

USE OF SWEET POTATOES FOR FLOUR AND BREAD *

By

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INTRODUCTION

According to Cooley (3), "The sweet potato surpasses the white potato in its content of fat, carbohydrates, fiber, sugar, starch, calories and the vitamins carotene, riboflavin and pantothenic acid. In 1944, of more than a billion bushels produced throughout the world, over 600 million were raised in China, over 68 million in the United States". He states: "In feed value three pounds of fresh sweet potatoes which contain from 60 to 70% moisture are roughly equivalent to one pound of corn. A 200—300 bushel crop of sweet potatoes per acre would therefore be equivalent to 100 bushels of corn.."

In Israel, yields of sweet potatoes (virus diseases free) are between 3—5 tons per dunam, that is 480—800 bushels per acre. Thus sweet potatoes raised on one acre in this country are equivalent, in feed value, to 260—400 bushels of corn.

Work on the possibilities of raising sweet potatoes in Israel began in 1940. At that time experiments were carried out at the request of the growers to determine the possibilities of using this crop as a commercial source of alcohol. The analytical results given by the Laboratory of the Israel Chemists' Association (7) on air-dried sweet potatoes (locally grown variety Puerto Rico) were as follows:

<u>Water</u>	<u>Nitrogen</u>	<u>Fat</u>	<u>Sucrose</u>	<u>Invert. sugar</u>	<u>Total sugar</u>	<u>Starch</u>
11.94	0.53	0.38	11.12	8.28	19.40	19.63

These analyses showed that starch or energy value of a sample of sweet potato flour not containing water was 23%, i.e. equal to 28.7 liters of 95% alcohol, according to specific gravity; 20% of the weight of the original sample (water-free) was equivalent to 25 liters of 95% alcohol.

* Publication of the Agricultural Research Station, Rehovot. 1957 Series, No. 206-E

** 1 dunam = approx. 1/4 acre.

In 1950, it was decided once again to examine the agrotechnical problems pertaining to sweet potato production in Israel and to determine the uses to which the crop could be put. Thus a research project was carried out in Israel on yields and composition of 44 varieties of sweet potatoes (8).

A second research project was carried out on new varieties of sweet potatoes and their production (2). These investigations determined the characteristics of 60 varieties of sweet potatoes from all over the world, and included fertilizer experiments, seed spacing, harvest dates, and preliminary experiments on composition (sugar and starch). Yields per dunam averaged between 3 and 5 tons, i.e. much higher than for potatoes. The percentage of total and reducing sugars varied greatly for the different varieties. It is evident that there must be a differentiation between varieties destined for starch production and sweet varieties.

Simultaneously with these investigations, experiments were carried out in India (7). The Indian authors obtained a flour, cream white in color (rather than grey), by treating the red tubers for two minutes with boiling water. Experiments were made on the addition of sweet potato flour to bread. 1—30% sweet potato flour was added to non-leavened bread, an addition of 5% was found to give the best results.

The figures given by the authors upon addition of sweet potato flour to bread are:

<i>% sweet potato flour per 100g</i>	<i>Volume (cc)</i>	<i>Quality scale</i>
0	405	51.5
2	422	49.2
5	420	48.0
10	368	36.8

EXPERIMENTS AND RESULTS

Preliminary experiments showed that it is possible to add 3—10% sweet potato flour to regular wheat flour; best quality is obtained by adding 6% sweet potato flour. The following series of experiments was therefore arranged.

1. Use of peeled sweet potato flour for bread;
2. Use of sweet potato flour for bread after first pressing the peeled sweet potatoes;
3. Use of sweet potato flour for biscuits;
4. Use of sweet potato flour for cakes;
5. Use of dried unpeeled sweet potatoes as flour for bread;
6. By-products after processing starch of sweet potatoes; their composition and uses.

