# Evaluation of Ten Varieties of Yam (*Dioscorea* spp.) for Production of Instant Flakes[1]

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## INTRODUCTION

Yam (*Dioscorea* spp.) is planted on a seasonal basis closely following the natural periods of heavy rainfall during spring, summer, and fall months. The yam crop matures and is harvested during periods of drought and short days (dry seasons). Although the natural yam season can be extended somewhat by early planting, early harvesting, and storage of tubers, the availability of the crop is nevertheless restricted by the season. In countries where the yam is in demand as part of the diet, means of preservation on a year-round basis are highly desirable. Processed products with long storage life also would be helpful in stabilizing the market.

Tests with two varieties of yam conducted previously in this Laboratory revealed differences in processing characteristics that could not have been anticipated. In addition, each variety has unique limiting agronomic characteristics. This study thus has been extended to additional yam varieties in search of cultivars with better field and laboratory characteristics. Some unusually shaped varieties, or with a high-flesh oxidation, were included in these trials to estimate the effect of such characteristics.

## MATERIALS AND METHODS

Following is a summary of the yam varieties processed, species to which they belong, sources, and pertinent observations of the agronomic characteristics which affect their processing.

Hawaii Branched, *D. alata*, is a variety seen occasionally for sale on the local market at a low price. It branches from the neck into slightly irregular cylinders. Soil is caught in the forks of the branches. Secondary roots of the upper part are thick.

Ashmore, *D. alata*, sometimes is seen in Puerto Rican markets and sometimes growing wild. It is ellipsoid in shape but with irregular ridges. Secondary roots are abundant and deeply imbedded in the flesh.

Farm Lisbon, *D. alata*, is grown extensively in Trinidad and Barbados.

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It is pyramidal in shape, with many short "fingers." It is a very difficult yam to peel. It has many secondary roots but these are small and come off easily.

Macorís, *D. alata*, often grows wild in western Puerto Rico. Its tubers are large and rather cylindrical with a few thin roots. Nevertheless, the peel is thick and difficult to remove by mechanical methods.

Seal Top, *D. alata*, is a large, spindle-shaped yam with irregularities, but without branches. It is difficult to peel.

Morado, *D. alata*, is grown on a small scale in Puerto Rico. It is highly branched and has a smooth skin. Soil frequently is caught in the forks of the yam, and difficult to remove. Secondary roots in the upper part are thick and difficult to remove.

Feo, *D. alata*, is a variety seldom seen on the market, but has excellent cooking characteristics. The tubers are wider than long with numerous irregularities, and have abundant, superficial secondary roots. It is difficult to clean and peel.

Gordito, *D. alata*, is a variety recently introduced from India. It is rather spherical to pyramidal in shape, and has few secondary roots. It has good peeling qualities.

Prolific, *D. alata*, was recently introduced from India. Its tubers are very large and rather spherical with large, smooth bumps. A few irregularities make it hard to peel.

Pana, *D. esculenta*, is a common species in Puerto Rico but seldom utilized. It has small, potato-like tubers on thorny roots. It peels fairly easily.

Florido, *D. alata*, is a standard variety for consumption in Puerto Rico and is used for control purposes in this study. Its tubers are spherical to cylindrical in shape and peel very well.

A method for preparing an instant yam flake has been described by Rodríguez-Sosa and González (4). Briefly, this method consists of the following steps: Washing, peeling for 4 minutes in a 20-percent boiling lye solution, brushing to remove any peel left, trimming, slicing into ½-inch slabs, steam-cooking for 15 minutes, mashing, dehydrating the mash as thin films in a double-drum dryer, breaking into flakes. sieving to control particle size, and packaging. The finished yam flakes are reconstituted as mashed yam (110 g.) by mixing 23 percent yam flakes with 73 percent tap water at 180° F. (82.2° C.) 3 percent olive oil, and 1 percent table salt.

The appearance, flavor and overall acceptability of the flakes were sensory evaluated (using a hedonic scale of 6 points) in triplicate, and averages were calculated. The sensory evaluation was performed in two separate tests. Each test covered three different varieties randomly chosen. These were compared to the Florido variety control. Four samples, including the control, were evaluated by the panel per sitting.

