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Studies in Composite Flours I-The Use of Sweet Potato Flour in Bread and Pastry Making

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The use of sweet potato flour as a partial substitute for wheat flour has been studied in India (SINGH et al., 1953), in Israel (PLAUT et al., 1953) and in Peru (FEUNTA, 1960) and it was found that five to ten percent of wheat flour could be so replaced without difficulty. The feasibility of admixing other root-crop flours and defatted oilseed meals with wheat flour for baking has also been studied by ANON, 1953; FINNEY et al., 1950; GREWE, 1945; KIM and DE RUITER, 1968; SUBRAHMANYAN and SWAMINATHAN, 1959; and SUMMERS and THURBER, 1953.

Baked goods made from wheat flour are staple foodstuffs in most parts of the world and especially in the West Indies. Wheat is a typically temperate and sub-tropical plant seldom grown in the tropics, and as most developing countries are in the tropical zone they are therefore dependent on imported wheat for baking. Such countries spend large amounts of their foreign exchange on imported wheat and wheat flour, to reduce which they must find a full or partial substitute for wheat flour.

The Food and Agricultural Organization (FAO) of the United Nations is aware of this problem and is investigating the possibilities of using substitutes derived chiefly from root-crops and defatted oilseeds (FAO, 1968).

In this paper, experiments on the use of sweet potato flour as a partial substitute for wheat flour in baked goods, especially bread, are described and discussed.

MATERIALS AND METHODS

The sweet potatoes used were cvs '049' and 'C9', both grown at the University Field Station, St Augustine, Trinidad. '049' is the standard commercial cultivar in Trinidad, while 'C9' is an experimental cultivar which has been giving comparatively good yields.

Treatment of tubers

In order to improve the colour of the flour, the tubers were cut into tramverse slices of various thicknesses and treated with different concentrations of sodium metabisulphite for different periods of time in an attempt to improve the colour of the flour by arresting enzyme activity without adversely affecting baking quality.

The best method for obtaining the desired flour was to treat the sweet potato slices, 2 to 3 mm thick, by soaking in a one percent sodium metabisulphite solution for one hour, then washing twice with water before drying or osterizing (preparation of slurry for spray drying).

Preparation of flour

(a) Spray drying—The tubers were cut into slices 2 to 3 mm thick and treated with one percent sodium metabisulphite solution, before osterizing for 15 minutes at medium speed in a Waring Blender (Model CB 5) with twice their weight of water. The slurry obtained was strained through a No 30 sieve and spray dried in batches of about one litre each.

The spray drier used was an A/S Niro Atomizer No 1484 made by Niro Atomizer Ltd, Copenhagen, Denmark, and operated at inlet and outlet temperatures of 200°C and 100°C, atomizer pressure of 4 kg/cm^2 and slurry feed rate of 10 ml/min.

(b) Cabinet drying—The sweet potato tubers were sliced and treated with metabisulphite as for spray drying and then dried in a cabinet drier with an upward draught, at a temperature of 90 to 100°C, to

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a moisture content of six to eight percent dry weight. The dried slices were ground in a Wiley Mill using a screen with 0.5 mm diameter perforations.

Wheat flour

The wheat flour used was that generally used for bread making in Trinidad. It was milled in Trinidad (Trinidad Flour Mills Ltd) from Dark North spring wheat and contained 12.2 percent crude protein (N% x 6.25), 0.39 percent ash and 13.7 percent moisture.

High protein additives

Cottonseed flour and fish protein concentrate (FPC) were used as high protein additives. Two types of cottonseed flour were obtained from Dr Hugh H. Mottern, Food Products Investigations Engineering and Development Laboratory, U.S.D.A., Agricultural Research Service, New Orleans, Louisiana 70119, U.S.A.: glandless cottonseed flour (No F2051) and Liquid Cyclone Process (LCP) cottonseed flour (No 83169) (awl-Rock et al.,1969).