SERIES I — USE OF PEELED SWEET POTATO AS FLOUR FOR BREAD

A. PRELIMINARY EXPERIMENTS ON THE ADDITION OF SWEET POTATO FLOUR TO WHEAT FLOUR FOR BAKING

1. *Composition of Flours (%)*

<i>Ingredients</i>	<i>Sweet Potato Flour</i>	<i>White Flour</i>	<i>Standard Flour 87% milling</i>
Water	11.7	14.0	13.5
Ash	2.6	0.6	1.0
Protein	3.6		
Total Sugar	19.1		
Red. Sugars (% of total sugar)	7.2		
Cellulose	2.7		
Starch (calculated by diff.)	60.3		

2. *Diastase Activity (mg maltose /10 g flour)*

	<i>Without addition</i>	<i>Addition of 3% sweet potato flour</i>	<i>Addition of 6% sweet potato flour</i>
White flour	156	166	180
Standard flour	126	145	156

There is a parallel increase in diastase activity with addition of reducing sugars from sweet potato flour

3. *Flour Strength* — diameter of 100 g ball dough after remaining 3 hours at 30° C (mm)

	<i>Without addition</i>	<i>Addition of 3% sweet potato flour</i>	<i>Addition of 6% sweet potato flour</i>
White flour	78	75	72
Standard flour	69	65	61

The dough does not seem to soften, but rather becomes firmer. The dough also feels drier, probably because of the large water absorbing capacity of sweet potato flour.

4. *Baking Experiments*

<i>Sweet potato flour</i>	<i>With sugar (2½ %)</i>		<i>Without sugar</i>	
	<i>White flour</i>	<i>Standard flour</i>	<i>White flour</i>	<i>Standard flour</i>
Without addition	440	405	385	320
3% addition	450	400	440	360
6% addition	450	410	465	365

The addition of sweet potato flour + sugar does not decrease the volume of the bread.

Because of the sugars it contains the addition of sweet potato flour alone was sufficient to increase fermentation of the dough and the volume of the bread. The color of the bread-crust and crumbs becomes darker as the amount of sweet potato flour added increases.

B. ADDITIONAL EXPERIMENTS ON THE ADDITION OF SWEET POTATO TO WHEAT FLOUR FOR BAKING

1. Gas production (cc CO₂/100 g flour)

Period of fermentation	Without addition		3% sweet potato flour		6% sweet potato flour	
	white flour	standard flour	white flour	standard flour	white flour	standard flour
1 hour	156	246	288	220	240	256
2 hours	308	256	304	352	268	388
3 hours	272	292	248	336	352	328
4 hours	156	156	148	172	184	104
5 hours	4	112	64	124	52	140
Total	896	1062	1052	1204	1096	1216

The addition of sweet potato flour noticeably increased the amount of CO₂ during the 5 hours of dough fermentation.

2. Gas retention (volume of dough (100 g flour) after 3 hours (in vessel 5 cm diameter))

	Without addition	3% sweet potato flour	6% sweet potato flour
White flour	373	367	367
Standard flour	347	328	321

3. Diastase Activity

	Without addition	3% sweet potato flour	6% sweet potato flour
White flour	178	180	180
Standard flour	203	208	200

C. BREAD BAKING WITH ADDITION OF 6% SWEET POTATO FLOUR*

Tests and experiments: 1) Composition of the raw materials — sweet potato flour, white flour, standard flour; 2) baking experiments on an industrial scale with white and standard bread; 3) maintenance of freshness of white and standard bread with and without sweet potato flour, and 4) nutritional composition of white and standard bread with and without addition of sweet potato flour. All tests were duplicated.

* Sweet potatoes were stored during the winter before processing.

The tests were carried out according to Official Methods of American Agricultural Chemists as well as Methods of American Cereal Chemists (6, 1).

1. *Composition of Flours (%)*

<i>Ingredients</i>	<i>Sweet Potato flour</i>	<i>White flour</i>	<i>Standard flour</i>
Water	7.3	12.8	12.4
Ash	3.61	0.75	1.06
Gluten — wet		36.8	36.4
dry		12.5	12.6
Protein	4.7	11.4	12.2
Cellulose	5.3	0.2	0.8
Fat	0.84		
Red. sugars (dextrose)	21.2		
Sucrose	11.9		
Starch	45.0		
Ca as CaCO ₃		0.23	0.43

2. *Baking Experiments*

Two baking cycles were carried out, (Achdut Bakery, Tel Aviv), one on standard bread and the other on white bread. Each dough consisted of 50 kg flour plus 3 kg sweet potato flour, i.e. 6% sweet potato flour.

The addition of other ingredients — water, yeast, salt, and also kneading time and fermentation, were according to current bakery practices.