Total solids and moisture content were determined by the conventional vacuum oven method (2), and free starch or blue value index (BVI) by the method of Mullins et al. (3). This method is based on the appearance of a blue color due to the reaction between iodine and free starch. Shear press measurements were taken on individual 50-g. samples of fresh, lye-peeled, and cooked-yam slabs of about ½ inch chosen at random. The shear press system used was adjusted to 1-minute stroke. The standard compression cell was equipped with a 3,000-pound proving ring set at a range of 600 pounds (20 percent). The maximum force applied to break the yam slabs

TABLE 1.—*Quantities of yam tubers processed and losses in weight during peeling (pounds)*

| Variety | Weight of tubers | Weight of peeling lost | Loss in trimming | Weight after peeling and trimming | Weight after cooking | Weight lost during cooking | Weight of tuber water mixture | Weight of flakes | Percent yield |
|---|---|---|---|---|---|---|---|---|---|
| Florido | 20 | 2.5 | 1.5 | 16 | 15.5 | −0.5 | 23.5 | 3.25 | 16.3 |
| Hawaii Branched | 19.75 | 3 | — | 11.25 | 11.25 | 0 | — | — | — |
| Ashmore | — | — | — | 12.5 | 12.5 | 0 | 20.5 | 3 | — |
| Farm Lisbon | 22.50 | 3.5 | 5.5 | 13.5 | 12.5 | −1 | 17.5 | 2.75 | 12.2 |
| Macorís | 21.50 | 4 | 6.5 | 11 | 11 | 0 | 14.5 | 2.25 | 10.5 |
| Seal Top | 21.50 | 4 | 2.5 | 15 | 14.5 | −0.5 | 18.5 | 2.75 | 12.8 |
| Morado | 20.50 | 2.5 | 8 | 11 | 11 | 0 | 13.5 | 2 | 9.8 |
| Feo | 27.50 | 5.75 | 9 | 12.5 | 12.5 | 0 | 20.5 | 3.5 | 12.7 |
| Gordito | 21.00 | 2.5 | 6.5 | 12 | 11.5 | −0.5 | 15 | 2.75 | 13.1 |
| Prolific | 21.00 | 2.5 | 4.5 | 14 | 13 | −1 | 18.5 | 2.75 | 13.1 |
| Pana | 16.50 | 5.25 | 2.25 | 9 | 9 | 0 | 12.5 | 1.75 | 10.6 |

was read directly from the time force curves and the area under the curves was measured with a planimeter.

## RESULTS

The yam varieties tested differed in their response to cleaning and peeling operations. Varieties with many small branches or surface irregularities were difficult to peel by the lye-peeling method. In addition, some varieties have thicker, more resistant skins (Seal Top) which also resisted lye peeling. A certain amount of hand trimming was always necessary, but least for spherical or cylindrical tubers. Small tubers were much easier to peel than large ones. When large tubers were cut into pieces, they could be lye-peeled more easily but considerably more flesh was lost in the peeling process.

The yield for each variety after each process is given in table 1. Peels were removed with lye and mechanical brushing but trimmings were removed by hand. Only a very slight amount of the pulp is lost during steam cooking. Before dehydrating, water was added to the yam mixture to bring the pulp to a total-solids content of about 20 percent for dehydration, which also is appropriate for white and sweet potatoes (1,5). The final yields of flakes were usually a little over 10 percent, which compares unfavorably with about 20 to 30 percent of measured dry matter in most yams.

After peeling and trimming, and during processing, pigments and unattractive colors often appear (table 2). Yam flesh colors are highly variable due to the presence of phenolic pigments (anthocyanins, flavonoids). In addition, the degree of whiteness is influenced by other substances. Finally, upon exposure to air polyphenolic substances oxidize rapidly to form a diversity of brown tones. This last change also was evaluated in all yam

TABLE 2.—*Flesh color, tendency to polyphenolic oxidation (browning), and response to dehydration*

| Variety | Color of flesh | Tendency to browning | Response to dehydration |
|---|---|---|---|
| Florido | White to cream | Medium | Good |
| Hawaii Branched | Cream | High | Poor |
| Ashmore | Dark cream | High | Do. |
| Farm Lisbon | White | Low | Normal |
| Macorís | Light orange | High | Poor |
| Seal Top | Dark cream | Medium | Do. |
| Morado | do. | High | Do. |
| Feo | White | Low | Do. |
| Gordito | White to purplish | High | Do. |
| Prolific | Cream | Medium | Fair |
| Pana | White | Low | Very poor |

varieties tested, varying considerably in intensity (table 2). The flakes of Macorís were light orange; those of Hawaiian Branched and Ashmore objectionably gray; and those of Seal Top and Prolific a good white color, although both these varieties are susceptible to oxidation.

Varieties differed also in their response to dehydration (table 2). The dehydration operation in fact proved to be the most difficult one to manage perfectly, requiring adjustments when changing from one type of yam to another. The most common problem encountered was stickiness of the mixture, which prevented the film from spreading evenly over the drums. In the case of Pana, the only variety of *D. esculenta* tested, caramelization of the mixture completely inhibited the flake-producing process.

