The Processing Potentials of Yams (*Dioscorea* spp.) II. Precooked Drum Dried Flakes—Instant Yams[1]

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ABSTRACT

Drum dried yam flakes were prepared from six varieties representing four species. Steam cooking led to lower flesh loss than water cooking. Certain parts of the cooked yams were pigmented. Stickiness of the reconstituted product varied with varieties, indicating that the free starch content (blue value) was not the only factor affecting stickiness; e.g. Lisbon with a blue value of 860 was less sticky than Cush-cush which had a blue value of 286. The effect of maturity on flake quality indicates that immature tubers were unsuitable for flake production, while storage of tubers up to 20 weeks had no apparent effect on flake quality. Storage studies show that there was a greater loss in quality of flakes stored in polyethylene bags than flakes stored in glass jars, with amber-coloured jars showing a slightly better keeping quality than clear jars. Moisture content was a critical factor in keeping quality. *D. alata*—Lisbon, Coconut and Oriental gave products with high acceptability.

INTRODUCTION

Most tropical root-crops store poorly; therefore, processing becomes essential if they are to make their contribution to the basic food supply of tropical developing countries. With this in mind the Department of Chemical Engineering, University of the West Indies, Trinidad, initiated research in tropical root-crops processing through the Root-Crops Programme of the Faculty of Agriculture. One of the tropical root-crops being studied is yam (*Dioscorea* spp.). This paper discusses the processing and storage of a precooked drum-dried product, which confirms the results of Rodríguez, et al. (4,5).

MATERIALS AND METHODS

The yams studied were six varieties from four species; *D. alata*—Lisbon or White Lisbon, Oriental, and Coconut; *D. rotundata*—Portuguese; *D. trifida*—White Cush-cush; and *D. esculenta*—Chinese.

The Lisbon, Oriental, Cush-cush, and Chinese were obtained from the

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University Field Station, St. Augustine, Trinidad; the Coconut, from Barbados; and the Portuguese, from St. Vincent. The yam tubers were hand-peeled, cubed (2 cm^3) and steam cooked (atmospheric pressure) for 25 to 30 min. Excessive cooking must be avoided as this results in cell rupture and thus a high blue value index. The cooked yams were mashed to a paste with the addition of 0.5% glyceryl monostearate in a Hobart[3] mixer at low speed using a "K" or paddle beater. Water may be added to obtain the desired consistency. The paste was fed to the nip of the double-drum drier.

Moisture and total solids were determined using the oven drying method at 100° C (3); the fat content, by Soxhlet extraction using petroleum ether; fibre and ash, by AOAC method (3); and crude protein, by Kjeldahl method using the conversion N × 6.25. The blue value index was determined by the Mullins' method (2); and phenol, by Swain and Hillis method (6). Total and reducing sugars were determined by a modified Berlin method (3).

The optical density (OD) of the 60% ethyl alcohol extract was determined as follows: 5 g of yam flakes were extracted with 25 ml 60% ethyl alcohol, centrifuged, and the optical density measured at 400 nm using 60% ethyl alcohol as standard on a Spectrum 20[3]. Water holding capacity (WHC) was determined as follows: 1 g of yam flakes was mixed thoroughly with 10 ml water in a 15-ml graduated centrifuge tube, then centrifuged for 15 min at 3500 r/m (1500 g), and the volume of solids and liquid read. Water holding capacity in milliliters is equal to volume of solids × 100 while WHC in grams is equal to [(10 − volume of liquid) × 100] + 100. Water holding capacity expresses the volume or weight of reconstituted solid per 100 g flakes.

Sensory evaluations were determined by trained panelists. Evaluations included appearance, odour, taste, and texture. The standard used was a freshly prepared, boiled and mashed yam. The score was as follows: 10, very good; 8, good; 6, satisfactory; 4, fair; 2, poor. A score of less than 4 was unacceptable in that particular property.

RESULTS AND DISCUSSION

Initially a preliminary survey was made of the six varieties using the following operating specifications which were previously determined as giving good results: Diameter of drums, 25.0 cm; speed of rotation, 3.5 r/m; clearance at nip between drums, 3 to 7 × 10^{-3} cm; surface tem-

[3] Trade names are used in this paper solely for the purpose of providing information. Mention of a trade name does not constitute a guarantee or warranty of the equipment by the Agricultural Experiment Station of the University of Puerto Rico or an endorsement over other equipment or materials not mentioned.

perature of drums, 150° C; approximate moisture range of "mash", 70 to 80%; and approximate moisture range of flakes, 6 to 10%.

