TECHNICAL PROGRESS REPORT NO. 153 DECEMBER 1966

Banana Dehydration

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HAWAII AGRICULTURAL EXPERIMENT STATION, UNIVERSITY OF HAWAII

TABLE OF CONTENTS

NOTE

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Banana Dehydration

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INTRODUCTION

Improved dried banana products made by modernized processing methods have been reported (*1, 3, 4, 5, 9, 11*) in recent years. These products generally represent considerable improvement over the sun-dried bananas that have been produced for many years in the tropics (*10*). Von Loesecke (*12*) noted that bananas have been sun-dried, drum-dried, spray-dried, and dried in a cabinet dehydrator. Banana flour (*11*) appears to have attracted more attention from commercial processors than other dehydrated banana products. Stability studies on dried bananas (*2, 6*) and other dried fruits (*8*) have shown the value of proper packaging, antioxidants, and moderate temperatures during storage.

In the work reported here, bananas were dehydrated by air drying, drum drying, and freeze drying. Samples of each product were held at 55°, 75°, and 100°F. for periods up to 1 year. The quality of the dried bananas was measured by objective and subjective appraisal and the quality changes during storage were evaluated.

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MATERIALS AND METHODS

The three common commercial banana varieties grown in Hawaii, Dwarf Cavendish (Chinese), Bluefields (Gros Michel), and Brazilian (Apple), have been dehydrated by the methods described here to yield high-quality dried slices or flakes. Yellow ripe or slightly overripe fruit with brown spots appearing on the skin is satisfactory for dehydration. The fruit is peeled by hand and sliced to 3/8-inch-thick radial slices by forcing it through a grid of stainless steel wires strung in parallel 3/8 inch apart on a frame. Fruit for drum drying is pureed by any of a number of milling devices.

Sulfur Dioxide Pretreatment

About half of each lot had sulfur dioxide added either by dipping slices in sodium bisulfite solution, or by adding the solution directly to puree. The rate of absorption of SO_2 by banana slices dipped in $NaHSO_3$ solutions is seen in Figure 1. The slices used for stability studies were dipped for 2 minutes in 1% $NaHSO_3$ to give about 125 ppm SO_2 in the tissues on fresh weight basis (about 500 ppm calculated on moisture-free basis). Sodium bisulfite was added to puree for drum drying in sufficient quantity to bring the SO_2 content of the puree to 1000 ppm on fresh weight basis.

Air Drying

Sliced bananas were placed in a single layer on stainless steel trays with 5/32-inch perforations on 5/16-inch centers. Tray surfaces were treated with a silicone product to prevent sticking of the slices. Drying was in a forced-draft oven (air velocity 2000 fpm) operated at 180°F. for the first 2 hours, then finished at 140°F. so the piece temperature did not exceed 140°F. Total drying time depends upon tray and oven load, humidity of the air at the air intake, and final moisture content of the product.

Drum Drying

Banana puree was fed to the trough of a steam-heated double-drum drier with the drums spaced 0.010 inch apart. The steam pressure in the drum was 50 psig, and the drums rotated at 2 rpm. At this drum speed the product was on the heated surface of the drums for 20 seconds. Data showing the relationship between moisture content of the product and the time it is drying as a thin layer on the surface of the drum is in Table 1.