The solids and moisture contents of the tubers and their flakes were measured at appropriate stages. Yam flesh after it is lye-peeled contains from 20 to 30 percent solids (principally starches), but varieties differ among themselves (table 3). Ashmore, Feo, and Pana are particularly dense-fleshed. The differences in solids are readily noted in the fresh tubers upon visual inspection. Differences after mashing reflect chiefly the amount of water that has been added to produce a smooth yam mixture. Table 3 shows (last two columns) the drastic reduction in water content that takes place during dehydration in the double-drum dryers. From an initial concentration of about 20 to 76 per cent water in the fresh tubers, moisture content is rapidly reduced to about 4 to 10 percent in the flakes. In white potatoes, a moisture content of about this range in the flakes is considered safe for storage stability (6). Differences in final moisture content of the flakes are mostly associated to processing details (thickness of film, initial moisture content of mixture, and temperature of drum).

TABLE 3.—*Total solids and moisture content (percent) at several stages of preparation*

| Variety | Total solids | | Moisture | |
|---|---|---|---|---|
| | After cooking | After mashing | Fresh yam | Flakes |
| Florido | 26.65 | 15.73 | — | 5.47 |
| Hawaii Branched | 22.18 | — | 73.53 | — |
| Ashmore | 30.90 | 18.09 | — | 10.77 |
| Farm Lisbon | 26.01 | 16.56 | 69.00 | 9.55 |
| Macorís | 21.35 | 14.14 | — | 9.30 |
| Seal Top | 28.10 | 18.22 | 71.57 | 3.97 |
| Morado | 21.60 | 16.90 | 76.83 | 8.28 |
| Feo | 31.30 | 19.97 | 71.90 | 5.60 |
| Gordito | 23.99 | 18.52 | 79.24 | 5.43 |
| Prolific | 25.62 | 17.82 | 73.01 | 4.40 |
| Pana | 30.41 | 19.62 | 76.31 | 5.39 |

Free starch content (BVI) of the yam varieties tested and their flakes is shown in table 4. The free starch content increased somewhat in each variety after mashing and much more after dehydration. These increases are due to the breaking of cell walls during processing.

Free starch concentrations were higher in varieties with low total solids. More compact tubers such as Feo and Pana released much less starch during the flaking process.

The shear press maximum force and area under the curve determinations of yam slabs taken at the various processing steps, i. e., fresh, lye-peeled, and steam cooked, differed somewhat among the varieties (table 5). This is an indication of differences in firmness or hardness of the material examined. Lye peeling generally softened the tubers to some extent whether measured as maximum force in pounds necessary to break the standardized yam slab, or total work performed (measured as square inches under the time force curve).

Steam cooking softened the tubers to the point where only 25 to 55 percent as much force was required to shear the slabs. A few of the varieties, specially Macorís, Seal Top, and Feo, were still somewhat hard after cooking, but none were too hard or difficult to process.

Some of the varieties yielded an unacceptable product after processing. These were not included in the final sensory evaluation. Hawaii Branched was not completely processed into flakes because the mash became too

TABLE 4.—*Free starch content of tubers and flakes, as measured in terms of blue value index* (BVI)

| Variety | After cooking | After mashing | Flakes |
|---|---|---|---|
| Florido | 6 | 23 | 276 |
| Hawaii Branched | — | — | — |
| Ashmore | 4 | 15 | 114 |
| Farm Lisbon | 11 | 17 | 258 |
| Macorís | — | — | 344 |
| Seal Top | 4 | 18 | 338 |
| Morado | 4 | 14 | 363 |
| Feo | 0 | 6 | 145 |
| Gordito | 0 | 10 | 284 |
| Prolific | 6 | 15 | 320 |
| Pana | 7 | 15 | 160 |

TABLE 5.—*Shear press strength of fresh, peeled, and cooked tubers*

| Variety | Fresh yam | | After lye peeling | | After cooking | |
|---|---|---|---|---|---|---|
| | MF[1] | A[2] | MF | A | MF | A |
| Florido | 233 | 1.07 | 258 | 1.01 | 66 | 0.37 |
| Hawaii Branched | 294 | 1.13 | 317 | 1.36 | 69 | .27 |
| Ashmore | — | — | 291 | 1.34 | 75 | .41 |
| Farm Lisbon | 234 | .94 | 192 | .71 | 83 | .45 |
| Macorís | — | — | 245 | 1.08 | 107 | .47 |
| Seal Top | 314 | 1.14 | 255 | 1.17 | 125 | .54 |
| Morado | 349 | 1.66 | 264 | 1.07 | 93 | .81 |
| Feo | 282 | 1.12 | 344 | 1.16 | 117 | .60 |
| Gordito | 386 | 1.40 | 381 | 1.23 | 54 | .29 |
| Prolific | 229 | .92 | 194 | .77 | 37 | .19 |
| Pana | 201 | 1.14 | 183 | .85 | 57 | .38 |

[1] MF equals maximum force in pounds registered by the shear press to break the yam slice.