The fish protein concentrate (FPC) used was manufactured by the VioBin Corporation, Monticello, Illinois, U.S.A. and was obtained from the Trinidad and Tobago Nutrition Unit. Some of the properties of these high protein additives are given in Table 1.

Baking trials

Bread baking trials were conducted under controlled conditions and under home baking conditions using a composite flour containing various proportions of wheat flour, potato flour and high protein adjunct. Table 2 gives the recipes for controlled and home baking.

Controlled bread making procedure

Controlled baking trials were done at the laboratory of the Trinidad Flour Mills Ltd. The dry ingredients (Table 2) and shortening were mixed together. The yeast and sugar were dissolved in water (86 to 104°F) and added to the dry mix with the remainder of the water. The dough was kneaded using a Hobart mixer with a dough hook for two minutes at No 1speed then for five minutes at No 2 speed. The dough was put in a fermentation cabinet kept at 86°F and 75 percent relative humidity for two hours. The dough was scaled and given a further thirty minutes in the fermentation cabinet, after which it was panned and returned to the cabinet where it was allowed to rise again for about 30 to 45 mins. It was then baked at 375°F for 45 mins.

Table 1. Properties of high protein additives

Property	*Cottonseed*		*FPC*
	Glandless (F 2051)	*LCP (83169)*	
Moisture (%)	6·54	—	5·0
Fat (%)	1·42	0·6	—
Protein (N% × 6·25) (%)	57·94	70·0	90·3
Protein solubility in 0·02N NaOH (%)	99·06	98·0	—
Ash (%)	7·33	—	4·9
Crude fibre (%)	2·7	—	*Trace*
Free gossypol (%)	0·02	⩽0·045	—
Total gossypol (%)	0·03	⩽0·30	—
Colour	*White*	*Light cream*	*Light brown*
Flavour	*Bland*	*Bland*	*Bland*
Odour	*Odourless*	*Odourless*	*Very slightly fishy*

Table 2. Bread making recipes for controlled and home baking

Constituent	*Quantity*	
	Controlled Baking (g)	*Home Baking (g)*
Composite flour	700·0	350·0
Water	420·0	220·0
Shortening (vegetable)	14·0	5·0
Yeast (compressed)	14·0	—
Yeast (dry granular)	—	2·5
Sugar	28·0	10·0
Salt	7·0	1·5
Powdered skim milk	14·0	10·0

Home bread-making procedure

The dry ingredients (Table 2) and shortening were mixed. The yeast was dissolved in 50 to 75 ml warm water (104 to 120°F) and added to the dry mix with the remainder of the water. The dough was kneaded using a dough hook on a Kenwood Chef at No 3 speed for five minutes. The dough was allowed to prove for one and a half to two hours at room temperature (86 to 90°F). It was then kneaded for three minutes and allowed to prove for a further hour. It was panned, allowed to rise for about an hour to approximately double its bulk and baked at 340 to 360°F for forty to fifty minute:.

Home-baked pastries

The recipes for sponge cake, sweet cream biscuit, pancakes, and doughnuts were taken from HARVEY (1962). The recipe for the sugar cookies was taken from WILSON (1962), while that for raisin bread was taken from ANON, 1963.

Roti (chapati) is an unleavened bread and was made from the following recipe: 2 lb flour, 6 teaspoons baking powder, 1 teaspoon salt and 2 to 2 1/4 cups water. The dry ingredients were mixed together, then kneaded as for bread. The resulting dough was divided into twelve equal portions and formed into balls. This was allowed to stand for one hour, then rolled into circular shapes about nine inches in diameter and about a quarter of an inch thick, and grilled on a hot griddle iron for about five minutes.

Analyses

Colour was determined visually; crude fibre, ash and SO_2 by A.O.A.C. method (A.O.A.C., 1965); moisture by direct oven method at 105°C and by moisture balance (CENCO). Total nitrogen, determined by micro-Kjeldahl method, was used for calculation of the crude protein content (N%x 6.25). Reducing and total sugars were determined by the volumetric method of Lane and Eynon (PEARSON,1962) and total fat by Soxhlet extraction using carbon tetrachloride as solvent Bread volume was determined by displacement using rapeseed.