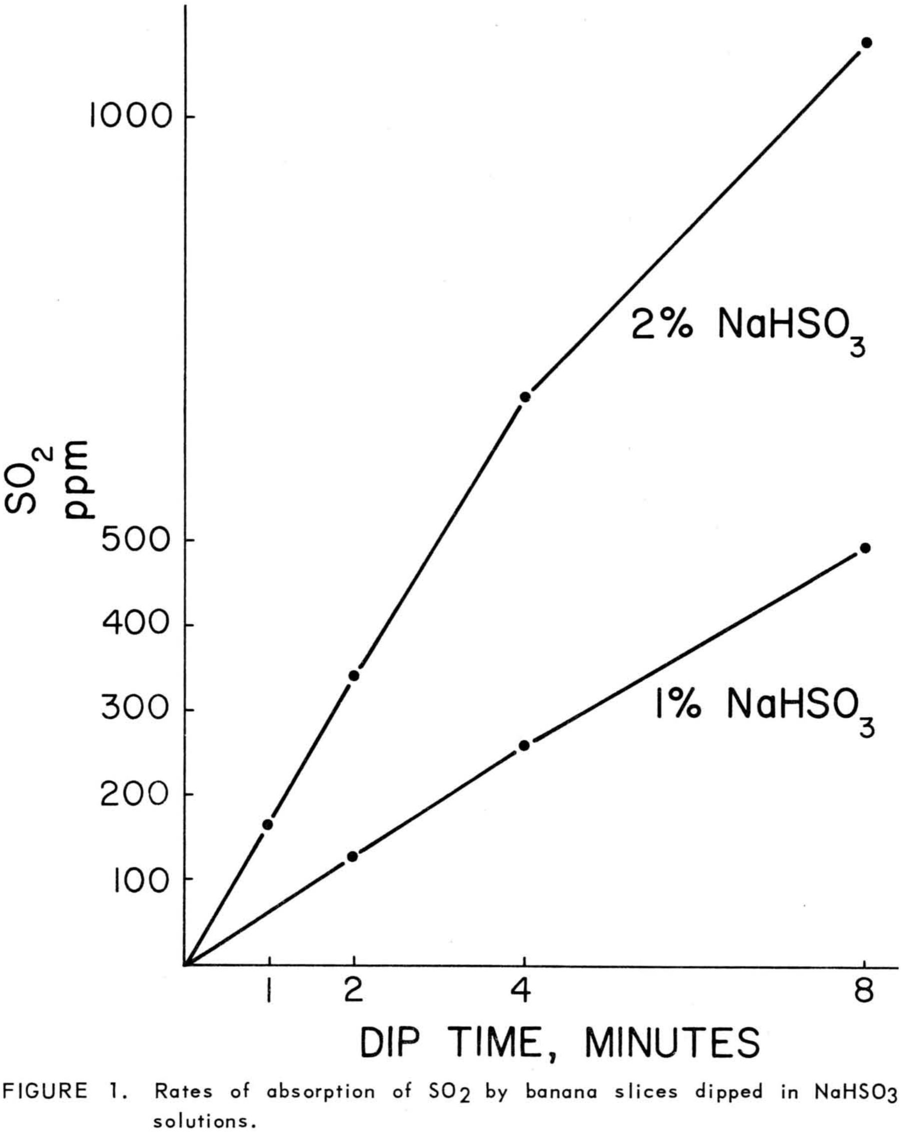

FIGURE 1. Rates of absorption of SO_2 by banana slices dipped in $NaHSO_3$ solutions.

The dried material was removed as a thin sheet from the drum surface by doctor blades and received in plastic bags. The product was then repackaged in 6-ounce hermetically sealed cans. It contained about 2.5% moisture and the sulfited product contained about 700 ppm SO_2. It was dry, brittle, and easily disintegrated to flakes and powder during packing. Flakes with 3.5% moisture tended to cake; those below 3% remained free-flowing.

TABLE 1. Relationship between drum residence time and moisture content of banana flake product (50 psig steam in drum; 0.010-inch drum spacing)

Residence time on drum (Seconds)	% Moisture
17	4.5
20	2.5
26.5	2.13
30	1.75

Freeze Drying

Banana slices were spread in a single layer on 1/2-inch galvanized hardware cloth trays and frozen at 0°F. The trays were then placed 1/2 inch above the shelf surfaces in a Model 15 RePP Sublimator. Radiant heat panels were 1/2 inch above the slices. Copper-constantan thermocouples in slices on each shelf activated switches to turn off the radiant heat panels when slice temperatures reached +10°F. Shelf temperature was kept at 140°F. for 4 hours, then 100°F. for the rest of the drying cycle. The drying chamber pressure was at 5 μ Hg. The complete drying cycle was 24 hours. Dried slices contained 3–3.5% moisture, and sulfited slices had about 300 ppm SO_2.

