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Non-Enzymatic Darkening in Young Hot Water-Peeled Green Bananas[1]

F. Sánchez Nieva and M. Mercado[2]

ABSTRACT

When green bananas with a pulp to peel ratio of less than 1.3 are exposed to air after a hot-water treatment to inactivate the enzyme systems and to facilitate peeling, a dark discoloration appears on the exposed surface. This after-peeling darkening was controlled by dipping the peeled fruit in Na_2 EDTA solutions or blanching in 2% solutions of sodium acid pyrophosphate. Sulfitation in $K_2S_2O_5$ solutions had only a minimal effect in controlling the darkening reaction. Treatment with Na_2 EDTA did not control the after-peeling darkening due to an excessive sloughing of the surface tissue. Green bananas were found to have a higher iron content on the surface tissue prone to darkening than in the rest of the fruit, which suggests that the darkening reaction involves the formation of a color complex by reaction of iron and o-diphenols.

INTRODUCTION

Sánchez Nieva and Mercado (3) showed that on freezing green bananas, the enzymatic browning can be controlled by heating the unpeeled fruit in water at 200° F (93° C) for 30 minutes. Besides controlling browning, the hot water treatment loosens the peel, facilitating its removal by hand. However, when fruit with a pulp:peel ratio of less than 1.3 is treated with hot water, even though the enzyme systems have been inactivated, a gray discoloration appears which becomes more intense after prolonged exposure to air. This discoloration adversely affects the appearance of the product.

Some potatoes may suffer an after-cooking darkening which has been attributed to the reaction of ferrous ions and o-diphenols. This reaction may be controlled with EDTA salts, sulfites and blanching in sodium acid pyrophosphate solutions (5, 6, 7).

Since the after-peeling darkening in green bananas may involve a mechanism similar to that in potatoes, a series of tests was conducted to

[1] Manuscript submitted to Editorial Board October 25, 1979.

[2] Consultant and Research Assistant, respectively, Food Technology Laboratory, Agricultural Experiment Station, Mayagüez Campus, University of Puerto Rico, Río Piedras, P.R.

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determine whether this type of discoloration could be controlled or reduced by treating the hot water-peeled fruit with Na_2 EDTA potassium metabisulfite and sodium acid pyrophosphate.

MATERIALS AND METHODS

Green bananas with a pulp to peel ratio ranging from 1.0 to 1.3 were heated in water at 93° C (200° F) for 30 minutes to inactivate the enzyme systems and to facilitate peeling, as described by Sánchez and Mercado (4). Immediately after peeling, the fruit was treated with the different chemicals tested as follows: a) Na_2 EDTA. The fruit was dipped at room temperature 26.7° C (80° F) in the Na_2 EDTA solutions of the concentration desired for a specific time, and drained; b) sulfitation. The peeled fruit was sulfited by being dipped in a $K_2S_2O_5$ solution containing .37% SO_2 with the pH adjusted to 5.4; c) sodium acid pyrophosphate (SAPP). The peeled fruit was blanched at 82° C (180° F) for 3 and 6 minutes in a 2% SAPP solution and drained. After the chemical treatments, the fruit was packed in cardboard containers and vapor-moisture proof overwraps and frozen at −40° C (−40° F). The frozen samples were stored at −23.3° C (−10° F). Control samples were packed and frozen immediately after peeling without any further treatment.

Color was measured, on the outer and inner surfaces of peeled, thawed and cooked fruit, with a Hunterlab Model D color difference meter calibrated with Hunterlab yellow standard No. 3127 ($L = 78.2$, $a = 4.1$, $b = 30.8$). For measuring the color of the outer surface the fruit was placed on its side in the cell with the cell as full as possible to avoid excessive open areas. For measuring the color of the inner surface, the fruit was cut lengthwise in halves, and the halves were placed in the cell with the cut surface down. The cell was covered with a Kodax neutral test card with the white side of 90% reflectance down. When the slices cooled to room temperature the color of the peeled fruit was measured immediately. The frozen product was thawed at room temperature for about 2 hours until the temperature reached about 21.1° C (70° F) before color measurement. For the cooked product, about 12 oz (320 g) of frozen slices were placed in one liter of boiling water and cooked 5 minutes after the water boiled again.

The degree of tissue sloughing was determined as follows: three 1-inch thick slices were weighed and boiled for 1 min in a wide mouth Erlenmeyer flask. The flask contents were cooled to about 60° C (140° F) and shaken for 5 min in a Burrel shaker at setting 2. The contents were drained through a ¼-inch (63-mm) screen into a 250 ml graduated cylinder. The solids on the screen were washed with distilled water, the washings collected in the cylinder. The volume was brought to 250 ml with distilled water and the solids left to settle for 1 hour. The volume of

sediment was determined. The degree of sloughing is expressed as milliliters of sediment calculated to 100 g sample weight.

