Flours Made from Edible Yams (*Dioscorea* spp.) as a Substitute for Wheat Flour[1]

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ABSTRACT

Flours were prepared from peeled, sliced, dried, and ground tubers of several species and varieties of yam, *Dioscorea* spp. The flours were used in conventional cookery as a wheat flour substitute in pancakes, cupcakes, and breads. Differences were found among yam flours in color, odor, and in their suitability as a substitute for wheat flour. Acceptable products were made using 50 percent, or in some cases 100 percent, yam flour. Varieties that yield superior flours were selected.

Yam flour prepared from appropriate varieties grown under advanced and economical methods could reduce need for imported wheat flour.

INTRODUCTION

The flour from which bread and baked products are made, generally of wheat or rye, contains gluten, a protein that gives the particular cohesive properties necessary for good texture of the product. The actual amount of gluten depends on the degree of refinement of the flour, as well as on the variety of cereal grain and its agronomic history. Highly refined flours contain less gluten. Flours for breads contain about 11–12 percent protein, but flours for cakes and cookies are made of soft wheat and contain as little as 8 percent.

In countries where cereals are not produced in sufficient quantities to fill local needs, flours from roots and tubers are often substituted for at least a part of the cereal flour. These flours are obtained by three basic processes. The cooked root or tuber can be used as a flour substitute. For raw flour, the root or tuber is cut into slices or ground into a meal, and the resulting pieces are then dried at moderate temperatures. For cooked flours, heat is applied at some stage of the process which changes the nature of the product considerably. The heat may be applied early in the process as in some yam flours, or late as in the production of the meal "gari" from cassava root. Both these types of flour may be substituted in part for cereal flours. In addition, the tubers and roots are used directly sometimes after cooking without first drying the cooked paste to a flour.

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Potato flour is commonly used in temperate zones. It is produced on a large scale in Germany. The traditional method is to wash, peel, and slice the potatoes, dry them with heat, then grind the residue, and sieve to the partical size desired. The temperature and duration of drying must be critically controlled to avoid discoloration (9). About 5 percent of this flour can be used with whole wheat flour.

Flour made from cassava (*farinha*) is produced in several different ways. A primitive method still used widely is to cut the roots into pieces or slices, dry them in the sun, and mill them to the size desired. In better mills the fresh root is washed, peeled, grated finely, pressed to remove some of the water, dried, milled, and then sieved (7, 11).

The principal use of cassava flour is in the production of bread. Use of such flour is required in certain proportions by law in both Brazil and Paraguay. Farinha also is used widely as an additive to other types of food, and is sprinkled over other foods at the table. A by-product in the production of farinha is "afrecho," an animal feed (2).

Gari, a similar product in Africa, is permitted to ferment several days and then dried over a fire. Thus the product is partially cooked and can be used in simple porridges without further cooking.

Sweet potato flour has been prepared both as noncooked and a fully cooked product. For the uncooked product, the tubers are washed, scraped to remove the peel, sliced, sun-dried, ground, and sieved (20). The process can be mechanized or industrialized at any stage. Sweet potato flour is not widely used, but in recent years it has been studied and promoted, especially in Peru (4). Plaut and Zelzbuch (14) have analyzed the flours of sweet potato and studied their effects on bread quality. Only about 6 to 10 percent of the wheat flour can be replaced by sweet potato flour before deleterious effects are noted, such as cracking of the crumb.

In contrast to uncooked flour, the use of precooked sweet potato flour has been studied extensively in Alabama (21). Preparation includes washing, trimming, baking, peeling, and pulping. The pulp can be used without further processing. Or the pulp can be extruded, dried, and toasted to provide a durable product. The extruded strips are then milled to a flour. This product has been termed Alamalt. Such sweet potato flour can be used in a conventional bakery to replace not only part of the wheat flour, but also part of the required eggs, butter, and sugar (10).

Flours from yams (*Dioscorea* spp.) have not been studied extensively. Nevertheless large amounts are produced and consumed in West Africa, and lesser amounts in the Far East. In Africa the yams are sliced and sun-dried, with or without preboiling. The dried slices are ground into a suitable meal, and are stored in this form. The general form of cooking is to stir the

flour into boiling water to obtain a paste. Cooked products made with yam flour are considered inferior to those containing fresh yams.

Jarmai and Montford (8) described an improved method for producing yam flour. The steps include washing, cooking, peeling, mashing, drying, and packing. During treatment the weight is reduced by 70 percent and the resulting flour is both durable and of good quality.

