiled pieces and fried chips, and to see whether the quality of the latter could be predicted from the former.

## MATERIALS AND METHODS

Roots of thirty cultivars and breeding lines as well as 310 unselected seedlings were sliced, observed for oxidation, boiled 18 minutes, and evaluated for 5 characteristics (table 1). Characteristics reducing quality, such as unsightly color, extreme dryness or softness, and occasionally harsh or unusual flavor, were also noted. On the basis of overall acceptability as a boiled food, the roots were rated from 1 to 5. Three traits, orange color (white, yellow, orange), sweetness (low, medium, high), and mouthfeel (dry, intermediate, moist) were used to categorize roots in 27 classes (table 2). The frequency of each class was calculated as well as the average rating.

TABLE 1.—*Characteristics of sweet potato roots and chips*

| Number | Characteristics | Scale |
|---|---|---|
| 1 | Oxidation (darkening) 15 minutes after cutting | 0 = none<br>1 = very little<br>2 = some<br>3 = much |
| 2 | Orange color after boiling | 0 = white<br>1 = cream<br>2 = yellow<br>3 = light orange<br>4 = dark orange |
| 3 | Purple color | 0 = white<br>1 = medium<br>2 = slightly purple<br>3 = purple<br>4 = deep purple |
| 4 | Softness | 1 = very hard<br>2 = hard<br>3 = intermediate<br>4 = soft<br>5 = very soft |
| 5 | Mouthfeel | 1 = very dry<br>2 = dry<br>3 = intermediate<br>4 = moist<br>5 = very moist |
| 6 | Sweetness | 1 = not sweet<br>2 = slightly sweet<br>3 = sweet<br>4 = very sweet |
| 7 | Rating of boiled root | 1 = not acceptable<br>2 = poor<br>3 = acceptable<br>4 = good<br>5 = excellent |
| 8 | Orange color of fried chip | 0 = white<br>1 = cream, tan<br>2 = yellow, light brown<br>3 = light orange<br>4 = dark orange |
| 9 | Purple color of fried chip | 0 = none<br>1 = minimum<br>2 = some<br>3 = very much |
| 10 | Attractive appearance | 1 = not attractive<br>2 = attractive<br>3 = very attractive |

TABLE 1—*Continued*

| Number | Characteristics | Scale |
|---|---|---|
| 11 | Oil residue on chip | 1 = much oil evident<br>2 = some<br>3 = very little<br>4 = none |
| 12 | Crispness | 1 = flaccid<br>2 = not completely crisp<br>3 = crisp |
| 13 | Sweetness | 1 = not sweet<br>2 = slightly sweet<br>3 = sweet<br>4 = very sweet |
| 14 | Flavor | 1 = not acceptable<br>2 = poor<br>3 = good<br>4 = excellent |
| 15 | Rating of fried chip | 1 = not acceptable<br>2 = poor<br>3 = acceptable<br>4 = good<br>5 = excellent |

Superior examples of most classes were selected for frying as chips. Twenty standard cultivars or breeding lines and 55 seedlings were used. A complete list with their characteristics is available to interested persons.

Sweet potatoes for frying were sound roots 5–8 cm in diameter, freshly harvested, or stored up to 6 weeks at room temperature. The roots were washed, drained, hand peeled, and sliced with a sharp knife to about 1 mm thickness. The slices were then deep-fried in soybean oil at 177° C (350° F) for 4 minutes in a household deep fat fryer. They were removed, drained briefly, and placed on paper toweling. Roots, chips, and boiled pieces were evaluated for 7 additional characteristics, and were rated for overall acceptability. Ratings of the boiled and fried sweet potatoes were made independently by 5 trained panelists, then these ratings were averaged.

The relation among the characteristics of fried sweet potatoes was studied by simple correlation, canonical correlation, and factor analysis. The SPSS computer system, version 8 (7) was used for all analyses.

## RESULTS

Among 310 seedlings, all of the extremes were found for characteristics listed in table 1. Within this sample, individual seedlings were found with 25 of the 27 theoretical combinations of color, sweetness, and

mouthfeel. Certain combinations appeared to be more frequent than others. When all seedlings were classified as dry versus intermediate or moist, and as low in sweetness as compared to medium or high, dryness proved to be significantly associated with sweetness ($\chi^2 = 4.48$, $p < 0.05$). Orange color was not associated with dryness but possibly with sweetness ($\chi^2 = 1.64$).