RESULTS AND DISCUSSION

Table 3 gives some properties of the fresh tubers of sweet potato cultivars '049' and 'C9'.

Table 3 some properties of the fresh tubers of sweet potato cvs '049' and 'C9'.

Property	Cultivar '049'	Cultivar 'C9'
Shape	Globular	Cylindrical
Skin colour	Light reddish brown	White
Flesh colour	White	White
Moisture (%)	69 to 71	66 to 69
Starch (by diff.) (% dry wt)	83·64	82·92
Crude protein (% dry wt)	3·50	3·06
Fat (% dry wt)	0·48	0·62
Reducing sugars (% dry wt)	3·24	3·24
Total sugars (% dry wt)	6·31	7·12
Fibre % dry wt)	1·18	1·62
Ash (% dry wt)	1·65	1·62

Effect of peeling tubers on flour properties and baking characteristics

Table 4 gives some properties of flours obtained from untreated slices of peeled and unpeeled sweet potato. Peeling had little effect on these properties. Baking trials using a white wheat flour to which had been added ten and fifteen percent of these flours gave products that were indistinguishable in colour, texture and taste. Flour from unpeeled sweet potatoes was therefore used in all subsequent experiments.

Effect of SO_2 treatment on colour and baking properties

Improvement in colour of the raw flour was obtained without loss of baking quality by SAKURAI et al. (1953) in flour containing more than 120 ppm SO_2.

Table 4. Some properties of spray-dried light brown flour prepared from untreated slices of the peeled and unpeeled sweet potato cultivars

	Cultivar '049'		Cultivar 'C9'	
	Peeled	Unpeeled	Peeled	Unpeeled
Moisture % (dry wt)	3·24	3·34	3·12	3·15
Fibre % (dry wt)	0·92	1·20	1·57	1·69
Ash % (dry wt)	1·58	1·72	1·69	1·74
Reducing sugars % (dry wt)	4·05	4·31	3·15	3·09
Total sugars % (dry wt)	8·24	8·04	7·22	7·12
Crude protein % (dry wt)	3·8	3·6	3·0	2·8
Particle size:				
Through No. 150 Sieve (%)	69·4	69·0	68·8	68·4
Through No. 100 retained on No. 150 Sieve (%)	14·5	14·3	20·5	21·0
Through No. 60 retained on No. 100 Sieve (%)	16·1	16·7	10·7	10·6

However, our baking trials have indicated adverse effects on baking properties when the SO_2 content exceeded 100 ppm.

Soaking sweet potato slices of 2 to 3 mm thickness in a one percent sodium metabisulphite solution for one hour, and washing twice with water before drying, gave a cream coloured flour with an SO_2 content of 25 to 50 ppm and with unimpaired baking properties.

Effect of sweet potato flour particle size on loaf volume

The sweet potato flour was graded into three batches, the first containing all flour passing through a No 200 sieve, the second containing those in the range No 100 to No 200 sieve and the third containing those in the range No 60 to No 100 sieve. The total sweet potato flour was made up of 54 percent of batch one, 39 percent of batch two and 7 percent of batch three.

Batches of composite flour were made up containing 15 percent of any one grade and made into bread to test the effect of sweet potato flour particle size on loaf volume. Table 5 shows that as the particle size decreased the loaf became denser, giving a smaller volume of bread. The small decrease in volume of loaf with particle size may be due to the larger amount of free starch in the batch with particle sizes all passing through a No 200 sieve.