After drying and thorough mixing, the products were packed in 6-ounce cans and hermetically sealed. Fifteen cans of each product were placed in storage at 55°F., 75°F., and 100°F. Two cans of each product at each temperature were transferred to 0°F. storage at intervals during 1 year.

Analytical Procedures

Seventy-five g. of dried banana and 300 g. of distilled water were blended 3–4 minutes to yield a homogeneous puree; fresh banana was pureed without added water.

A portion was poured at once into a 3½-inch-diameter Petri dish and Hunter Meter R_d, a, and b color values measured. The meter was standardized with Plate No. C-LY-532-56 (R_d = 61.2, a = − 1.8, b = + 22.8). This measurement must be made rapidly as enzymatic discoloration may take place in a matter of minutes.

For the color determination, a 50-g. portion of puree was weighed into a 125-ml. Erlenmyer flask, 50 ml. of methanol added, and the stoppered flask shaken vigorously. This sampling likewise must be done quickly to preclude enzymic change in color of some of the purees. The flask was allowed to stand for at least an hour with intermittent shaking. The contents were filtered in vacuo, yielding a clear filtrate. The absorbance of this liquid at 440 mμ was measured with a Spectronic 20 spectrophotometer-colorimeter with 50% methanol as the reference material. Brown pigment, usually associated with deteriorative change, is extracted by the methanol in this procedure, and the more brown pigment present, the more the quality has deteriorated. In preliminary studies, methanol extracts showed less interference by carotenoid-like pigments than did ethanol or isopropanol extracts. Results are expressed as Color Value (absorbance/dilution factor x light path in centimeters) on a dry weight basis.

The SO_2 assay was by the method of Nury *et al.* (*6*) with slight modifications. A 100-g. portion of puree was weighed into a 500-ml. Waring blender cup, 100 g. 0.1 N NaOH added, and the mixture blended for 1–2 minutes. After 20–30 minutes a clear layer separated at the bottom, of which 10 ml. was pipetted into a 100-ml. volumetric flask containing 15 ml. 0.1 N HCl. The sample and acid were mixed by gentle swirling and 25 ml. of sodium tetrachloromercurate reagent was added before making to volume with distilled water. A flocculent precipitate sometimes formed which was easily removed by filtration through glass wool. Five ml. of the clear filtrate was transferred to a large test tube containing 5 ml. of p-rosaniline hydrochloride reagent. Ten ml. of 0.015% formaldehyde was mixed in. After the mixture had stood 30 minutes at 70–75°F., the absorbance at 580 mμ was measured. Results were calculated from the regression equation of a standard curve and expressed as ppm SO_2 on dry weight basis.

For moisture determination, 5–10 g. of puree were weighed into previously dried moisture dishes containing 5–10 g. of silicate sand. About 10 ml. of 95% ethanol was stirred into the puree-sand mixture and it was evaporated to near dryness on a steam bath. Drying was completed in a vacuum oven at 60°C., 1.5 mm. Hg pressure, for 30 hours. The percentage loss in weight was recorded as the moisture content.

TABLE 2. Quality measurements of fresh and dried bananas

Sample	% H_2O	Color Value[a] (methanol extract)	Hunter Meter R_d value	SO_2[a] ppm
Fresh banana	73.5	0.43	50.1	0
Air-dried:				
Sulfited	17.7	1.03	35.7	240
Control	17.5	1.87	30.8	0
Freeze-dried:				
Sulfited	3.5	0.40	50.8	250
Control	3.6	0.59	39.5	0
Drum-dried:				
Sulfited	2.5	1.22	29.0	690
Control	2.7	1.31	26.2	0
Commercial Products:				
Flakes X	2.3	1.01	29.6	0
Y	3.1	2.80	17.0	0
Z	1.2	4.80	14.4	0
Freeze-dried	2.3	0.99	40.0	0

[a]Moisture-free basis

RESULTS AND DISCUSSION

Objective Quality Measurements

Values for objective quality measurements that appeared most applicable and that reflected subjective appraisal most accurately are shown in Table 2. The Hunter Meter R_d value agreed with observed color more closely than a and b values. Fresh banana puree gave values of $R_d = 50.1$, $a = -1.5$, and $b = +21.8$, reasonably close to the standard plate values.