TABLE 2.—*Classification of unselected sweet potatoes after cooking into 27 classes on the basis of carotene content (color), sweetness, and mouthfeel*

| Color | Sweetness | Mouthfeel | Classification | Frequency | Average rating |
|---|---|---|---|---|---|
| | | | | % | |
| White or cream | Not sweet | Dry | 1 | 65 | 1.6 |
| | Not sweet | Intermediate | 2 | 22 | 2.9 |
| | Not sweet | Moist | 3 | 3 | 2.3 |
| | Slightly sweet | Dry | 4 | 26 | 2.5 |
| | Slightly sweet | Intermediate | 5 | 26 | 2.8 |
| | Slightly sweet | Moist | 6 | 7 | 2.6 |
| | Very sweet | Dry | 7 | 0 | — |
| | Very sweet | Intermediate | 8 | 2 | 2.5 |
| | Very sweet | Moist | 9 | 2 | 2.0 |
| Yellow | Not sweet | Dry | 10 | 38 | 3.0 |
| | Not sweet | Intermediate | 11 | 13 | 2.6 |
| | Not sweet | Moist | 12 | 3 | 2.4 |
| | Slightly sweet | Dry | 13 | 21 | 2.7 |
| | Slightly sweet | Intermediate | 14 | 10 | 2.8 |
| | Slightly sweet | Moist | 15 | 3 | 2.3 |
| | Very sweet | Dry | 16 | 0 | — |
| | Very sweet | Intermediate | 17 | 6 | 2.3 |
| | Very sweet | Moist | 18 | 1 | 2.0 |
| Orange | Not sweet | Dry | 19 | 17 | 1.8 |
| | Not sweet | Intermediate | 20 | 7 | 2.3 |
| | Not sweet | Moist | 21 | 3 | 2.0 |
| | Slightly sweet | Dry | 22 | 14 | 2.3 |
| | Slightly sweet | Intermediate | 23 | 7 | 2.7 |
| | Slightly sweet | Moist | 24 | 9 | 2.4 |
| | Very sweet | Dry | 25 | 1 | 2.5 |
| | Very sweet | Intermediate | 26 | 1 | 3.0 |
| | Very sweet | Moist | 27 | 3 | 3.0 |

The rating of overall value assigned to sweet potatoes ranged from 1 to 5. However, within the 27 groups average ratings ranged from 1.8 to 3.0 (table 2). Relatively average values reflect the fact that there were good and bad varieties in almost all classes. No single class could be distinguished as always superior. Only 17 of the 310 seedlings were considered to be excellent in overall quality. Very few seedlings roots

were found to be uniform and attractive white, free from gray or khaki green after cooking.

The following characteristics were seen among cooked sweet potato pieces that made many roots unacceptable. Less severe stages also reduced quality.

| *Defect* | *Frequency* |
|---|---|
| Gray color | 7.5 |
| Khaki green color | 5.2 |
| Marbling or non-uniformity of color | 7.0 |
| Ugly distribution of anthocyanin | 0.3 |
| Excess hardness | 2.5 |
| Excess softness | 3.3 |
| Excess dryness | 4.0 |
| Excess fiber | 2.3 |
| Off flavor | 1.6 |

Cultivars and breeding lines from the United States as well as West Indian cultivars were not considered in the above comparisons because they were considered selected. Most from the United States were orange to deep orange, with sweet, moist flesh. Cultivars from the West Indies were light fleshed, less sweet, and intermediate to dry in texture. Their colors on cooking were often not acceptable by the author's standards.

Two very different kinds of sweet potato chips were distinguished, those that were not sweet, which can be compared to potato chips, and those that were sweet. Because sweetness is distributed on a continuous basis, intermediate type chips were also found. The sweetness of the boiled sweet potato slice often was not obvious in the corresponding chip, but contributed a rich, cookie-like flavor. Sweet potato chips varied in color from white or tan to yellow or orange. Anthocyanin, when present, contributed purple spots which were judged attractive. However, attractive appearance depended on factors other than principal color, including luster, lack of grayness, and uniformity.