The organoleptic properties of the freshly prepared flakes and after 6 months storage in clear stoppered glass jars placed on open shelves at ambient conditions (28 to 30° C and 80 to 90% relative humidity) and in the presence of sunlight, are given in table 1. From this survey three varieties Lisbon, Coconut, and Chinese were chosen for more intensive study. This selection was based on availability. They were studied for the effect of maturity on keeping quality when stored under air and nitrogen in glass jars and polyethylene bags.

COOKING

Boiling the peeled yams in water, in a 2:1 ratio by weight of water to yam, resulted in leaching and fragmentation loss of the order of 6.0 to 18.0% on a dry weight basis. When the proportion of water was increased, the losses increased. Increasing the particle size of the yam pieces only slightly reduced the loss. Cooking in open steam reduced the loss considerably, to 2 to 3%.

The tubers often showed color changes on cooking. These varied from faint pink to grey or brownish grey. These changes were especially evident in immature tubers, near the stem end of mature tubers, and around damaged parts. Judicious blending of white with discoloured parts produced acceptable products.

DRUM DRYING

Paste made from Lisbon, Coconut, Portuguese, and Oriental tended to stick to the drum surface, that is, the knife edge did not remove the product from the drum surface clearly. Improvement was obtained by the addition of 0.5% glyceryl monostearate. The varieties Cush-cush and Chinese posed no problem even without the additive. The sticking problem was more intense in immature than in mature tubers.

A high temperature (150° C) and a short retention time (9.6 s) were found to produce a better product than a low temperature (105° C) with long retention time (30.0 s).

Blue value index and stickiness of yam flakes (≃700) when reconstituted was relatively higher than for potato (*Solanum tuberosum*) flakes (≃75). Free starch, as indicated by the blue value index, does not seem to be the only factor contributing to stickiness, e.g. table 1 shows that stickiness increases from Lisbon (b.v. 860) through Oriental (b.v. 717) to Cush-cush (b.v. 286) while the blue value index decreases, respectively. Maturity or length of post-harvest storage did not seem to affect this property.

TABLE 1.—*Organoleptic properties of yam flakes from mature tubers before and after storage*

Property	*D. alata*			*D. rotundata*	*D. trifida*	*D. esculenta*
	Lisbon	Coconut	Oriental	Portuguese	Cush-cush	Chinese
			Freshly prepared flakes			
Color (score-10)	White to pale cream (10)	Pale-cream (10)	White with purple tinge (10)	Cream (10)	White (10)	Pale yellow (10)
Odour (score-10)	Characteristic yam odour (10)	Characteristic yam odour (10)	Characteristic yam odour (10)	Characteristic yam odour (10)	Characteristic yam odour (10)	Characteristic yam odour (10)
Taste (score-10)	Yam flavour Blandish (10)	Yam flavour Blandish (10)	Strong yam Flavour (10)	Mild yam flavour (10)	Sweetish yam flavour (10)	Sweetish with bitter after taste (4)
Texture (score-10)	Fluffy (10)	Fluffy (10)	Fluffy but slightly sticky (8)	Sticky (6)	Sticky (6)	Very sticky (4)
Blue value index	860	605	717	941	286	1039
			After 6 months storage in clear glass jars at ambient conditions (28–30° C, 80 to 90% relative humidity in the presence of sunlight)			
Color (score-10)	Darkens slightly (8)	Darkens (6)	Darkens (6)	Darkens (7)	Darkens slightly (8)	Darkens slightly (9)
Odour (score-10)	Tinge of rancidity (7)	Tinge of rancidity (7)	Slightly rancid (6)	Tinge of rancidity (7)	Tinge of rancidity (7)	Slightly rancid (6)
Taste (score-10)	Fresh-bland (8)	Stale-bland (8)	Stale (6)	Stale-bland (7)	Little change (9)	Sweetish with slight bitter aftertaste (6)
Texture (score-10)	No change (10)	No change (10)	No change (8)	No change (6)	No change (6)	No change (4)
Blue value index	880	702	720	900	300	986

TABLE 2.—*Comparison of effect of maturity and storage of Lisbon yam on flake quality*