Effect of introducing various quantities of potato flour

(a) '049' Flour

Introduction of 15 percent '049' flour gave a loaf which was almost identical to the standard wheat loaf, except for the light grey colour of the crumb. A twenty percent introduction gave a smaller and less attractive loaf. It had a very slight off-odour and taste when hot, but this disappeared on cooling. This loaf was acceptable but less so than the 15 percent loaf. The 25 percent loaf was unacceptable because of its distinct off-flavour and taste. The loaves are illustrated in Figure I.

An acceptability trial with ten families (40 individuals) showed full acceptance for the 15 percent loaf. The crumb colour was commented upon but no objection was raised.

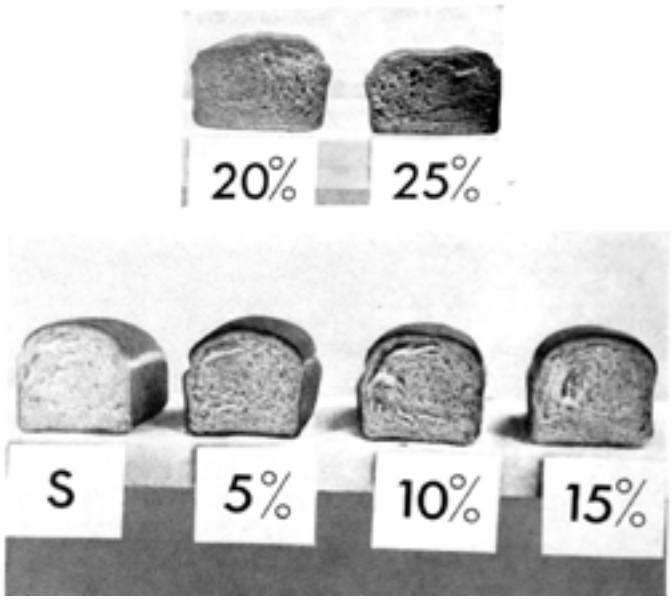

Figure 1. Loaves containing various proportions of sweet potato flour. S denotes the standard loaf (100 percent wheat). Percentages denote proportion of sweet potato flour in each loaf

(b) 'C9' Flour

Bread containing five percent 'C9' flour gave an acceptable loaf; with ten percent the loaf was fair, but that from 15 percent substitution was unacceptable.

Table 6 gives the properties of bread baked from composite flours containing varying proportions of sweet potato flour.

Comparison of spray-dried and cabinet-dried flours

Table 7 gives some properties of spray-dried and cabinet-dried flours prepared from treated slices of '049'. The products were similar except for the higher moisture content of the cabinet-dried flour and the higher sugar content of the spray-dried flour. The latter possibly arose from hydrolysis of the slurry during preparation and storage in the feed hopper while spray drying. Bread baked from 15 percent substitution gave very similar products. Table 8 gives the properties of the bread.

Table 5. Relationship between sweet potato flour particle size and loaf volume

Particle size batches	*> No. 200 Sieve*	*No. 100 to No. 200 Sieve*	*No. 60 to No. 100 Sieve*	*Total*
Loaf volume ml/g ml/kg flour	3·3 5800	3·4 5950	3·5 6200	3·5 6205

Table 6. Effect of different proportions of sweet potato and wheat flour on characteristics of loaves baked under controlled conditions

Character	Cultivar								
	'049'						'C9'		
Sweet potato flour %	0	5	10	15	20	25	5	10	15
Loaf volume:									
ml/g	4·6	4·2	4·3	4·3	3·7	2·8	4·0	3·8	2·7
ml/kg flour	7429	7214	7286	7357	6333	5000	7000	6428	4571
Shape:	stable	stable	stable	stable	slight fall	fallen	stable	slight fall	fallen
Colour:									
crust	pale brown	pale brown	brown	brown	brown	brown	pale brown	brown	brown
crumb	white	light grey	light grey	light grey	light grey	light grey	light grey	light grey	light grey
Texture:									
crust	smooth	smooth	smooth	smooth	rough few cracks	rough many cracks	smooth	rough few cracks	rough many cracks
crumb	cells even (good)	cells even (good)	cells even (good)	cells even (good)	cells uneven (very fair)	cells uneven (fair)	cells even (good)	cells uneven (very fair)	cells uneven (fair)
Taste:	good	good	good	good	fair	poor	good	fair	poor