Tannins were determined by the method described by Leonard et al. (1). For iron determination, a sample weighing from .5 to 5 g depending on the iron content was wet digested with nitric and sulfuric acids. The iron content in the digest was determined by the AOAC colorimetric procedure (3) with a Beckman DBG spectrophotometer.

To determine visual difference in color among treated samples, the triangular test was used. A panel of 10 tasters selected the sample based on the color as judged under natural light.

RESULTS AND DISCUSSION

TREATMENT WITH Na_2 EDTA SOLUTIONS

The results of preliminary tests in which hot water-treated peeled green bananas were dipped for 1, 2 and 3 minutes, in Na_2 EDTA solutions

TABLE 1.—*Effect of dipping time in .5% w/w EDTA Na_2 solution on the color and sloughing of the surface tissue of thawed and cooked green bananas*

Dipping time	Hunter color						Sediment
	Thawed fruit			Cooked fruit			
	L	*a*	*b*	*L*	*a*	*b*	
min							*ml*
0	58.5	−1.05	11.05	56.1	0.4	6.8	25.2
1.5	64.9	−1.1	16.0	59.4	2.7	11.9	51.3
2.5	66.3	−.15	14.6	60.4	2.1	12.5	64.6
3.5	64.6	+.7	17.9	61.5	2.4	13.8	67.6

ranging in concentrations from 0.2 to 1.0% w/w in .2% steps, showed that the after-cooking darkening could be controlled by dipping the fruit in the .4% solution for 1 min.

Treatment of the green fruit with Na_2 EDTA resulted in the development of a yellow which became deeper as dipping time and Na_2 EDTA concentration increased. Dipping the fruit for 2 minutes in a .6 to 1.0% solution resulted in a product with such an intense yellow that it resembled a ripe banana. The development of such an intense yellow color was objectionable from a quality standpoint. Besides the development of the yellow color, it was also observed that treatment with Na_2 EDTA solutions caused a marked sloughing of the surface tissue. Reducing the dipping time to a range from 15 to 60 seconds in solutions of concentration of .1, .2 and .3% had no appreciable effect on the color, the treated fruit having a gray color similar to that of the untreated controls.

Table 1 shows the effect of three dipping treatments in 0.5% Na_2 EDTA

solution on the color of thawed and boiled fruit when measured on the Hunter color difference meter, and the effect on the degree of sloughing of the surface layers. Increasing the dipping time from 1.5 to 3.5 minutes resulted in an increase in L and b values indicating an increase in lightness and yellowness, respectively. All these treatments proved effective in controlling the after-peeling darkening. Although the treatments resulted in the development of a yellow color, the color developed was not too intense to appreciably affect the quality of the frozen green fruit.

Sloughing of the tissue, however, increased with dipping time as shown in table 1. All treatments resulted in excessive sloughing of the surface layers thus affecting adversely the appearance of the product, and upsetting the beneficial effect of the treatment in controlling the darkening

TABLE 2.—*Effect of sulfiting in $K_2S_2O_5$ solution (.37% SO_2 content) on the color of hot water treated green bananas*

Treatment	Hunter Color					
	L	*a*	*b*	*L*	*a*	*b*
	Surface tissue					
	Thawed			*Cooked*		
Control	62.8	−.8	11.5	57.9	+.8	9.4
Sulfited	63.1	−1.7	12.9	57.5	−.3	10.0
	Inner tissue					
	Thawed			*Cooked*		
Control	66.6	−1.9	15.8	60.8	−.8	12.1
Sulfited	66.4	−2.4	16.0	62.4	+1.6	14.4

reaction. EDTA and its salts are known to dissolve the insoluble salts of pectic acids which bind the cells together (2), all of which may result in casting off of the tissue most exposed to the action of this chemical.

TREATMENT WITH POTASSIUM METABISULFITE SOLUTION

Table 2 shows the effect of sulfiting on the color of thawed and boiled green fruit. Both in the thawed and boiled fruit sulfitation resulted only in a slight increase in yellowness (Hunter b) with practically no effect on lightness (Hunter L) on both the outer and inner tissues. Although only a small change in color could be detected when measuring the color in the Hunter meter, in pair comparisons the tasters could detect a difference in color between sulfited samples and controls (results significant at 1% P). Although both samples looked gray, the sulfited sample appeared to be somewhat bleached. In regard to the appearance of the thawed or cooked product, not much difference was observed between the treated samples and controls. Sulfitation had no significant effect on the slough-

ing of the tissue. Sulfitation apparently is not effective in controlling the after-peeling darkening in green bananas.