Ratings of the chips ranged from 2.2, poor, to 4.8, excellent, but even poorly rated chips were considered edible. Ratings of chips had no obvious relationship to the scheme to classify varieties (table 3). Table 4 gives correlation coefficients among chips characteristics. Highest rated chips were low in oil residue, crisp, attractive, with good flavor, but not necessarily sweet. An intermediate level of sweetness appears to be most appealing. Flavor was related to the absence of an oil residue and crispness. Sweetness was partially correlated with crispness but not with other characteristics of the chip.

Several characteristics of the cooked and uncooked root contribute to the characteristics of the chip (table 4). Mouthfeel is correlated with

crispness. Those chips from roots that appear moist in the mouth are usually not crisp. As orange color increases, crispness decreases. Sweetness of the chip is correlated with a number of different characteristics of the root, especially mouthfeel and orange color. Sweetness of the boiled root is not highly correlated with sweetness of the fried root.

A multiple regression analysis indicated that the best predictors for chip rating were flavor and crispness, with all other characteristics being nonsignificant. A canonical correlation analysis of root characteristics with chip characteristics produced two significant canonical variate pairs, R = 0.945 and 0.900, respectively. The resulting scores for cultivars were not useful in determining the best varieties for making chips, because the two variate pairs essentialy emphasize orange and purple color, respectively.

TABLE 3.—*Distribution of 27 classes of sweet potato chips by final rating*

| Rating | Number of varieties | Classification of varieties |
|---|---|---|
| 2.0–2.4 | 6 | 10, 22, 23, 26, 27 |
| 2.5–2.9 | 8 | 5, 12, 21, 22, 23 |
| 3.0–3.4 | 23 | 4, 5, 10, 12, 13, 14, 15, 16, 17, 19, 21, 22, 24, 26, 27 |
| 3.5–3.9 | 15 | 1, 4, 7, 9, 13, 16, 23, 27 |
| 4.0–4.4 | 18 | 1, 4, 7, 8, 10, 14, 15, 16, 17, 26, 27 |
| 4.5–5.0 | 5 | 16, 22, 24, 25, 26 |

TABLE 4.—*Correlation coefficients among chip characteristics (upper part of table) and between root and chip characteristics (lower part of table)*[1]

| Character | Character Number for Chips | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Chip | | | | | | | | |
| 8 Orange | – | | | | | | | |
| 9 Purple | −.08 | – | | | | | | |
| 10 Attractiveness | −.08 | −.19 | – | | | | | |
| 11 Oil residue | −.18 | −.01 | .13 | – | | | | |
| 12 Crispness | −.42 | .09 | −.07 | .44 | – | | | |
| 13 Sweetness | .62 | −.07 | .05 | .07 | −.34 | – | | |
| 14 Flavor | .07 | .02 | .33 | .44 | .28 | .15 | – | |
| 15 Rating | −.16 | −.03 | .28 | .45 | .54 | .03 | .73 | – |
| Root | | | | | | | | |
| 1 Orange | .88 | −.08 | −.03 | −.23 | −.42 | .58 | .06 | −.14 |
| 2 Purple | −.16 | .89 | −.11 | .03 | .12 | −.07 | .09 | .06 |
| 3 Oxidation | −.08 | .11 | −.09 | .04 | .07 | −.17 | .09 | .09 |
| 4 Softness | .43 | −.15 | −.01 | −.22 | −.32 | .37 | .02 | −.13 |
| 5 Mouthfeel | .47 | −.06 | −.22 | −.24 | −.45 | .62 | −.15 | −.22 |
| 6 Sweetness | .37 | .04 | −.08 | −.06 | −.13 | .29 | .09 | −.07 |
| 7 Rating | .42 | −.19 | .12 | −.14 | −.23 | .13 | .03 | −.03 |

[1] Each *r* value higher than 0.23 is significant (P = 0.05).

