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## Studies of the Freezing of Green Plantains (*Musa paradisiaca*)

### IV. Effect of Cold Storage on the Quality of Frozen Sliced Green Plantains<sup>1</sup>

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#### ABSTRACT

Green plantains stored at 7° C (45° F) showed chilling injury about the 10th day. Slight changes in texture and a decrease in the starch content occurred during a storage period of 20 days. Dark spots in both peel and pulp caused by chilling injury affected the appearance of the fried tostones but did not lower the overall quality of the product. High quality tostones could be prepared from plantains stored at 13° C (55° F) for as long as 20 days. No significant difference could be found in the quality of tostones prepared from fruit stored at 7° and 13° C for 20 days. The time of storage had no effect on the yield of slices prepared from the refrigerated fruit at these temperatures.

#### INTRODUCTION

Hernández (2) in his study on the storage of green plantains showed that fruit treated with thiobendazole could be stored in sealed polyethylene bags containing an ethylene absorbent (Purafil) for 25 days at room temperature 29.0° C (85° F) and for 55 days under refrigeration at 13° C (55° F). Throughout this storage period, tostones of excellent quality were obtained, comparing favorably with those prepared from fresh green fruit. This study also showed that green plantains stored at 7.0° C (45° F) for 19 days suffered no change in chemical composition. During storage, a hardening of the pulp took place as evidenced by an increase in texture values measured with the shear press. When the fruit was stored at 13° C

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(55° F) it reached a turning stage around the twelfth day, the starch content decreasing while the total and reducing sugars increased.

The data presented by Hernández suggest that at both storage temperatures, 7° C (45° F) and 13° C (55° F), there is a time interval of several days in which the fruit suffers little change in chemical composition. If during a reasonable storage period, frozen slices of good quality could be prepared, the processor would have at his disposal a method of extending the storage life of the plantains without having to use the more expensive Purafil storage system. Therefore, it was felt convenient to investigate the effect of the cold storage of plantains at 7° C (45° F) and at 13° C (55° F) on the quality of the frozen slices and of the tostones prepared from them.

### MATERIALS AND METHODS

Plantains for these studies were obtained from experimental plots located on a private farm in the Naranjito area and from the local Río Piedras market. The fruit was stored in bunches in walk-in refrigerators at 7° C (45° F) and 13° C (55° F) with a relative humidity of 85 to 90 percent. Bunches were selected randomly at regular intervals for processing.

Fingers were removed from the stems and steam-peeled by treating them in a retort for 30 seconds at 80 lb/in<sup>2</sup>g. After releasing the steam pressure, the fruit was cooled with water sprays and the loose peel removed by hand. The peeled fruit was sliced crosswise into sections 2.54 cm (1 inch) thick. The fruit slices were steam blanched for 4 minutes and cooled with water sprays. The slices were sulfited by dipping for 4 minutes in a 0.6 percent potassium metabisulfite solution at pH 3.3. Following the sulfiting treatment, the slices were drained, packed in waxed cardboard boxes with vapor-moisture proof overwraps and quick frozen in a plate freezer at -43° C (-45° F). The frozen product was stored at -23.0° C (-10° F) until used.

For organoleptic tests, the samples were fried without thawing in shortening at 176.6° C (350° F) for 8 minutes, drained, flattened by pressing, and fried for a second time for 5 minutes at 190.5° C (375° F). The fried slices or tostones were submitted for organoleptic evaluation to a trained taste panel either under red or daylight according to the quality attributes to be measured. Two types of organoleptic tests were used: overall quality rating using a  $\pm 2$  scale (3) and ranking (4).

Starch was analyzed by the Carter and Neubert procedure (1). Texture was measured using a Food Technology Corporation electrical recording texture instrument following the procedure described by Sánchez Nieva et al. (5).

### RESULTS AND DISCUSSION

Processing data, shear press values and starch content for fruit stored at 7° C (45° F) are summarized in table 1. The data for the two experiments

conducted are listed separately. Storage at 7° C (45° F) for a period ranging from 5 to 20 days had no apparent effect on the yields of slices for processing. During storage, a progressive slight hardening of the pulp was observed and starch values decreased, indicating a slow ripening which is in accord with the results previously reported by Hernández (2).

