

Storage of Green Plantains¹

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INTRODUCTION

Plantain (*Musa paradisiaca*) processing is one of the largest and most modern of the food industries in Puerto Rico. In the processing of food products derived from green plantains (normally used for cooking a variety of dishes, not as fresh fruit) it is of prime importance that they are at an adequate stage of development: fully mature but completely green. After harvest, fully mature plantains tend to ripen quite fast, with an accelerated change of starch into sugars. Fried products prepared from plantains at this turning stage have a poor appearance due to the caramelization of the sugars, and exhibit an unwanted sweet taste which is easily detected on sensory evaluation. Both these factors lower quality of the finished product.

Freshly harvested green plantains are usually kept under refrigeration to delay natural ripening. However, this practice does not prevent undesirable changes which affect processing characteristics. The difficulty of maintaining plantains in the green stage poses a problem to both producer and industrialist. The former must market his product immediately after harvest to avoid fast ripening and the latter is completely dependent on the daily fresh market supply for his operation. This problem is still more important when the fresh green fruit is exported to be consumed as such because the plantains quite often start to ripen while in transit.

The work herein presented was carried out to develop a method for delaying the natural ripening of green plantains without affecting their general quality and processing characteristics.

REVIEW OF LITERATURE

The literature reveals no research conducted on the storage of green plantains for extending their shelf life. By contrast, however, it is plentiful with respect to green bananas (*M. sapientum*), a very closely related botanical species.

Smock (1) reviewed the work done on the behavior of green bananas

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under different storage conditions: He reports the use of controlled atmospheres as one of the most effective techniques. A simple type of controlled atmosphere is obtained from sealed polyethylene bags. Liu (2) stated that the shelf life in this type of storage is limited if no means are available for removing the generated ethylene gas accumulated in the sealed containers. Smock (1) and Scott et al. (3) reported that the ripening of bananas stored in this type of container is triggered by the endogenous ethylene produced by the more mature fruits or the fruits injured during handling. To control this condition, Smock used brominated (20 percent by weight) activated coconut charcoal which absorbs the ethylene produced. This proved effective but not practical due to the corrosiveness of the brominated charcoal. Scott et al. reported positive results by use of vermiculite containing saturated KMnO_4 to remove the gas. Liu (2) reported the successful use of Purafil, a commercial ethylene absorbent consisting of alkaline KMnO_4 on a silicate carrier with a built-in color indicator to show when the material is saturated. The product proved useful in retarding the ripening of green bananas unless ripening had already started.

MATERIALS AND METHODS

The fruit used in this study came from experimental plots located at the Gurabo Substation of the Puerto Rico Agricultural Experiment Station. The plantains, from Maricongo and Guayamero cultivars, were harvested fully mature at a 60-percent pulp content, as recommended by Sánchez et al. (4).

Several storage techniques were used to determine the most appropriate method for prolonging the shelf life of green plantains to a maximum without affecting their processing characteristics and overall quality.

Refrigeration of freshly harvested green plantains was tried. Sample bunches were placed in chambers at 45° and 55° F. with a relative humidity of approximately 86 to 90 percent. In one experiment, the chambers were never ventilated; in a second experiment they were ventilated every 6 hours. Samples were checked and chemically analyzed every 3 days.

Experiments were also performed with freshly harvested plantains stored in polyethylene bags (150 gauge), perforated or sealed, under ambient temperature conditions (about 85° F.) or under refrigeration (55° F.). In the study performed with sealed polyethylene bags, samples were stored, one hand per bag, using different rates of Purafil as the ethylene absorbent, and again kept at 85° and 55° F. Levels of 50, 100, 200, and 300 g. per polyethylene bag were studied and compared with a control, packed similarly but without Purafil. Purafil packed in porous paper was placed in the bag. The samples were checked periodically for color changes and other signs of ripeness. To determine the effect of prolonged storage in

polyethylene bags with an ethylene absorbent on the processing characteristics and general quality of the green plantains, freshly harvested fruits were stored, one bunch per bag, both under room and refrigerated conditions. They were first treated with a 200-p.p.m. thiobendazole (TBZ) solution for 2 minutes, and then packed in polyethylene bags containing 200 g. of Purafil. Samples were checked periodically for color; their chemical composition and processing characteristics were evaluated weekly.

Moisture content of the stored fruits was determined by the A.O.A.C. vacuum oven technique (5). Starch was analyzed following the Carter and Neubert (6) procedure, and total and reducing sugars by the Moyer and Holgate method (7). Texture was measured using a Food Technology

TABLE 1.—*Chemical evaluation of green plantains stored at 45° F., 86 percent relative humidity*

Characteristic measured	Days in storage					
	0	5	8	12	15	19
Moisture (percent)	60.56	61.30	58.50	61.42	—	57.75
Starch (percent)	29.73	25.37	23.80	21.67	21.74	25.29
Reducing sugars (percent)	.12	.10	.07	.06	.31	.17
Total sugars (percent)	.59	.98	1.21	1.28	1.94	2.06
Texture maximum force (pounds)	825	810	1,365	1,590	1,665	2,190
Observations	Chilling damage					

Corporation electrical recording texture instrument as described by Sánchez et al. (10).