Table 7. Some properties of spray-dried and cabinet-dried flours prepared from slices of sweet potato cv. '049'

Method of Drying	Spray	Cabinet
Colour	cream	cream
Moisture % (dry wt)	2·48	7·2
Fibre % (dry wt)	1·20	1·42
Ash % (dry wt)	1·71	1·55
Reducing sugars (dry wt)	4·43	2·80
Total sugars % (dry wt)	8·24	6·30
Crude protein % (dry wt)	3·5	3·2
Fat % (dry wt)	0·40	0·41
Particle size:		
Through No. 150 Sieve %	69·2	68·0
Through No. 100 retained on No. 150 Sieve %	14·8	20·5
Through No. 60 retained on No. 100 Sieve %	16·0	12·5

Comparison of controlled and home baking

In most developing countries baking is commonly done by primitive manual methods and seldom with semi-automatic equipment. A comparison was therefore made between baking under conditions which were all carefully controlled and baking under home conditions where personal judgement was used.

Except for a difference in loaf volume between the controlled and the home baked bread, the loaves were identical. Table 9 gives the loaf volumes for controlled and home-baked bread.

Use of binding agents

It has been reported (Jongh et al., 1968 and KIM and De Ruiter, 1968) that the problem with root-crop flour doughs arises from the absence of the strongly cohesive and elastic properties of wheat flour doughs. Jongh showed that the addition of one percent glyceryl monostearate strengthens the root crop flour dough and produces a loaf of greater volume and better crumb texture. This was confirmed by KIM and DE Ruiter who studied 20 different binding substances using a composite flour made up of 70 percent yam flour and 30 percent low fat groundnut flour.

In an attempt to increase the proportion of sweet potato flour, one percent glyceryl monostearate and one percent glyceryl monopalmitate (commercial grades) were added to two composite flours, one containing 20 percent '049' and 80 percent wheat flour and the other 20 percent '049', five percent of a high protein additive and 75 percent wheat flour. Three high protein

Table 8. Characteristics of bread baked under home conditions from a mixture of 85% wheat flour and 15% spray-dried or cabinet-dried sweet potato flour made from treated slices of cv. '049'

	Flour type	
	Spray dried	*Cabinet dried*
Loaf volume		
ml/g	3·5	3·5
ml/kg flour	6200	6205
Shape	*Normal*	*Normal*
Colour		
Crust	*Brown*	*Brown*
Crumb	*Light grey*	*Light grey*
Texture		
Crust	*Smooth*	*Smooth*
Crumb	*Cells even, normal*	*Cells even, normal*
Taste	*Good*	*Good*

Table 9. Comparison of loaf volume between controlled and home-baked bread

Method of baking	*Controlled*		*Home*	
Composite flour	100% *Wheat*	15% *'049'*	100% *Wheat*	15% *'049'*
Volume:				
ml/g	4·6	4·3	3·7	3·5
ml/kg flour	7429	7357	6500	6200

additives were used, fish protein concentrate and two types' of cottonseed flour.

The results obtained as shown in Table 10 were disappointing because the small improvement in loaf volume, shape and texture was smaller than had been expected from previous reports.

Effect of high protein additives on baking properties

Table 11 shows that the addition of five percent of a high protein concentrate such as fish protein concentrate or cottonseed flour to a composite flour containing 20 percent potato flour had very little effect on the baking properties. The texture and flavour did not differ from that of bread made from composite flour containing 75 percent wheat flour.

Effect of sweet potato flour on pastries

Composite flours containing various proportions of sweet potato flour were used for making pastries (Table 12). The proportion of sweet potato flour that could be used increased in accordance with the sweetness of the product, ranging from 15 percent for unleavened bread to 30 percent for cookies.