The sulfite-treated, air-dried slices were light yellow; the untreated were slightly browned, but not to the point of being objectionable. The flavor of the air-dried slices differed distinctly from that of sliced fresh

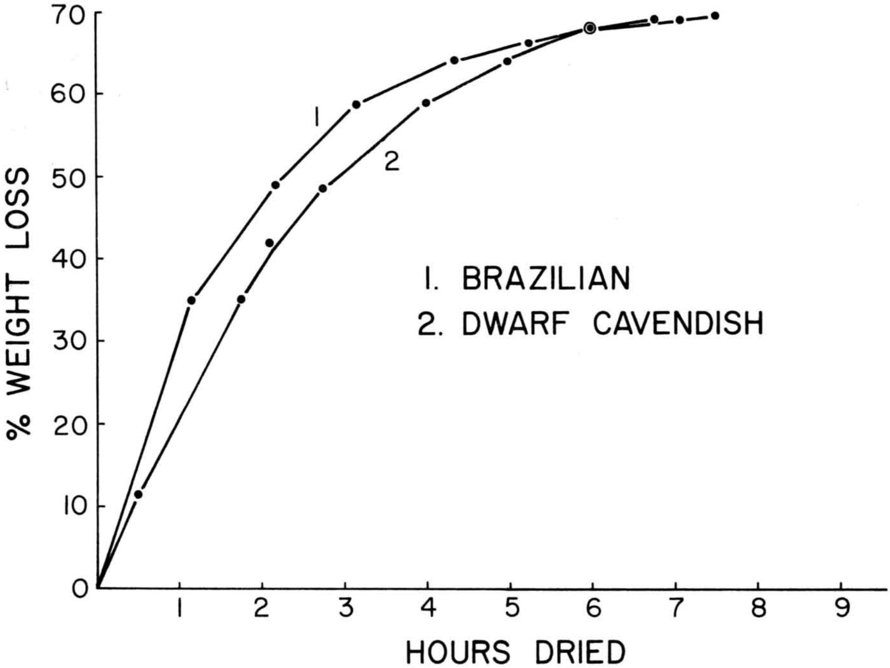

FIGURE 2. Drying rates of banana slices in air-blast oven.

bananas, but was unmistakably banana-like; the sulfured slices resembled fresh banana more closely than did the unsulfured. In several experimental runs, drying times of 8–11 hours gave satisfactory products containing about 17–20% moisture. The finished sulfured product used for the stability studies contained 240 ppm SO_2. Typical drying curves for Dwarf Cavendish (Chinese) and Brazilian (Apple) varieties are shown in Figure 2. The Bluefields (Gros Michel) variety gave similar results.

Freeze-dried slices were nearly white in color, crisp, porous, and essentially the same shape and size as the fresh slices from which they were made. The Hunter R_d value and color value (methanol extract) were much closer to those of fresh banana than the other dried samples (Table 2). Both the sulfured and unsulfured products had excellent flavor, very nearly identical to the flavor of fresh slices. The flavor of SO_2 was easily detected in the sulfured slices but did not appear to lessen the banana flavor.

The sulfited drum-dried flakes were light ivory, slightly darker than the standard plate used for color comparisons; the control (not sulfite treated) was slightly browner than the sulfured.

The differences in the products were obvious and the casual observer could see that, upon rehydration, the freeze-dried slices more nearly resembled fresh banana than did the other products. Flavor of the drum-dried flakes or powder resembled fresh banana least of the three. It had the flavor of cooked bananas, and the product would be a high-quality ingredient in cooked or baked products. Brazilian bananas appeared to develop brown discoloration less than the other two varieties. The addition of SO_2 did improve the color of all the dried products, most strikingly so in the air-dried.

The interacting elements of pretreatment, temperature, and time the samples were held affected the quality of the dried bananas. The temperature of storage was the over-riding factor in the deterioration of the samples.