In the Far East yams are often used as food and sometimes are prepared into flours. Methods for preparing flour from *D. alata* are given by Afable in the Philippine Islands (1). The Chinese yam, *D. batatas*, has been studied rather thoroughly as a source of flour (13).

In the New World yam flours are practically unknown, but the production of a starchy flour in Panama by the techniques used for producing cassava starch has been mentioned (5).

The preparation of yam flour brings considerable problems. Washing and peeling is a problem with many varieties because of their irregular shapes. The problems of lye peeling have been worked out by Rivera and González (15). Once the yam is cut, polyphenolic oxidation begins. The brown compounds formed have been identified in *D. batatas* as phenolic amines (18). Antioxidants are useful in reducing this undesired tendency but the most effective technique is to use varieties that are not prone to browning.

MATERIALS AND METHODS

Newly harvested yams of three species (table 1) were cleaned, peeled, and sliced to 1 or 2 mm thickness. The slices were placed on trays and dried overnight in a forced-draft oven at 58° C. The dried chips then were ground to a fine flour and stored in sealed plastic bags until used.

From these flours, three kinds of cooked products were prepared for comparison to controls: pancakes, cupcakes, and hard bread rolls. The products were then evaluated both informally and by a taste panel for relevant characteristics, and quality scores were given. The recipes for these products were:

Pancakes: 0.5 cup each of yam and wheat flours were mixed with 0.5 tsp. salt, 2 tsp. baking powder, and one tbls. sugar. One egg, and 0.5 cup of milk, were mixed in. The pancakes were cooked at about 160° C in the manner usual for pancakes.

Cupcakes: 0.5 cup of butter was blended with one cup of sugar. Beaten yolks from 2 eggs were mixed in, together with 1.5 tsp. vanilla. Meanwhile, 0.67 cup each of yam and wheat flours were sieved with 1.5 tsp. baking powder and 0.5 tsp. salt. The flour, butter, and egg mixtures were then intermixed. Finally, the whites of two eggs were added. The mixture was poured into containers and baked in a preheated oven at 170° C for 25 minutes.

Hard bread rolls: two packages of granulated yeast were activated in 1 cup of warm water with 1 tbsp. of sugar. Three cups each of yam and wheat flours were mixed with 0.5 tsp. salt, 0.25 cup sugar, 0.5 cup hot milk, 0.3 cup butter, and 1 beaten egg. The activated yeast was added, and the mixture was kneaded to provide a smooth dough. The dough was permitted to rise for 2 hours. It then was kneaded and formed into rolls. The rolls were permitted to rise to about double their volume, and then were baked in a preheated oven at 200° C for 10–12 minutes.

TABLE 1.—*Yam species and varieties prepared as flour and tested in fried and baked products*

Species and variety	Flesh color	Flesh texture	Shape of tuber	Suitability for machine-handling	Whiteness of flour
Dioscorea alata					
Ashmore	Off-white	Coarse	Cylindrical	High	Medium
Vino Blanco	White	Intermediate	Irregular	Low	Low
Purple Lisbon	Purple	Intermediate	Irregular	Low	Very low
Florido	White	Fine	Short cylindrical	Very high	High
Farm Lisbon	White	Fine	Pyramidal	Low	High
Seal Top	Off-white	Coarse	Spindle-shaped	High	Low
Feo	White	Fine	Irregular	Medium	High
Gordito	Off-white	Coarse	Irregular	Medium	Medium
Forastero	White	Fine	Cylindrical	High	High
Dioscorea rotundata					
Guinea Blanco	White	Intermediate	Cylindrical	Medium	Low
Dioscorea esculenta					
Papa	White	Fine	Spindle-shaped	Very high	High

When preliminary tests had been completed, two superior flours were selected. Samples were sent to the Department of Grain Science and Industry, Kansas State University, where they were used to make breads by the K-State Process (19). Breads were made with 20 or 40 percent of the wheat flour replaced by the yam flour. These breads were evaluated in comparison to high-quality American-type bread.

RESULTS

The species and varieties of yams used for these tests are given in table 1, together with some of their characteristics and the color of the flours. Yams varied in flesh color from white to purple, in texture from fine to very coarse

fleshed, and in shape of tuber, a very important characteristic for machine-handling. The color of the flour was determined by the color of the flesh of the yam, and by the tendency for polyphenolic oxidation of the cut slices. The flours all possessed a good odor and a good taste.