Quality of the product was related to the sweet potato cultivar from which the flour was made, and at any given rate of admixture with wheat flour '049' gave a more acceptable product than 'C9', although neither yielded a satisfactory biscuit. The data in Table 3 give no indication of why '049' should have better baking properties than 'C9'. The differences in fibre, sugar, fat, and crude protein content seem too small to affect the baking properties to so great an extent.

Table 10. Effect of glyceryl mono-esters on bread made from a mixture of 80% wheat and 20% sweet potato ('049') flour under home baking conditions

	Composite flour	*Composite flour plus 1% glyceryl monostearate*	*Composite flour plus 1% glyceryl monopalmitate*
Loaf Volume:			
ml/g	2·9	2·9	3·1
ml/kg flour	5050	5100	5400
Shape:	*Slight fall*	*normal*	*normal*
Colour:			
crust	*Light brown*	*light brown*	*light brown*
crumb	*light grey*	*light grey*	*light grey*
Texture:			
crust	*Rough, few cracks*	*smooth*	*smooth*
crumb	*uneven cells*	*uneven cells*	*uneven cells*
Taste:	*slight potato*	*slight potato*	*slight potato*

Table 11. Effect off five per cent high protein additive and binding agents on bread made from a mixture of 75% wheat and 20% sweet potato flour (cv. '049') under home baking conditions

	High protein additive								
	FPC			*Cottonseed flour (glandless)*			*Cottonseed flour*		
	Binding agent			*Binding agent*			*Binding agent*		
	0	1% *stearate*	1% *palmitate*	0	1% *stearate*	1% *palmitate*	0	1% *stearate*	1% *palmitate*
Volume:									
ml/g	2·9	2·9	2·8	2·6	2·8	2·8	2·7	2·8	2·8
ml/kg	5100	5050	5000	4600	4750	4700	4800	4850	4900
Shape:	*normal*	*normal*	*normal*	*normal*	*normal*	*normal*	*normal*	*normal*	*normal*
Colour:									
crust	*pale brown*	*pale brown*	*pale brown*	*brown*	*brown*	*brown*	*golden brown*	*golden brown*	*golden brown*
crumb	*grey*	*grey*	*grey*	*light grey*	*light grey*	*light grey*	*yellowish*	*yellowish*	*yellowish*
Texture:	*uneven, cells larger at top, compressed at bottom, gritty to the tongue*			*uneven, cells larger at top, compressed at bottom*			*uneven, cells larger at top, compressed at bottom*		
Taste:	*All had slight off flavour*			*All had slight off flavour*			*All had slight off flavour*		

Table 12. Effect of sweet potato flour on pastry quality

Product	*% Sweet Potato flour*	*Cultivar* '049'	*Cultivar* 'C9'
Roti (unleavened bread)	15	*good*	*poor*
Sponge cake	20	*good*	*poor*
Raisin bread	20	*good*	*poor*
Cookies	30	*good*	*poor*
Pancakes	20	*good*	*poor*
Doughnuts	20	*good*	*poor*
Sweet cream biscuits	15	*poor*	*poor*

Good denotes acceptable as compared with product made from all wheat flour.
Poor denotes unacceptable.

Sweet potato flour prepared from cultivar '049' may be used without any difficulty as a substitute for wheat flour at a rate of up to 15 percent in bread making and at 20 to 30 percent in pastries. Bread containing 20 percent was also acceptable although less so than that containing 15 percent. Flour from this cultivar was of poor quality for bread and pastries.

Flour made from peeled and unpeeled sweet potatoes differed little in baking properties. Sodium metabisulphite treatment improved the colour of the flour, but an SO2 content greater than 100 ppm affected baking properties.

Addition of one percent glyceryl monostearate and one percent glyceryl monopalmitate to the composite flour only slightly improved the bakingproperties.

A high protein additive had little effect on baking properties.

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