TABLE 3. Color values (alcohol-extractable pigment) of dehydrated banana samples held at different temperatures

Storage temperature °F	Storage time Months	Color values: No pretreatment	Color values: Bisulfite pretreatment
Air-dried slices			
	No storage	1.87	1.03
55	12	2.60	1.99
75	12	5.97	5.25
100	4	28.1	27.5
Freeze-dried slices			
	No storage	0.59	0.40
55	12	0.95	0.53
75	12	1.41	0.56
100	9	11.55	6.10
Drum-dried puree			
	No storage	1.31	1.22
55	12	1.34	1.22
75	12	1.50	1.36
100	9	7.10	5.85

In Table 3 the color values (alcohol extractable color) of the freshly prepared samples (starting material) and the stored samples are shown. The color values increase as deterioration proceeds. The stability experiments at 55°F. and 75°F. were concluded at 1 year; at 100°F. the samples deteriorated more rapidly and the experiments were concluded at 4 months for air-dried bananas and at 9 months for freeze- and drum-dried bananas. The color values in Table 3 give the gross changes in this quality attribute and it can be seen that the air-dried product is the least stable, whereas the drum-dried changes the least. The rates of change in color value are shown in Figure 3 which is a plot of the color values of air-dried, non-sulfited banana slices held at the three different temperatures noted.

Hunter Meter R_d values determined with standard Plate No. C-LY-532-56 likewise provided an index of the changes in quality, the values decreasing as deterioration proceeded. This is shown by Figure 4 in which the R_d values of air-dried untreated bananas held at the three temperatures are plotted. The 100°F. samples were black at 4 months; the 75°F. samples were decidedly brown at 12 months; those held at 55°F. for 12 months were very slightly different from the freshly dried material.

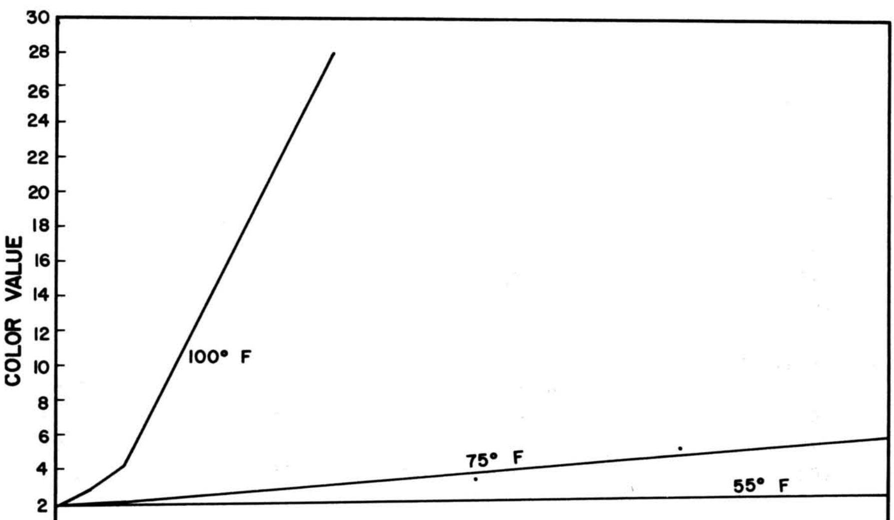

FIGURE 3. Color value change for air-dried, non-sulfited banana slices at 3 temperatures.