The dough characteristics of standard and white flour + the 6% sweet potato flour as compared to those of ordinary flour were:

Strength: regular

Touch: wet to the hand when worked

Color: regular

Fermentation: quicker (with sweet potato flour).

Of the 200 loaves of white bread obtained, 20 were taken for tests and experiments while 180 were sold in stores together with the regular white bread from the same baker. No comments were made by the stores or the customers, i.e. the public did not observe any change.

Also 50 loaves of bread were sold in stores together with regular standard bread from the same bakery. Again no comments were made.

Properties of the bread as compared to regular standard or white bread:

<i>Taste</i>	<i>Smell</i>	<i>Appearance</i>	<i>Crust structure</i>	<i>Crumb structure</i>
Normal	Normal	No difference in crumb color	Small cracks, crust browner	Larger pores

3. Stalenes of Bread

a) Compressibility (cc)

Time	Standard Bread		White bread	
	regular	6% <i>s.p.f.</i>	regular	6% <i>s.p.f.</i>
after 24 hrs.	0.4	0.4	0.5	0.6
after 48 hrs.	0.3	0.35	0.3	0.4
after 72 hrs.	0.25	0.3	0.3	0.35

As compressibility is increased, so too is the feeling of freshness.

b) Water Absorption

Time	Method	Standard Bread		White Bread	
		Regular	6% <i>s.p.f.</i>	Regular	6% <i>s.p.f.</i>
After 24 hrs.	weighing	3.1	3.0	3.7	3.6
After 48 hrs.	weighing	2.75	2.5	3.3	3.0
After 72 hrs.	weighing	2.6	2.5		
After 72 hrs.	Measurement of sediment (10 g)	32	39.5	38	39.0

Swelling of stale bread, i.e. amount of water which stale bread absorbs, is much smaller than that of fresh bread.

4. Comparison of Food Composition and Properties (%)

Ingredients	Standard Bread		White Bread	
	Regular	6% <i>s.p.f.</i>	Regular	6% <i>s.p.f.</i>
Water	35.9	37.4	31.6	32.1
Ash (incl. salt)	2.5	1.9	1.8	1.6
Protein	8.9	8.6	8.6	8.3
Cellulose	0.7	0.9	0.2	0.3
Red. Sugars	1.4	1.7	1.2	1.8
Sucrose	0.3	1.4	0.4	0.7
Starch	49.3	48.2	53.2	54.1
Acidity	7.0 ⁰	6.2 ⁰	3.0 ⁰	3.0 ⁰
porosity	56.0	56.9	69.9	70.2

Both for standard and white bread containing sweet potato flour, water content and porosity are higher.

CONCLUSIONS

1. Bread baked with 6% sweet potato flour was similar in taste, quality, and inner and outer appearance to regular and white bread.

2. Volume of bread compared to weight: In laboratory baking experiments where dough composition and preparation were supervised, volume of bread made with sweet potato flour was, on the average, 15% greater than that of regular bread. Even in a large bakery where workers were unused to such flour composition and took no extra precautions in obtaining maximum results, porosity of this bread was noticeably higher.

3. Output (quantity): The addition of sweet potato flour increased the output of the bread; water content in this bread was, on the average, 1% higher.

4. Freshness and prevention of staleness: The experiments proved that there is no difference in the degree of freshness between regular and sweet potato bread.

5. Nutritional value: No obvious difference exists in the nutritional value of sweet potato and regular bread. There is a slight decrease in protein content, from 8.9% to 8.6%.

SERIES II — USE OF SWEET POTATO FLOUR FOR BREAD AFTER FIRST PRESSING THE PEELED SWEET POTATO

The experiments included tests on the raw materials (sweet potato flour after pressing, and white and standard flour mixtures), and baking experiments with both types of flour with additions of various percentages of sweet potato flour. These experiments included volume measurements of the baked product, measurements of the influence of sweet potato flour additions on diastase activity of the flour as well as physical properties of the dough. The baking experiments with ordinary dough as well as with dough containing added sugar were carried out according to the methods of the Cereal Chemists of the United States (1).