Ranking tests were conducted with tostones prepared from fruit stored from 5 to 21 days at 45° F (7° C). Flavor and mouth-feel properties were evaluated under red light; color and appearance were judged under daylight. The results of the ranking tests for flavor and mouth-feel attributes show that tasters could not consistently detect significant differences among the samples that could be related to the time in storage.

TABLE 1.—*Starch content, shear press values and processing data for fruit stored at 7°C (45°F)*

Storage period	Starch content	Shear press values	Yield of slices	Trimming	Peel
Days	Percent	Kg	Percent	Percent	Percent
<i>Experiment 1</i>					
5	28.14	263.1	48.80	19.00	32.14
10	11.24	272.2	57.14	19.64	30.15
15	18.70	317.5	55.35	14.28	30.35
20	18.95	317.5	56.16	13.69	30.13
<i>Experiment 2</i>					
6	28.50	272.2	49.18	14.75	32.78
10	25.07	285.5	45.58	16.17	38.23
15	—	231.3	47.45	15.25	37.28
20	19.97	281.0	48.32	15.0	36.66

Processing data, texture values and starch content for fruit stored at 13° C (55° F) for 6 to 20 days is given in table 2. The data shows no effect of time of storage on the yield of slices. During 20 days of storage at 13° C (55° F) a slight softening of the pulp took place and starch values decreased, indicating progressive ripeness. The sample stored for 20 days was found to be in the turning stage when removed from the cold storage room.

The data from the two experiments in which samples were ranked for flavor and mouth-feel under red light (table 3) show that tasters could not find any difference among the samples. In the second experiment in which a fresh control also was included, tasters could not find any difference among the samples kept in cold storage nor between these and the control. In both experiments, tasters selected the sample stored for 20 days as superior in appearance. As the sample stored for 20 days was in a turning stage (starch content of 12 to 14 percent), it is probable that the more intense yellow color of this sample due to a more advanced stage of ripeness influenced taster

TABLE 2.—*Starch content, shear press values and processing data for fruit stored at 13°C (55°F) for 6, 10, 15 and 20 days*

Storage period	Starch content	Shear press values	Yield of slices	Trimming	Peel
<i>Days</i>	<i>Percent</i>	<i>Kg</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
<i>Experiment 1</i>					
6	25.47	244.9	50.76	15.38	33.84
10	27.90	263.1	54.43	12.65	32.91
15	14.10	235.8	50.00	14.70	35.29
20	12.14	258.0	50.98	13.72	35.29
<i>Experiment 2</i>					
6	28.50	326.5	47.2	15.3	37.5
10	22.19	263.1	46.1	15.8	38.2
15	28.62	222.3	51.4	12.2	36.5
20	20.00	231.3	50.0	11.9	38.1

TABLE 3.—*Results of ranking test to compare the quality of tostones prepared from fruit stored at 13° C (55° F) for 6 to 20 days*

Storage intervals compared	Number of tasters	Type and purpose of test	Results
<i>Days</i>			
<i>Experiment 1</i>			
6, 10, 15, 20	12	Ranking for flavor and texture under red light	No significant difference among samples
	14	Ranking for appearance under red light	15 days rejected, at 1 percent P. 20 days found superior at 1 percent P.
<i>Experiment 2</i>			
0, 6, 10, 15, 20	14	Ranking for flavor and texture under red light	No significant difference among samples
	14	Ranking for appearance under red light	Fresh control and 20 days sample found superior at 5 percent; 6 days sample, rejected

preference. It should be noted particularly that in these tests, tasters did not show any preference for flavor and mouth-feel for samples ranging in starch content from 12 to 27 percent.