One bunch of plantains from each treatment (85° and 55° F. storage temperature) was processed weekly. *Tostones*³ and plantain chips were prepared from experimental plantains and then sensory evaluated by a taste panel using a ± 2 scale. For preparing *tostones*, the green plantains were steam-peeled, sliced and frozen, and later properly cooked for evaluation.

Plantains chips were prepared following the method developed by Cancel et al. (8).

RESULTS AND DISCUSSION

Green plantains stored at 45° F. in environmental chambers developed black spots after 12 days due to chilling damage. The results obtained

³ *Tostones*—a Puerto Rican dish prepared by slicing green plantains cross-wise, and frying, pressing and frying the slices again in moderately hot fat.

from the periodical chemical evaluation performed on the experimental samples are presented in table 1. The plantains hardened during storage, increasing the maximum force value from 825 to 2,190 pounds after 19 days and showing a decrease in starch and increase in sugars suggesting an incipient ripening.

Samples kept at 55° F. seemed to have reached a turning stage after 12 days in storage and a yellow skin on the 19th, together with the appearance of black spots due to chilling damage. Sánchez-Nieva et al. (9), working on the ripening of green plantains, found that fruits at the turning stage have a starch content which ranged from 16.84 to 7.92 percent; reducing sugars, from 4.46 to 11.94 percent; total sugars, from 11.87 to 14.92 percent;

TABLE 2.—*Chemical evaluation of green plantains stored at 55° F., 88 percent relative humidity*

Characteristic measured	Days in storage					
	0	5	8	12	15	19
Moisture (percent)	58.75	58.49	60.56	61.18	58.57	60.49
Starch (percent)	29.93	28.07	24.89	24.15	18.61	9.99
Reducing sugars (percent)	.02	.21	.33	.85	.76	.86
Total sugars (percent)	.38	1.13	1.51	3.12	2.75	3.79
Texture maximum force (pounds)	930	915	885	728	735	705
Observations					Turning peel; chilling damage	Ripe color 4 ¹

¹ Banana Ripening Manual, Cir. No. 31, Fruit Dispatch Co., Boston, Mass., 1961.

and a maximum force value in texture measurements which varied from 453 to 124 pounds. If these values are compared to those given in table 2, it is evident that the ripening changes have taken place mostly in the peel. Although at the end of 19 days the fruits had softened a little, and the starch content had been reduced noticeably, it was not its conversion into sugars which gave the plantains their characteristic ripe appearance.

Results similar to those reported above were obtained from fruit kept in storage chambers which were ventilated every 6 hours.

In the preliminary work on the storage of green plantains in polyethylene bags at room temperature, it was observed that samples kept in sealed bags with Purafil (100–300 g.) remained completely green for 17 days, although all of them developed a mold growth early in storage. Samples kept in perforated bags started to turn ripe after 11 days, just as those kept in sealed bags without Purafil or those with only 50 g. of the ethylene ab-

sorbent, which started to turn ripe after 11 and 9 days, respectively. Unpacked controls were fully ripe after 9 days.

When the green plantains were treated with TBZ to control mold growth, the shelf life of the fruits packed in sealed polyethylene bags containing 200 g. of Purafil and kept under room temperature was lengthened from 17 to 25 days, as compared to controls equally kept but without Purafil, which were fully ripe after 6 days in this case. Samples similarly packed but kept under refrigeration (55° F.) remained completely green for 55 days as compared to unpacked controls which started turning ripe after 18 days. At the end of both experiments it was observed that samples had developed black spots on the tips, indicating the presence of fungi.

TABLE 3.—*Evaluation of overall quality and processing characteristics of green plantains stored in polyethylene bags with 200 g. of Purafil, at 85° F.*

Storage	Characteristics measured						Sensory evaluation	
	Pulp content	Moisture	Starch	Reducing sugars	Total sugars	Texture maximum force value	Tostones using ± 2 scale	Chips using ± 2 scale ¹
<i>Days</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Pounds</i>		
0	60.9	59.4	28.34	0.05	0.26	837	0.47	1.20
6	62.6	62.2	27.79	.09	.80	620	.53	1.10
13	61.6	58.9	23.76	.07	1.11	750	.65	1.20
20	60.6	57.8	27.63	.13	.84	630	.80	1.10
27	64.2	60.6	22.50	.32	1.63	570	.40	.81

¹ A + 2, -2 scale of 5 points was used, where +2=very acceptable, +1=acceptable, 0=questionable, -1=slightly unacceptable, and -2=not acceptable.