A. COMPOSITION OF THE FLOURS (%)

1. *Sweet potato flour after pressing*

Water	7.1
Ash	3.0
Protein	4.6
Fat	1.1
Cellulose	6.0
Red. sugars (dextrose)	19.2
Sucrose	9.7
Starch	49.3
pH	5.3
color	whitish-yellow

The high percentage of sugars in the sweet potato flour maintained after pressing may be noted from the table.

2. Wheat flour (%)

	White flour	Standard flour
Water	13.2	12.9
Ash	0.68	1.52
Ca (as carbonate)	0.14	0.24
Protein	10.3	12.9
Gluten — wet	31.8	32.6
“ — dry	10.3	10.8
“ — quality	good	weak, short

* flour in this country is tested for Ca (expressed as carbonate) as calcium carbonate is added in the mills.

At the present time standard flour is of high milling percentage; the white flour has been removed by sifting, hence the large variations in baking characteristics of the flour.

B. INFLUENCE OF ADDITION OF SWEET POTATO FLOUR AFTER PRESSING ON FIRMNESS OF THE DOUGH

Testing was made by measuring the degree of expansion of the dough (100 g) after remaining for 3 hours at 30° C (official method in the Soviet Union). Diameter of the ball of dough was:

White flour	66 mm
White flour + 3% sweet potato flour	68 "
Standard flour	63 "
Standard flour + 3% sweet potato flour	63 "

Firmness of the dough and its strength (without fermentation) are not influenced by the addition of sweet potato flour.

C. DIASTASE ACTIVITY (mg maltose per 10g flour)

	White flour	Standard flour
Without addition	156	130
3% sweetpotato flour	188	201
6% sweet potato flour	231	231
10% sweet potato flour	267	292

D. BAKING EXPERIMENTS (cc per 100 g flour)

Sweet potato Flour	With sugar		Without sugar	
	white flour	standard flour	white flour	standard flour
Without addition	415	305	315	275
3% addition	340	305	360	308
6% addition	310	264	340	290
10% addition	280	242	315	280

Addition of sweet potato flour (after pressing) does not change the taste of the bread. The crumb color of standard bread, which at any rate is dark grey, does not change; on the other hand, with increased additions of sweet potato flour the crumb of the white bread acquires a grey appearance.

The internal structure of the bread to which 6% sweet potato flour has been added does not differ from that of the regular bread.



Plate 1: Standard bread, from left to right:
without sweet potato flour addition (0); 3% addition; 6% addition.

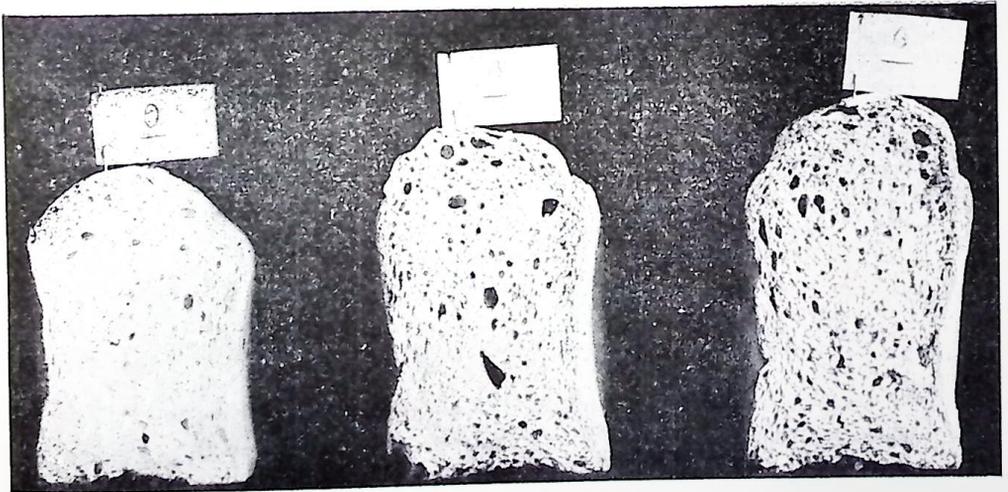


Plate 2: White bread from left to right:
without sweet potato flour addition (0); 3% addition; 6% addition.

CONCLUSIONS

By pressing sweet potatoes a product is obtained which is cheaper and easier to dry, has a high nutritive value, and contains a considerable amount of sugars.

As a by-product, a liquid is obtained which is rich in sugars and which in other countries is used for yeast production and beverages.