During cooking the pancakes, a considerable difference was noted in the ability of the pancake mixture to rise normally. Pancakes varied in appearance from very good to poor (table 2). Flours that were colored usually gave considerable color to the pancake. Pancakes of flours from Purple Lisbon were particularly unpleasant in appearance but tasted good. The flavor of

TABLE 2.—*Characteristics of pancakes made from 50 percent yam flour, as compared with those of a control**

Variety	Cooking time	Ability to rise	Outside color	Outside appearance	Inside appearance	Smoothness of texture	Flavor	Total score	Final rating
	Minutes	*		*	*	*	*		*
Control	5	3	Light brown	2.5	2.5	2.5	2.5	13.0	3
Ashmore	5	1.5	Grey cream	1	1	2	2	7.5	1
Vino Blanco	5	1.5	Dark cream	1	1	2	2	7.5	1
Purple Lisbon	10	2.5	Dark grey	0.5	0.5	2	1.5	7	1
Florido	5	1	Grey cream	2	2	2	2.25	9.25	2
Farm Lisbon	6	3	Cream	3	3	2	2.75	13.75	3
Seal Top	9	3	Clear brown	1.5	2.5	1	1.75	9.75	2
Feo	5	2	Grey cream	2.5	2.5	2	2	11	2.5
Gordito	8	3	Grey cream	2.5	2	2	2.5	12.0	2.5
Forastero	6	3	Cream	3	3	3	2.5	14.5	3
Guinea Blanco	8	2	Brown	1	1	2.5	1.75	8.25	1
Papa	12	1	Cream	2	3	3	1	10	2

* Characteristics rated on a scale of 1 to 3, where 3 is the most desirable phase of the attribute tested.

pancakes also varied. Independent observations of flavors by the authors were usually in agreement. A few flavors were disagreeable. Yams rated highest as pancake ingredients, in general, were those previously found to boil and fry well. The varieties Forastero and Farm Lisbon were outstanding.

Cupcakes made from yam flours were much more satisfactory than pancakes (table 3). First, all doughs rose satisfactorily or almost satisfactorily. Secondly, dark flours in cupcakes were not as objectionable as dark colors of pancakes. Thirdly, the flavors of the cake batter evidently masked the disagreeable flavor of some yam flours. The cupcakes were almost all good, but those of the varieties Forastero and Feo were clearly superb. One batch of cupcakes was cooked with 100 percent yam flour (Forastero), which

TABLE 3.—*Characteristics of cupcakes made from 50 percent yam flour, as compared with those of a control**

Variety	Ability to rise	Outside appearance	Outside color	Inside appearance	Inside color	Lack of stickiness	Sponginess	Taste	Total score	Final score
	*	*		*		*	*	*		*
Control	2	2	Yellow brown	3	Light	2.5	2	2	13.5	3
Ashmore	2.5	1.75	Grey brown	1.5	Grey cream	1.5	3	1.75	12.0	2
Vino Blanco	2	2	Brown	2	Brown	1	2	2	11	2
Purple Lisbon	2	0.5	Grey	0.5	Dark grey	1.5	2.5	1.75	8.75	1
Florido	2.25	2.25	Light brown	2.25	Dark cream	1.5	2.5	1.5	12.25	2
Farm Lisbon	2.5	2.25	Light brown	2.5	Dark cream	2	2	2.25	13.25	2.5
Seal Top	2.5	2	Brown	2	Brown	2	1.5	2.25	12.75	2
Feo	3	2.25	Clear brown	2.5	Dark cream	2	2	2.25	14	3
Gordito	3	2.25	Dark cream	2.25	Dark cream	2	2.5	2	14	3
Papa	2	2.25	Light brown	2.5	Cream	2	2	1	1.75	2
Guinea Blanco	3	1	Brown	1	Dark brown	0.5	3	0.75	9.25	1
Forastero**	2.5	2.75	Light brown	3	Cream	2.5	1.5	2.25	14.5	3
Forastero***	3	2	Light brown	2.5	Dark cream	2	2.5	2.25	14.5	3

* See footnote, table 2. ** 50 percent yam flour *** 100 percent yam flour.