State	Tuber (raw)						Flakes (freshly prepared)					
	Immature		Mature		Over mature		Immature		Mature		Over mature	
Storage period of tubers (weeks)	0	20	0	20	0	20	0	20	0	20	0	20
Moisture, %	74.3	70.8	73.9	70.5	72.5	69.1	9.7	10.6	10.0	10.2	9.3	10.3
Total sugar, %[1]	2.77	2.33	3.71	3.89	3.92	4.24	2.30	2.30	3.59	3.70	4.01	2.62
Red sugar, %[1]	0.16	0.26	0.50	0.60	0.19	0.21	0.16	0.31	0.63	0.48	0.21	0.23
Crude fat, %[1]	0.17	0.20	0.14	0.31	0.17	0.22	0.21	0.41	0.25	0.36	0.23	0.26
Crude protein, %[1]	12.5	13.0	12.2	13.00	10.3	12.2	12.1	12.1	13.3	13.2	9.3	12.0
Vitamin C mg/100 g,	8.0	8.2	8.8	8.9	8.0	6.8	7.2	6.8	7.1	6.7	6.6	5.5
Fibre, %[1]	2.60	2.73	1.45	2.54	2.96	3.02						
Pectin, %[1]	2.83	5.01	4.61	5.71	5.81	5.10						
Ash, %[1]	3.33	4.00	2.22	3.02	2.62	3.02						
Phenol, %[1]	0.19	0.22	0.15	0.32	0.24	0.28						
Acidity mg NaOH/g,	2.8	2.2	2.4	3.2	2.2	2.2	1.7	2.0	2.2	2.5	2.8	2.6
pH	4.8	5.8	5.9	5.2	6.0	6.2	5.9	5.8	5.9	5.8	5.8	6.1
Free fatty acid % of total fat							18.9	25.2	29.3	30.5	29.9	30.9
OD of 60% EtOH extract							0.19	0.38	0.34	0.34	0.20	0.25
Water holding capacity												
volume							530	455	555	505	525	525
weight							540	565	580	540	560	560
Blue value index							532	426	739	795	756	739
Organoleptic (total maximum score = 40)							20	29	37	37	37	37

[1] Dry weight basis.

TABLE 3.—*Changes in properties of stored (28° C) flakes from Lisbon yam*

Maturity	Storage period (Week)		Package	Moisture dry wt %	pH	Acidity mg NaOH/g	Optical Density of 60% EtOH extract at 400 mμ	Organoleptic properties				
	Tubers	Flakes						Appearance (10)[1]	Odour (10)	Texture (10)	Taste (10)	Total (40)
Mature	0	0	Clear glass jar	10.0	5.6	3.3	0.115	9	10	8	10	37
	0	12	"	10.1	5.5	3.8	0.165	7	9	8	9	33
	0	24	"	10.6	5.4	4.6	0.240	6	8	8	8	30
	20	0	"	10.2	5.6	4.2	0.125	9	10	8	10	37
	20	12	"	10.4	5.6	4.4	0.145	8	9	8	9	34
	20	24	"	10.5	5.6	4.8	0.170	7	8	7	8	30
	0	0	Amber glass jar	10.8	5.6	3.3	0.115	9	10	8	10	37
	0	12	"	10.8	5.5	4.0	0.150	9	9	8	9	35
	0	24	"	11.0	5.5	4.2	0.215	8	8	8	9	33
Over mature	0	0	Clear glass jar	8.0	5.6	2.8	0.065	9	10	8	10	37
	0	12	"	8.6	5.6	3.0	0.070	8	9	8	9	35
	0	24	"	8.7	5.5	3.2	0.110	7	8	8	9	32
	20	0	"	10.0	5.6	3.2	0.080	9	10	8	10	37
	20	12	"	10.5	5.6	3.6	0.145	7	8	7	8	30
	20	24	"	11.0	5.5	3.8	0.195	6	7	7	7	27
	0	0	Poly bags	8.0	5.6	2.8	0.065	9	10	8	10	37
	0	12	"	11.2	5.5	3.2	0.085	7	7	8	7	29
	0	24	"	11.9	5.6	3.8	0.125	6	6	7	5	24
	0	0	Clear glass jar under N_2	9.0	5.6	3.2	0.080	9	10	8	10	37
	0	12	"	9.4	5.6	3.6	0.130	9	9	8	10	35
	0	24	"	10.7	5.7	3.8	0.160	8	8	8	8	32

[1] Maximum acceptability value.