Addition of 3—6% sweet potato flour after pressing to white or standard flour has no deleterious effect on dough characteristics and firmness; rather it causes, because of its own sugar content (as compared to the practice of adding sugar) a large increase in the volume of the baked product and an improvement in the quality of the bread.

There is no negative influence on the color and taste of standard bread due to this addition; white bread becomes greyish as additions are increased.

ADDITION OF SWEET POTATO FLOUR TO STANDARD AND WHITE FLOUR

The results of various methods of preparing sweet potato flour carried out in previous years, are herein given. These experiments on the additions of sweet potato flour to standard and wheat flour had no negative influence upon bread quality.

1. COMPOSITION OF SWEET POTATO FLOUR

<i>Experiment No.</i>	<i>Sweet Potato Color</i>	<i>Method of treatment</i>	<i>Date</i>	<i>Moisture %</i>	<i>Ash %</i>	<i>Protein %</i>	<i>Total sugars</i>	<i>Reduc. sugars.</i>	<i>Cellulose %</i>	<i>Starch %</i>	<i>Color of flour</i>
1	white	regular drying before grinding	30/4/54	11.7	2.6	3.6	19.1	7.2	2.7	60.3	reddish grey
2	white	regular drying before grinding	30/8/55	9.4	3.7	6.7	20.1	7.8	3.1	53.0	grey
3	white	sweet potatoes placed in boiling water before drying	30/8/55	7.7	2.0	8.0	23.3	16.5	3.7	55.3	yellow
4	white	sweet potatoes pressed before drying	30/8/55	4.7	2.8	6.7	11.6	6.2	3.1	71.7	brown
5	red	regular drying before grinding	26/11/42	11.9	3.14	3.3	19.4	8.28	2.9	—	red

2. BAKING EXPERIMENTS (cc per 100 g flour)

Experiment	Method of treatment	Date	Without addition of sweet potato flour		Addition of 3% sweet potato flour		Addition of 6% sweet potato flour		Addition of 10% sweet potato flour	
			standard flour	white flour	standard flour	white flour	standard flour	white flour	standard flour	white flour
1	Regular drying before grinding	1954	320	385	360	440	365	465	—	—
2	Regular drying before grinding	1955	265	275	295	325	290	390	280	400
3	Sweet potatoes placed in boiling water before drying	1955	—	275	—	285	—	320	—	335
4	Sweet potatoes pressed before drying	1955	285	275	310	310	295	320	275	320

SERIES III — BISCUIT BAKING WITH ADDITION OF 10% SWEET POTATO FLOUR

The baking experiments were carried out at the Froumine Biscuit Factory at Bnei Brak.

A. COMPOSITION OF FLOUR USED FOR BAKING EXPERIMENTS (%)

Water	12.2
Ash	0.80
Ca as CaCO ₃	0.32
Protein (N x 6.25)	11.1
Crude fiber	0.7
Gluten — wet	29.0
— dry	10.0
— quality	weak
pH	5.3

As sweet potato flour contains 37% sugar the amount of sugar usually added was reduced by 3%. Starch was also not included though usually 6% is added.

Dough — characteristics did not differ from regular dough under similar conditions.

B. COMPOSITION AND QUALITY OF BISCUITS

<i>Physical characteristics</i>	<i>Regular</i>	<i>Addition of s. p. f.</i>
appearance	good	browner
inner appearance	white	white
taste	good	good
crumbing	none	none
pH	6.2	6.4
<i>Nutritional composition (%)</i>		
water	3.3	3.2
fat	18.9	18.4
red. sugars	3.6	4.8
sucrose	17.8	18.3
protein (N x 6.25)	9.2	9.3
crude fiber	0.5	0.6

CONCLUSIONS

The addition of 10% sweet potato flour did not change the taste, quality, or nutritional composition of the biscuits.

SERIES IV — USE OF SWEET POTATO FLOUR FOR CAKE BAKING

Two types of cakes were baked with flour containing 10% sweet potato flour; the control was white cake flour.

The two types of cakes were: a) Yeast cakes; b) cookies.