When the overall relationship of root and chip characters were examined by principal factor analysis, with varimax rotation of axes, the first axis appeared to be an orange factor; the second, a best chip factor; with the remaining three factors purple, mouthfeel, and attractiveness, respectively (table 5). Factor name for a given column in the table related to the character with highest ± magnitude (factor loading). These five factors in a simplified form fairly well account for the correlation among the root and chip characters. However, factor 2 has high scores for oil residue, crispness, and flavor as well as chip rating, and these can be considered minor factors responsible for correlations.

TABLE 5.—*Varimax rotated principal factor solution of 15 characters*

| Character | Axis | | | | |
|---|---|---|---|---|---|
| | 1 (orange) | 2 (best chip) | 3 (purple) | 4 (mouthfeel) | 5 (attractiveness) |
| 1 Orange root | .93 | −.11 | −.04 | .00 | .01 |
| 2 Purple root | −.11 | 05 | .91 | .03 | −.02 |
| 3 Oxidation | .05 | 07 | .07 | .34 | −.08 |
| 4 Softness | .44 | −.13 | −.09 | −.27 | .10 |
| 5 Mouthfeel | .38 | −.20 | .00 | −.67 | −.19 |
| 6 Sweetness | .38 | .02 | .03 | −.04 | −.09 |
| 7 Root rating | .44 | −.11 | −.17 | 04 | .24 |
| 8 Orange chip | .91 | −.08 | −.05 | −.18 | −.05 |
| 9 Purple chip | −.03 | −.02 | .97 | .11 | −.13 |
| 10 Attraction | −.04 | .21 | −.10 | −.04 | .69 |
| 11 Oil residue | −.17 | .61 | −.01 | .01 | −.03 |
| 12 Crispness | −.37 | .57 | .02 | .32 | −.23 |
| 13 Sweetness | .57 | .16 | .01 | −.65 | −.05 |
| 14 Flavor | .18 | .79 | .08 | .04 | .29 |
| 15 Chip rating | −.06 | .82 | .00 | .11 | .17 |

The 75 types tested included 20 named cultivars or lines, 17 selections and 28 unselected seedlings. The 10 with the highest ratings of flavor included 6 cultivars or breeding lines, one selection, and three seedlings (table 6). Outstanding types were from soft sweet potatoes. Mouthfeel and sweetness varied, as well as did color. Chips from outstanding varieties were crisp to very crisp, with good flavor. Although sweetness varied, only one outstanding variety could be considered quite sweet. Seven of the 10 varieties were orange, only two were cream or white.

Although the top 10 varieties did not include any white-fleshed non-sweet types that produce chips like those of the potato, chips of this sort can be produced from several varieties, including our selections 51, 62, and seedling 87. The white-fleshed cultivars Rojoblanco and Miguela yield good cookie type chips.

TABLE 6.—*Some characteristics of the roots and chips of the 10 most highly rated varieties or lines, with means and standard deviations of all varieties*

| Variety | Softness | Mouthfeel | Sweetness | Color | Classification | Crispness | Sweetness | Flavor | Rating |
|---|---|---|---|---|---|---|---|---|---|
| NC 317 | 4.0 | 2.0 | 2.0 | Orange | 22 | 3.0 | 2.0 | 4.0 | 4.8 |
| NC 719 | 4.0 | 1.0 | 3.0 | Orange | 25 | 3.0 | 1.6 | 4.2 | 4.8 |
| White Jewel | 4.0 | 3.0 | 3.0 | Lt. orange | 26 | 2.6 | 1.7 | 3.8 | 4.7 |
| Seedling 211 | 3.7 | 2.5 | 1.5 | White | 4 | 3.0 | 1.2 | 3.8 | 4.6 |
| Selection 59 | 5.0 | 3.5 | 2.5 | Lt. orange | 24 | 3.8 | 1.5 | 3.5 | 4.5 |
| Seedling 97 | 3.0 | 1.8 | 2.8 | Cream | 7 | 2.8 | 1.3 | 3.7 | 4.3 |
| Seedling 272 | 3.3 | 2.3 | 1.0 | White | 1 | 3.0 | 0.7 | 3.7 | 4.3 |
| NC 718 | 3.0 | 3.0 | 3.0 | Orange | 26 | 3.0 | 2.0 | 4.3 | 4.3 |
| Gem | 5.0 | 5.0 | 3.0 | Orange | 27 | 2.3 | 2.4 | 4.0 | 4.3 |
| Centennial | 4.0 | 3.0 | 3.0 | Orange | 26 | 3.0 | 1.4 | 3.6 | 4.3 |
| Mean | 3.64 | 2.79 | 2.48 | | | 2.64 | 1.39 | 3.23 | 3.49 |
| Standard deviation | 1.04 | 1.02 | 0.58 | | | 0.46 | 0.70 | 0.42 | 0.66 |