TABLE 4.—*Characteristics of hard bread rolls made from yam flour, as compared to those of a control**

Variety and percent yam flour used	Cooking time	Ability to rise	Outside appearance	Outside color	Inside appearance	Inside color	Sponginess	Taste	Total score	Final score
	Minutes									
Control	20	3	2.5	Cream	3	Cream	2	2	12.5	3
Florido-50	20	1.5	2.25	Dark cream	2	Dark cream	2	2	9.75	2
Seal Top-50	30	1.75	1.75	Brown	2.25	Brown	1.75	2	9.5	2
Feo-50	22	1.75	2	Dark cream	1.5	Dark cream	1.75	1.75	8.75	2
Forastero-50	20	2.25	2.25	Light brown	2	Dark cream	2	2	10.50	2.5
Forastero-100	25	1	1	Dark cream	2	Dark cream	1	1.5	7.5	1.5

* See footnote, table 2.

yielded a very good cupcake. Persons asked to comment on the better cupcakes said in effect "unusual flavor, but a very good cake".

Only a few of the flours were used in making hard bread rolls. Hard bread rolls made with 50 percent yam flours were not as good as the controls with wheat flour (table 4). The dough tended to rise very slowly, either because of the large starch granules of yams, or possibly because of damage to dough structure from the dilution of gluten. As we did not compensate for this difference, the yam breads were relatively heavy. Colors were sometimes objectionable, but this depended largely on personal opinion. None of the breads in these trials were as good as desired, but usually were equal in flavor to the control (wheat) bread. Only one bread of very poor flavor was encountered, that made of 100 percent yam flour (Forastero). Two other breads were quite edible, but not of high quality.

When yam flours were substituted for part of the wheat flour in American-style bread, a dough conditioner (sodium stearoyl-2 lactylate) was found necessary to maintain loaf volume. Although satisfactory bread was made using 20 percent yam flour, the bread was not acceptable when 40 percent yam flour was used. The breads were soft and good-tasting, but somewhat gummy. No significant difference was noted between the breads prepared from Farm Lisbon or Forastero flours. These are the flours that gave the most satisfactory results in the previous tests.

DISCUSSION

These preliminary investigations suggest that at least 20 percent, but less than 40 percent of the wheat flour in breads of American quality can be replaced by flours obtained by slicing, drying, and grinding yams. In other bakery products, even higher quantities of yam flour can be substituted successfully. More extensive studies of the preparation and use of yam flour now seem justified.

The relatively high percentage of yam flour that can be substituted for wheat flour may be related to the high protein levels of yam (12), as well as the nature of the protein. It occurs as a mucoid glycoprotein, which acts as both a binder and an extender (17).

If yam flours are to be successful, a variety of agronomic and engineering problems will have to be solved. Primary factors concern selecting appropriate varieties. These should yield well, be mechanizable, and have appropriate processing characteristics. Appropriate agronomic systems must also be developed for the inexpensive production of the tuber. These problems are under study.

Preliminary steps pertaining to processing methods have been taken. Techniques for peeling yams with lye have been developed by Rivera-Ortiz and González (15). Success in peeling and the proportion of the edible part

lost in the process depend on the shape of the yam. Small, ellipsoidal yams are best peeled by the lye-machine process.

Characteristics of the system that dries tuber slices have been investigated by Ghosh (6). Less sophisticated methods are presented by Jarmai and Montford (8). Improvements in methodology unfortunately depend to some extent on success in selecting better yams. The sophisticated methods of preparing precooked, drum-dried flakes (16) probably will prove suitable for making instant-yam products for home use, but too costly for preparing commercial flours.

Studies of yam flours in cookery must also be continued. Unfortunately, success with cookery studies also depend on appropriate varieties. Varietal differences were evident in these studies, and the two that yield superior flours are not ideal for machine-processing. Some cooking investigations are necessary and desirable while new varieties are under development.

As yam flour is not a commercial reality thus far, the various investigations must be integrated for satisfactory industrial use. Rather complex socio-economic problems also exist, but the potential benefits of yam flour to developing tropical countries probably justify the necessary effort.

RESUMEN

Se prepararon harinas de tubérculos pelados, rebanados, secos y molidos de distintas especies y variedades de ñame (*Dioscorea*). Estas harinas se usaron como substituto de la harina de trigo común para hacer panqueques, bizcochitos y pan. Se encontraron diferencias entre las harinas en cuanto a color, olor y utilidad como substitutas de la harina de trigo. Productos aceptables se lograron con 50, o a veces 100 por ciento de harina de ñame. Se seleccionaron variedades superiores como fuentes de harina. Es posible que la harina de ñame, si se prepara de variedades apropiadas producidas mediante técnicas avanzadas, pueda disminuir la necesidad de importar harina de trigo.

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