TABLE 4.—*Changes in properties of stored flakes from Chinese and Coconut yams*

Maturity	Storage period (Week)		Package	Moisture dry wt %	pH	Acidity mg NaOH/g	Optical Density of 60% EtOH extract at 400 mμ	Organoleptic properties				
	Tubers	Flakes						Appearance (10)	Odour (10)	Texture (10)	Taste (10)	Total (40)
				Chinese yam flakes stored at 28° C								
Mature	0	0	Clear glass jar	7.7	5.7	2.0	0.070	9	10	5	4[1]	28
	0	12	"	8.0	5.8	2.1	0.080	9	8	4	4	25
	0	24	"	8.9	5.8	2.2	0.100	8	7	5	5	25
	18	0	"	5.0	5.8	2.4	0.085	9	9	6	4	28
	18	12	"	5.2	5.8	2.4	0.085	9	8	5	3	25
	18	24	"	5.6	5.8	2.5	0.090	8	7	5	5	25
Very mature	0	0	"	6.5	5.7	2.6	0.080	9	9	5	4	27
	0	12	"	6.5	5.7	2.6	0.080	8	8	4	4	24
	0	24	"	6.6	5.7	2.6	0.095	8	8	4	5	25
	0	0	Poly bags	6.0	5.7	2.6	0.080	9	8	5	4	26
	0	12	"	9.4	5.7	2.9	0.092	8	7	4	3	22
	0	24	"	9.6	5.7	3.2	0.115	7	6	4	3	20
				Coconut yam flakes stored at 37° C								
Mature	3	0	Clear glass jar	6.2	5.5	3.6	0.055	9	10	8	10	37
	3	8	"	6.3	5.5	3.8	0.065	7	9	8	9	33
	3	16	"	6.5	5.3	3.9	0.085	5	9	8	9	31
	17	0	"	7.7	5.6	4.2	0.080	8	10	8	10	36
	17	8	"	7.8	5.7	4.5	0.145	7	9	8	8	32
	17	16	"	7.9	5.7	4.6	0.190	5	9	7	6	27
	17	0	Clear glass jar under N_2	7.7	5.6	4.2	0.080	9	10	8	10	37
	17	8	"	7.8	5.7	4.5	0.125	7	9	8	8	32
	17	16	"	8.0	5.7	4.8	0.155	6	8	7	6	27

[1] Flakes prepared from Chinese yam had a distinctly bitter aftertaste.

MATURITY AND STORAGE OF TUBERS

A comparison of maturity of Lisbon for flakes showed that immature tubers cannot be used, while there is little or no effect between the mature and over mature tubers (table 2). Storage of the tubers for 20 weeks had little effect on the finished product (tables 3,4).

STORAGE OF FLAKES

Storage of yam flakes under air and nitrogen in clear and amber glass jars showed little change in quality for a storage period of 24 weeks (tables 3,4). However, storage in polyethylene bags 0.012 cm thick showed greater deterioration (browning and rancidity) due mainly to moisture absorption. The moisture content increased by approximately 3.6% in 24 weeks.

The acid value and optical density of the 60% ethyl alcohol extract seem the best indicators of deterioration of flake quality (table 4). Despite the low fat content of the flakes, a distinct rancidity was noticeable with increase in storage time and moisture content when the latter exceeded 12%.

Appearance, odour, and taste slowly decreased in quality with storage time (tables 3,4). The appearance showed darkening (browning), while the taste became bland, losing the characteristic yam flavour, with the odour distinctly rancid.

In the case of the Chinese yam, the flakes maintained a good appearance. However, because of a bitter aftertaste and a sticky texture, this product had a low acceptability.

For a West Indian market where a fluffy texture is required, only *D. alata*—Lisbon, Coconut, and Oriental may be used for "instant yam" production. Where a sticky texture is preferred, e.g., *fufu* in Africa (1), *D. rotundata*—Portuguese and *D. trifida*—Cush-cush may also be used.

RESUMEN

De seis variedades de ñame (*Dioscorea* spp.), que representan cuatro especies, se preparon copos desecados en una secadora de rolos. En la cocción a vapor se logró menos pérdida de fécula que en la cocción en agua. Algunas partes de los ñames cocidos estaban manchadas. La glutinosidad del producto reconstituido varió con las especies, indicando que el contenido de almidón libre (valor azul) no era el único factor que afectó la glutinosidad; por ejemplo, la variedad Lisbon, con un valor azul de 860 era menos pegajosa que la variedad Cush-cush, cuyo valor azul era de 286.

El efecto de la madurez en la calidad de los copos indica que los ñames inmaturos no eran apropiados para la producción de copos. Por otro lado, el almacenamiento de los tubérculos hasta 20 semanas, aparentemente no la afectó.

Estudios sobre el almacenamiento del ñame demuestran que hay mayor pérdida de calidad de los copos cuando éstos se envasan en bolsas de polietileno que cuando se envasan en frascos de cristal, y que los de cristal ambarino son un poco mejores que los de cristal claro.

El contenido de humedad fue un factor critico en la conservación de la calidad.

Las variedades Lisbon, Coconut y Oriental, todas de la especie *alata*, produjeron copos muy aceptables.

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