[2] A equals area in square inches under the time force curve (total work required to break the yam slice).

sticky for the dehydrating process, and turned very dark grey giving the flakes an objectionable color. Ashmore tubers also produced objectionable dark gray flakes; Macorís, orange.

The results of sensory evaluations are given in table 6. In Test 1, variety Prolific was judged equal to Florido on all counts, and obtained scores between "like" and "like moderately." Varieties Feo and Gordito were not as acceptable although they obtained scores of "like moderately," and between "like moderately" and "neither like nor dislike" respectively. In Test 2, variety Seal Top was judged almost as acceptable as Florido, but less attractive, less flavorful, and of a coarser texture. Varieties Morado and Farm Lisbon were less acceptable.

TABLE 6.—*Average results of sensory evaluations*[1]

| Variety | Appearance | Flavor | Texture | Overall acceptability |
|---|---|---|---|---|
| | *Test 1* | | | |
| Florido | 2.2 | 2.7 | 2.6 | 2.5 |
| Prolific | 2.2 | 2.6 | 2.5 | 2.4 |
| Feo | 3.0 | 3.1 | 3.3 | 3.0 |
| Gordito | 3.4 | 3.3 | 3.2 | 3.4 |
| | *Test 2* | | | |
| Florido | 2.0 | 2.4 | 2.5 | 2.8 |
| Seal Top | 3.0 | 2.6 | 2.7 | 2.9 |
| Morado | 4.7 | 3.3 | 3.3 | 3.8 |
| Farm Lisbon | 2.8 | 3.1 | 3.4 | 3.4 |

[1] Rated on a scale of 1 (like very much) to 6 (dislike).

## DISCUSSION

The preparation of flakes for use as instant yam provides a method for use of excess and damaged tubers during the harvest season, and of extending the availability of yam to a year-round basis. The finished product is readily accepted by consumers acquainted with yam which can be packed attractively for mass distribution.

Our investigations indicate that yam varieties differ materially in their processing characteristics. Some of these differences are associated with size and shape of the tuber. Irregularly shaped and large tubers impede cleaning and peeling operations. Differences in pigment content influence the color and acceptability of the final flakes. Differences in total solids influence the amount of starch released during processing. More subtle differences influence taste and determine acceptability of the final product.

Such previously unknown differences indicate the characteristics desirable in a yam intended for processing into flakes. The tuber should be round or shortly cylindrical in shape, with a smooth, thin skin. The flesh preferrably should be low in pigments (tendency to polyphenolic oxidation, however, can be controlled and thus need not be considered a liability). Within the limits of these tests, total solids content and free starch released during processing do not particularly influence the quality of the final flake; neither does hardness of the tuber at various stages of processing.

Among the yam varieties tested thus far for flake production, the following are most acceptable: Florido, a common variety already established throughout the Island; Seal Top, a large-tubered variety with high yields that probably can be held to suitable size by crowding; and Prolific, a huge yam somewhat irregular in shape that can be planted from aerial tubers. The exceptionally big yields of this variety may compensate for some of its deficiencies.

## SUMMARY

Ten varieties of yam representing two species (*Dioscorea alata* and *Dioscorea esculenta*) were processed into yam flakes by previously described methods. The varieties differed in many characteristics that influenced ease of processing and final quality of the product. Large and irregularly shaped tubers could not be cleaned and peeled easily. Pigments influenced color of the product. Total solids and free starch content did not influence quality. Two varieties of *D. alata* (Prolific and Seal Top) yielded flakes which were rated about as high as Florido, the control. The only variety of *D. esculenta* (Pana) tested could not be adequately processed because it caramelized, preventing the flake-producing process.

## RESUMEN

Se prepararon hojuelas de ñame de 10 variedades de las especies *Dioscorea alata* y *Dioscorea esculenta* elaboradas según métodos descritos previamente. Hubo diferencias entre las variedades en cuanto a muchas de las características que afectaron de una manera u otra el procedimiento de elaboración y la calidad del producto final. Los tubérculos largos y de forma irregular no se podían limpiar ni pelar fácilmente. Los pigmentos influyeron en el color del producto. Dos de las variedades de *D. alata* (Prolific y Seal Top) produjeron hojuelas de una calidad tan buena como las del ñame Florido que sirvió de testigo. La única variedad de *D. esculenta* (Pana), que se sometió a la prueba no pudo elaborarse adecuadamente debido a que se caramelizó, evitando así el proceso necesario para la formación de las hojuelas.

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