1. COMPOSITION AND QUALITY OF WHITE CAKE FLOUR %

Water	14.2
Ash	0.64
CaCO ₃	0.19
Protein	11.5
Wet gluten	37.3
Dry gluten	12.5
gluten quality	good
pH	5.1

2. QUALITY ESTIMATION (scoring) (%)

a) *Yeast cakes*

	<i>With sweet potato flour</i>	<i>Without sweet potato flour</i>
Structure	15	15
Crust	5	5
Inner softness	15	15
Porosity (lightness)	15	15
Structure (granular)	20	15
Color	10	15
Taste and smell	10	10
General estimation	90	90

The main difference in the crumb is that cakes with sweet potato flour are slightly yellowish.

b) *cookies*

	<i>With sweet potato flour</i>	<i>Without sweet potato flour</i>
Crumb color	No change	No change
Porosity	good	No change
Taste and appearance	good	No change
Friability	normal	No change

3. SPECIFIC VOLUME (CC PER/G)

	<i>With sweet potato flour</i>	<i>Without sweet potato flour</i>
Yeast cakes	3.8	3.9
Cookies	1.8	1.6

4. NUTRIENT COMPOSITION (Yeast cakes)

	<i>With sweet potato flour</i>	<i>Without sweet potato flour</i>
Water	30.8	28.7
Protein	9.0	9.4
Fat	5.8	5.6
Total sugars	10.7	9.2

CONCLUSIONS

There was no difference in quality, appearance, taste and smell between cakes baked with or without the addition of sweet potato flour.

The two types of products baked with sweet potato flour additions were marketed in large quantities and no comments were received.

From the point of view of nutrient composition, there was no difference between ordinary cakes and those to which 10% sweet potato flour was added.

SERIES V — USE OF DRIED UNPEELED SWEET POTATOES AS FLOUR FOR BREAD

A. COMPOSITION (%)

Water	9.1
Ash	3.76
Acid in soluble ash	0.06
Protein	3.1
Crude fiber	3.1
Total sugars	32.7
Reducing sugars	17.8
Carbohydrates (by diff.)	48.0
Acidity	9.3 ⁰
pH	6.1
Appearance	Yellowish-grey

B. BAKING EXPERIMENTS — UNPEELED SWEET POTATO FLOUR (WITHOUT ADDITION OF SUGAR; (cc per 100 g flour)

	<i>White flour</i>	<i>Standard flour</i>
Without sweet potato flour	402	322
3% addition	438	334
6% addition	462	324
10% addition	436	289

The crumb of the bread became greyer with increased additions of sweet potato flour; there was no noticeable difference in the darkening of the crust.

The texture of the crumb was good. The porosity was especially good and regular in bread to which 3 and 6% sweet potato flour had been added. The crust of bread containing 10% sweet potato flour was full of cracks.

CONCLUSIONS

The addition to bread of 3 and 6% sweet potato flour from dried unpeeled sweet potatoes, considerably increases its volume and has a positive influence on the crumb structure.

The influence of a 10% addition is negative as cracks appear in the crumb.

Color of the crumb and crust became greyer with increased additions of this sweet potato flour.

SERIES VI — SWEET POTATO BY-PRODUCTS (RAW)

A. COMPOSITION

Water	13.1
Ash	2.97
Protein	0.9
Crude fiber	13.8
Total sugars	14.8
Red. sugars (% of total sugars)	11.4
Carbohydrates (by diff.)	64.4
Acidity	1.4 ^o
pH	6.4
Appearance	Grey color

B. BAKING EXPERIMENTS WITH FLOUR OF SWEET POTATO BY-PRODUCTS (without sugar; cc per 100 g flour)

	<i>White flour</i>	<i>Standard flour</i>
Without sweet potato flour	384	378
3% Addition	341	318
6% Addition	294	234
10% Addition	240	222

The crumb of standard bread became greyer with increased additions of sweet potato by-products.

The crust was not brown, and became greyer with increased additions of sweet potato by-products.

The dough of standard bread became more brittle as the percentage of sweet potato by-products increased, and more cracks appeared in the crumb.

No change took place in white bread.

CONCLUSIONS

The addition of sweet potato by-products to the dough of standard bread has a negative influence on the bread quality. Bread volume decreases, the crumb becomes grey, the crust does not become brown, and the dough becomes brittle. These negative characteristics become more pronounced as the percentage of sweet potato by-products is increased.

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