BLANCHING IN SODIUM ACIDPYROPHOSPHATE SOLUTIONS

Smith and Davis (4, 5) showed that blanching potato slices in 2% solutions of SAPP proved to be very effective in controlling after-cooking darkening. Table 3 shows results of experiments in which the hot-water treated green bananas were blanched in 2% SAPP solution for 3 and 6 min at 82° C (180° F). Both treatments controlled the darkening reaction resulting in an increase in *L* values (lightness) and in *b* values (yellowness). Both *L* and *b* values increased with dipping time. Treatment with SAPP resulted only in a small degree of sloughing of the surface tissue. These results suggest that treatment with SAPP may prove to be effective

TABLE 3.—*Effect of blanching in sodium acid pyrophosphate (SAPP) solutions on the color of hot-water treated green bananas*

Treatment	Visual color	Hunter color in—					
		Surface tissue			Inner tissue		
		L	*a*	*b*	*L*	*a*	*b*
		Color measured after 2 hour exposure to air					
Control	Gray	49.2	−.6	12.8	54.3	−2.2	16.2
3 min blanching	Yellowish gray	51.3	−.7	13.8	56.2	−2.2	17.7
6 min blanching	Yellowish	55.1	−.6	16.8	61.5	−1.9	19.9
		Color measured on frozen samples after boiling					
Control	Gray	55.2	+1.0	7.7	55.7	−1.0	13.7
3 min blanching	Light reddish yellow	56.7	+1.6	11.6	59.1	−.75	16.8
6 min blanching	Light yellow	57.4	+1.6	12.6	59.7	−1.2	17.4

in controlling the after peeling darkening in green bananas for freezing. It was observed that the treatment resulted in the development of a light yellow color which was not objectionable. It is felt, however, that further studies on the use of this chemical are needed before the treatment can be recommended for commercial use.

Green bananas have a fairly high tannin content which in the samples studied was found to decrease during development as shown in the following tabulation.

Pulp:peel ratio	*Tannin mg/100 g*
1.0	241.4
1.3	151.0
1.5	112.6

Analysis of the green fruit of low pulp to peel ratios for iron content showed that the surface layer where most of the darkening takes place had an iron content of 4.28 p/m, while the inner tissue which is less susceptible to darkening had a content of 2.89 p/m.

The facts that EDTA preferentially chelates iron (7), that SAPP is believed to form colorless complexes with iron (5), that the surface tissue has a higher iron content, plus the high tannin content of green bananas, suggest that the after peeling darkening, with the enzymes inactivated, a reaction of o-diphenols an iron, may involve a mechanism similar to the after cooking darkening in potatoes.

RESUMEN

En un proceso desarrollado por los autores de este trabajo para congelar el guineo verde, la fruta fresca se calienta en agua a 93° C (200° F) por 30 minutos para inactivar los sistemas enzimáticos y controlar el pardeamiento. Sin embargo, cuando la razón de pulpa a cáscara es menos de 1.3, si se trata del modo indicado, al exponerlo al aire una vez pelado, sufre un obscurecimiento en la superficie, el cual se intensifica gradualmente. Los resultados de los estudios que se llevaron a cabo para controlar este tipo de pardeamiento indicaron que, cuando la fruta se sumerge en soluciones de Na_2 EDTA en una concentración de 0.5% por peso y por un período de tiempo que fluctuó de 1.5 a 3.5 minutos, la reacción responsable del obscurecimiento se pudo controlar pero se desarrolló un color amarillo pálido. El tratamiento con Na_2 EDTA, sin embargo, afectó adversamente la apariencia de la fruta al causar un desprendimiento del tejido superficial.

La sulfitación de la fruta por inmersión en una solución de $K_2S_2O_5$ no fue efectiva para controlar el obscurecimiento de la superficie de la fruta. Este tratamiento solo blanqueó ligeramente el tejido expuesto sin mejorar significativamente la apariencia del producto.

Cuando el guineo verde se escaldó por 3 y 6 minutos a 82° C (180° F) en una solución al 2% de pirofosfato ácido de sodio el obscurecimiento del tejido se controló efectivamente sin afectar adversamente la apariencia de la fruta tratada. Durante el tratamiento, la fruta adquirió un color amarillo pálido atractivo y no se notó desprendimiento significativo del tejido de la superficie.

En el guineo verde la superficie más propensa al obscurecimiento resultó tener un contenido en hierro más elevado (4.28 pm) que el tejido interno, (2.59 ppm), la cual no es tan susceptible a obscurecerse al exponerse al aire. Ya que el EDTA y sus sales forman quelatos con el hierro y que se cree que el pirofosfato ácido de sodio forma complejos incoloros con el hierro, cabe la posibilidad que el obscurecimiento que se ha observado en el guineo sea el resultado de una reacción entre el hierro y los o-difenoles.

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