Tables 3 and 4 summarize the results obtained from the experiments in which the plantains stored in sealed polyethylene bags with 200 g. of Purafil per bag, under room and refrigerated conditions, respectively, were evaluated with regard to their processing characteristics and overall quality. The data shows that green plantains thus stored may remain in a completely green stage for as long as 55 days without any detrimental effect in their chemical composition or processing qualities. At the completion of the study the tostones and chips prepared from experimental samples compared favorably to those prepared from fresh fruit.

SUMMARY

Studies were made of green plantain behavior when stored under various conditions to develop the best method of prolonging their shelf life without affecting their overall quality and processing characteristics.

Freshly harvested green plantains start to ripen in about 7 days, reaching

full ripeness 2 days later, when kept under room conditions at temperature of about 85° F. When stored in refrigerated chambers, plantains from the Guayamero and Maricongo cultivars remain green for 12 days, at which time signs of chilling damage begin to appear. However, the quality of plantains stored in these refrigerated chambers at 45° and 55° F. with relative humidities of 86 to 88 percent are definitely affected. At 45° F. a marked hardening of the fruits was observed and at 55° F., signs of false ripening appeared, impairing the quality of the produce.

Shelf life of green plantains may be successfully prolonged, however, when thiobendazole-treated fruits are stored in sealed polyethylene bags containing an ethylene absorbent (about 200 g. of Purafil). TBZ was used in a

TABLE 4.—*Evaluation of overall quality and processing characteristics of green plantains stored in polyethylene bags with 200 g. of Purafil, at 55° F.*

Storage	Characteristics measured						Sensory evaluation	
	Pulp content	Moisture	Starch	Reducing sugars	Total sugars	Texture maximum force value	Tostones using ± 2 scale	Chips using ± 2 scale ¹
Days	Percent	Percent	Percent	Percent	Percent	Pounds		
0	60.9	59.4	28.34	0.05	0.26	837	0.47	1.20
6	64.6	59.6	28.91	.19	1.15	735	1.10	1.14
13	64.0	59.5	23.47	.14	1.31	750	.90	.92
20	62.6	59.5	—	.09	.66	635	.82	1.16
27	61.4	61.6	—	.07	.61	600	1.10	1.21
34	60.8	60.6	29.37	.08	.36	780	.89	.88
41	63.0	59.8	28.37	.10	.97	690	.50	.38
48	63.0	60.7	27.66	.07	.72	855	.64	.73
55	62.6	59.9	27.65	.07	.70	720	.53	.65

¹ See footnote 1, table 3.

200-p.p.m. concentration to control mold growth. By using these combined techniques plantains were kept perfectly green for 25 days at room temperature (85° F.) and for 55 days under refrigeration (55° F.). This method had no detrimental effect on the stored fruit, as shown by the sensory evaluations of two processed products prepared from the stored green plantains at various intervals throughout the study. Tasters rated the samples as good or superior to similar products prepared from freshly harvested green fruit.

RESUMEN

Varios estudios sobre el almacenamiento de plátanos verdes bajo diversas condiciones se llevaron a cabo, con el fin de determinar el mejor método para demorar su madurez mientras permanecían almacenados, sin afectar su calidad.

Los plátanos verdes recién cosechados y almacenados a temperatura ambiente

(alrededor de 85° F.) comienzan a madurar a los 7 días y alcanzan su madurez plena 2 días después. Al almacenarse plátanos de las variedades Guayamero y Maricongo bajo refrigeración, éstos permanecieron verdes por 12 días. Al cabo de este período se notaron señales de deterioro causado por refrigeración excesiva. Aunque permanecen aparentemente verdes, su calidad queda afectada por efectos de la refrigeración. Las muestras almacenadas a 45° F. se endurecieron marcadamente y las almacenadas a 55° F. dieron señales de una falsa madurez.

Sin embargo, el período de almacenamiento puede prolongarse satisfactoriamente si los plátanos se empaican en bolsas de polietileno selladas, que contengan un absorbente de etileno (200 g. de Purafil por bolsa), y pretratados aquéllos con una solución de tiobendazol (200 p.p.m.) para evitar que se desarrollen hongos. Las muestras así almacenadas permanecen perfectamente verdes por 25 días a temperatura ambiente (85° F.) y por 55 días si se refrigeran a 55° F. Durante este tiempo no ocurren cambios desfavorables para la calidad de las frutas, como se demostró mediante pruebas de catado. Los catadores consideraron los tostones⁴ y platanutres⁵ preparados a intervalos varios con las muestras experimentales de plátanos como iguales o superiores a los mismos productos preparados con plátanos verdes frescos.

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⁴ Tostones—un plato puertorriqueño preparado con plátanos verdes cortados en rebanadas de aproximadamente una pulgada de espesor, y luego fritas, aplastadas y fritas otra vez a temperatura moderada (375° F.).

⁵ Platanutre—hojuelas delgadas de plátano verde fritas a temperatura moderada (375° F.).