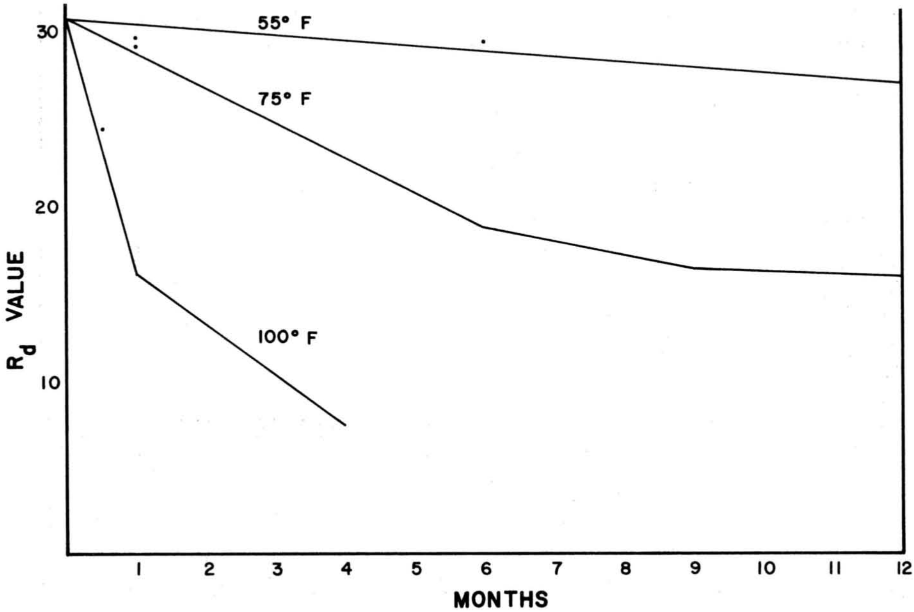

FIGURE 4. Changes in Hunter meter R_d values for air-dried, non-sulfited banana slices at 3 temperatures.

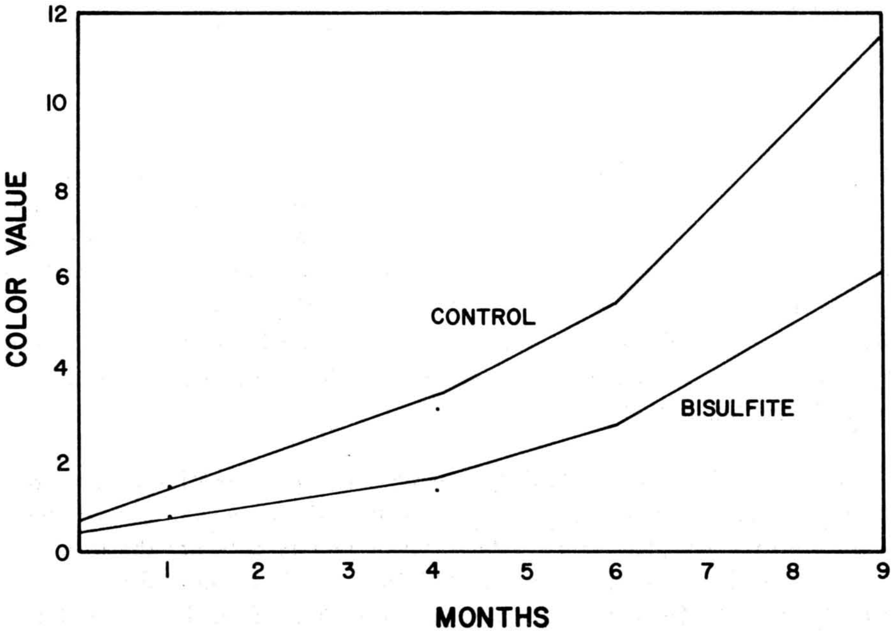

FIGURE 5. Color values of untreated (control) and bisulfite-treated freeze-dried banana slices stored at 100°F. up to 9 months.