As the main effect of storage time on product quality for both storage temperatures seems to be on the appearance due to chilling injury, it was considered necessary to investigate the extent to which the appearance attribute would affect the overall quality and acceptance of the fried

tostones by the tasters. All samples were submitted to organoleptic evaluation for overall quality using a  $\pm 2$  scale. The results of these tests are summarized in table 4. When the results from the first set of samples rated were analyzed statistically (storage temperature 7° C (45° F) the samples stored for 21 days were found superior to all others. In the second set of samples no significant difference was found among treatments. Similar results were obtained with the samples stored at 13° C (55° F). As a rating

TABLE 4.—Results of quality appraisal under artificial light using  $\pm 2$  scale

Storage temperature	Storage interval	Score	Results
	<i>Days</i>		
7° C (45° F)	5	0.92	Sample from fruit stored 20 days found superior to those from fruit stored for 10 and 15 days (1 percent P).
	10	.5	
	15	.4	
	20	1.4	
7° C (45° F)	0	0.8	No significant difference among samples.
	6	.22	
	10	1.2	
	15	.63	
	20	.4	
13° C (55° F)	6	1.0	No significant difference among samples.
	10	.8	
	15	1.1	
	20	1.1	
13° C (55° F)	0	0.84	No significant difference among samples.
	6	.15	
	10	.9	
	15	.9	
	20	.9	

of 0.5 and over in this type of test indicates that the sample has an acceptable quality (except for three samples rated lower which do not seem related to treatment effects) the majority of the samples prepared from fruit stored at 7° and 13° C (45 and 55° F) were found to be of acceptable quality. Although the scores for the samples prepared from fruit stored at 13° C (55°) were higher in general than for those prepared from fruit stored at 7° C (45° F), a comparison of both groups of samples by the *t*-test showed no significant difference between them.

The results of these experiments indicate that when plantains are stored at 7° C (45° F) the physical and chemical changes which take place during a storage period of 20 days do not have enough effect on flavor and mouth-

feel qualities to allow tasters to reject samples due to poor quality. Storage of the fruit under these conditions, however, cause a chilling injury affecting the appearance of the product. The change in appearance is detectable in samples stored for over 10 days when compared with samples prepared from fruit free of chilling injury, but the change in appearance does not seem to be sufficiently pronounced to affect product quality and acceptance when appraised alone. Storage for 20 days at 13° C (55° F) has no apparent adverse effect on quality and acceptance of fried tostones.

### RESUMEN

Cuando los plátanos<sup>3</sup> verdes se almacenaron a una temperatura de 7° C (45° F) por un periodo de 20 días, se observaron cambios en la textura y en el contenido de almidón de la fruta, endureciéndose un poco la fruta y disminuyendo el contenido de almidón. Después de los primeros diez días de almacenamiento se desarrollaron manchas oscuras en la cáscara y en la pulpa por efecto de la refrigeración. Los cambios observados en estas características químicas y físicas no tuvieron un efecto apreciable sobre el sabor o la calidad de los tostones<sup>4</sup> que se prepararon a intervalos de 5, 10, 15 y 20 días. Las manchas oscuras afectaron la apariencia de los tostones, notándose aún más esta condición adversa después de los primeros 10 días de almacenamiento.

El plátano almacenado a una temperatura de 13° C (55° F) se comportó de manera similar, excepto que los cambios en el contenido de almidón fueron más pronunciados, empezando a madurar la fruta al cabo de los 20 días de almacenamiento; además se observó que la pulpa se ablandó ligeramente. El desarrollo de las manchas oscuras por efecto de la refrigeración fue menos pronunciado que a la temperatura más baja. Fue posible preparar tostones de muy buena calidad de fruta almacenada a 13° C (55° F) por un período de hasta 20 días.

Aun cuando los cambios que sufrió la fruta en almacenamiento a ambas temperaturas afectaron la apariencia de los tostones, el efecto neto sobre este factor de calidad no fue lo suficiente para que los catadores pudieran notar consistentemente estos cambios.

El almacenamiento a ambas temperaturas por un período de 20 días no tuvo efecto alguno sobre el rendimiento de las rodajas que se prepararon a intervalos de 5, 10, 15 y 20 días.

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<sup>3</sup> *Musa paradisiaca*.

<sup>4</sup> Véase la introducción de la Parte I.