## DISCUSSION

The variablity in sweet potatoes for boiled slices as seen herein, can only be described as very extensive, and since sweet potatoes are propagated vegetatively, practically any combination of color, sweetness, mouthfeel and other characteristics can be selected and fixed in a clonal variety. Nevertheless, defects of quality are common, and very good combinations are apparently unusual. When one considers the large number of other desirable characteristics in a commercial cultivar (including yield, root shape, easy propagability, disease, and insect resistance, adaptation, it becomes easy to see why good cultivars are rare. It now appears that careful selection is necessary at the kitchen level to supplement field selection. It is not possible to judge the quality of a sweet potato as boiled slices until it is cooked.

The use of sweet potatoes as chips is not a novelty. A patent for the production of sweet potato chips was first obtained in 1936 (2), and methods were improved in Louisiana in 1958 (3). Boggens and Woodroof published instructions for the preparation of sweet potato chips (1). Yet sweet potato chips have not been produced commercially, except on a small scale. This is probably due to lack of promotion and development, and not to any fault in the product.

Sweet potato chips need not be as free of sweetness as potato chips to be good. Recently a slope diffuser has been used to remove much of the sugar from sweet potato chips, resulting in a product much more like potato chips, and with fewer problems of discoloration on cooking (6). This refinement is not necessary to produce an acceptable product.

Chips are a snack food, not a principal item of the menu. Sweet potato chips appeal to people on the basis of their flavor and crispness, and as shown here, to a lesser extent on the basis of their appearance. Sweet potato chips are seen here to be of two types, a cookie-like chip with rich flavor influenced in part by sweetness, and a "potato" type chip. The color of either type may vary, and indeed even anthocyanin, unattractive in the boiled root, may add attractiveness to the chips. Among tropical sweet potatoes there are types suitable for both kinds of chips.

Chips of many of the 75 types were rated good to excellent and factors associated with excellence were identified. Thus, roots that tend to be hard or dry after boiling are usually crispy after frying. A moderate amount of sweetness is desirable to give good flavor, and low oil absorption also appears important. However, it is not yet possible to predict chip quality without frying. Five of the best 10 types were cultivars or breeding lines from North Carolina; this fact suggests that flavor characteristics are concentrated in these varieties.

The technology of sweet potato chip preparation is simple and widely available. Some studies of shelf life, especially as influenced by frying oil

and packaging are desirable, however. It appears that commercialization will depend principally on cost and price, as well as other marketing factors.


## RESUMEN

Raíces de 30 cultivares y líneas, y de 310 plantas de semilla no seleccionadas de batata se evaluaron como rebanadas hervidas. Rebanadas finas de 75 selecciones de las arriba mencionadas se frieron en aceite de soya y se evaluaron como frituras. Por el color, dulzura y textura en la boca se clasificaron las 310 plantas en 25 de 27 clases teóricas. La poca dulzura estaba asociada con textura seca. La frecuencia de defectos en rebanadas hervidas se determinó. Se obtuvieron dos tipos de frituras, uno del tipo de galleta dulce y uno similar a la papa. Las características de calidad eran más o menos independientes unas de las otras y de otras características medidas. Se calcularon los coeficientes de correlación entre las evaluaciones de frituras con su sabor, fragilidad, falta de residuo de aceite y apariencia. Las altas evaluaciones no estaban correlacionadas significativamente con la dulzura. Las batatas sirven para frituras de tipo galleta dulce y tipo papa. Sin embargo, sus propiedades antes de freír no son guías confiables para lograr batatas fritas de buena calidad.


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