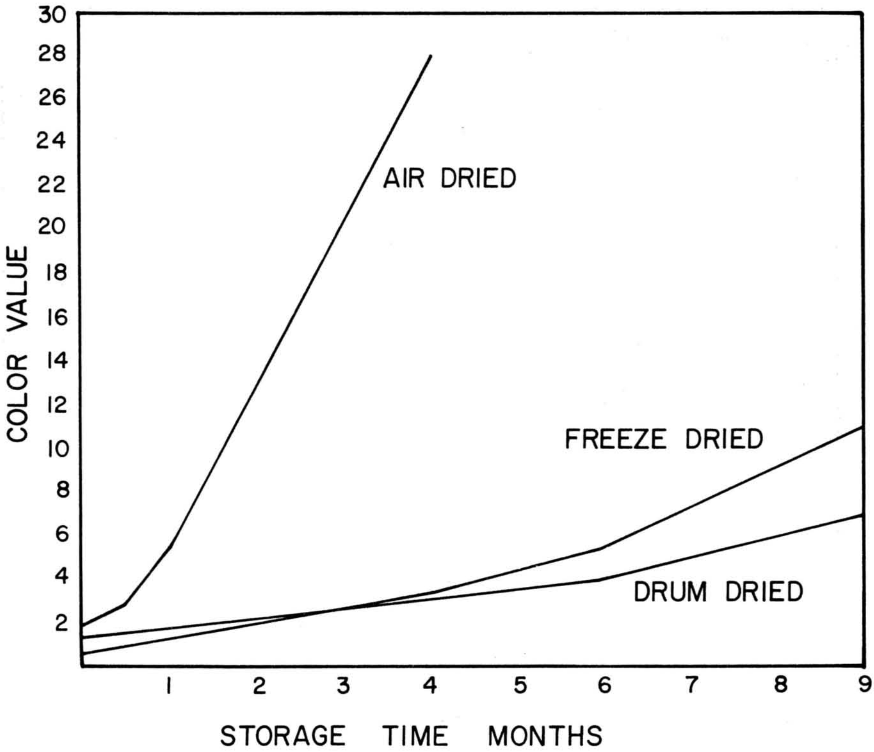

FIGURE 6. Color values of three types of dried bananas, non-sulfited, held at 100°F. up to 9 months.

Comparison of the rate of change in color values of untreated and bisulfite-treated freeze-dried bananas held at 100°F. is shown in Figure 5. The color value of the control (untreated) is roughly twice that of the treated samples. Air-dried sulfited samples lost SO_2 much more rapidly than the freeze-dried or drum-dried bananas. Air-dried samples at 75° and 100°F. lost all their SO_2 in 1 month, and at 55°F. all SO_2 was gone in 6 months. Freeze-dried and drum-dried samples held at 100°F. lost all SO_2 in 9 nonths; at 75°F. the losses were only about 20% after 1 year, and at 55°F. virtually no change took place in a year.

A comparison of the stabilities and rates of deterioration of the three types of dried bananas is given in Figure 6. This shows the color values of non-sulfited samples held at 100°F. Important to note are the moisture contents of the different products: air-dried, 17.5%; freeze-dried, 3.6%; drum-dried, 2.7%. Obviously the drier products changed much less, with the least change in the drum-dried flakes.

Subjective Quality Evaluations

Subjective observation of color led to the conclusion that samples with color values above 4 would be rejected as being objectionably brown. The air-dried samples held at 100°F. for 4 months were black and had color values about 28. Those with color values of 3–4 could be distinguished easily from the freshly prepared products, but would not necessarily be rejected. Samples held under unfavorable conditions tended to develop bitter flavor as well as brown color. This bitterness first appeared in air-dried samples when the color value was about 5; it appeared in the drum-dried and freeze-dried samples when the color value was about 3.

Observations on 1-year Stability Studies

Considering these approximate limits of color and flavor, an estimate of the storage life of the products was made. At 55°F. all products were acceptable after 1 year. At 75°F., air-dried samples treated with bisulfite were satisfactory in flavor for 9 months, the untreated for about 6 months drum-dried and freeze-dried bananas were satisfactory after 1 year at 75°F Air-dried bananas held at 100°F. were satisfactory for only 2 weeks. Freeze dried samples without bisulfite treatment were bitter in flavor after 4 months at 100°F.; the sulfited samples first showed bitter flavor at 6 months at 100°F. Drum-dried samples were bitter in flavor after 6 months at 100°F. A rough interpolation of data indicates that air-dried untreated banana slices the least stable of the dried banana products discussed here, would be of satisfactory quality after 1 year if held at 65°F. in a hermetically sealed container. The other types of dried bananas are much more stable. Drum dried and freeze-dried bananas that had bisulfite pretreatment were about 10 times as stable as the air-dried bananas.

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