COMPARISON OF PROCESSING METHODS FOR BANANAS

By

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CHAPTER I

COMPARISON OF PROCESSING METHODS FOR BANANAS

Introduction

Bananas (Musa sapientum), in many parts of the tropics, are as important to the inhabitants as grains to those living in cooler parts or regions. In India, the cultivation of bananas is limited to certain (southwestern) districts. This segregation of the banana crop to particular regions together with inadequate transportation facilities and storage, and the easily perishable nature of the fruit make difficult the problem of handling and distribution of this fruit. The delay caused in transportation damages the fruit so badly that by the time the fruit reaches the consumer a major portion of it is made unfit for consumption even within a distance of 100 miles. This automatically increases the price of bananas so much that an average Indian family, with his poor economic system, is unable to purchase them.

Absence of a ready market in these places of over production, furthermore, increases the problem of disposing of the produce and hence a major portion of it is wasted. During dull seasons the interior parts of India are almost deprived of bananas in their markets.

There are several varieties of bananas grown in tropical countries. The selection of particular variety best suited for the different processes should be made by experimentation. Since

"Gros michel" is the only variety available in the market here the processes surveyed had to be limited to this particular variety.

In food value the banana could well be compared with the potato which forms a major food in many parts of the world. Hence the banana will constitute a cheap and chief source of carbohydrate in the diet of millions if the fruits that are wasted are preserved and made available to the people.

Comparison of the composition of banana and potato (47)

Content	Potato	Banana
Water	78.3%	75.3%
Protein	2.2	1.3
Fat	0.1	0.6
Total carbohydrate including fibre	18.0	22.0
Ash	1.0	0.8
Calories per pound	385.0	460.0

Taking the above facts into consideration, processing methods like canning, freezing, dehydration, and brining and salting have been surveyed as a basis for the development of several other products which might find a very wide market in India and outside. The processing time and temperature in the case of canning have been adapted from those used for products of similar texture in

American products, (peach) the processes for which have been standardized by the National Canners' Association.

This work is mainly based on the experimental evidences as practically no literature is available on these various methods of preservation.

CHAPTER II

LITERATURE REVIEW

A. Canning

Processing.

Processing or cooking canned fruits has for its object the destruction of bacteria and fungi which would otherwise cause spoilage. The minimum requirement for the process for any product is that it be adequate to destroy the most heat resistant organism likely to be present which, if not destroyed, would be a hazard to the health of the consumer. Realizing the importance of this, the canning industry has tried to perfect these operations and has finally standardized them.

The work of several investigators, such as that of Magoon and Culpepper (42), Thompson (49), Bigelow et al (8), Burns (5), Lancefield (40), and Jackson and Olson (32) has been reported. Their investigations and findings have provided extensive information regarding the rates at which food in cans gets heated during processing and effects of such factors as filling temperature, weight of pack, vacuum, fluidity of the product upon the mechanism of heat penetration rates. Other workers determined the thermal death times of several canned food spoilage organisms, Bigelow and Esty (7), Weiss (55), Dickson et al (19).

This information was applied by Bigelow (9) and others to the calculation of thermal processes for canned foods. Ball (2) developed more flexible mathematical formulations for thermal-process calculations. These theoretical processes were tested by means of experimental packs innoculated with bacterial spores of significant resistance. The results were analysed and compared with the theoretical process, arrived at by mathematical means.

Usually commercial processes are based mainly upon technological data relating to heat resistance of spoilage organisms in canned foods and upon data pertaining to heat penetration in canned foods. For other products where technological information is not available, according to Cameron (11) the process is based upon analogy with similar products for which heat resistance and penetration data are available and also on general experience of the canning industry.

Esty and Meyer (23) have shown that the spores of Clostridium botulinum rapidly lose their resistance to high temperatures in a medium which is on the acid side of pH 4.5 and all products with a pH value higher than 4.5 should be processed under pressure so that all portions of the can are heated sufficiently to destroy most resistant strains of organism.

Bigelow and Esty (7) also point out that H-ion concentration is a better criterion upon which to base the relative time and temperature of sterilization of different materials than the total titratable acidity. Experiments of Dickson (19), Cruess, Fong and Liu (15) proved that the death temperature of spores of Clostridium botulinum is greatly reduced by acidification of the medium with organic acids like citric or acetic. Weiss (55) and others confirmed these results. On the basis of research of Meyer and Esty (23) and Dickson (18) the state Board of Health of California has established pH 4.5 as the dividing line between acid and non-acid foods.

Percentages of syrups used in fruits.

Fruits vary in the strength of syrup needed for a good pack. According to Osman Jones and T. W. Jones (45) the higher the concentration of the sugar the brighter the final syrup will be. On the other hand this must be restricted to avoid a sickly sweetness and an uneconomic expenditure on sugar. The percentage of soluable solids in the fruit affects directly the percentage in the final pack.. Since the fruits vary in this regard, so must the sugar strength of the syrup if the pack is to be a good one. Hirst and Adam (28) have carried out prolonged trials. The strength of syrup used also depends upon the standards and grades set up by canners' organizations or by the United States Department of Agriculture. (51) For example, fancy grade peaches are canned in 55° Brix, choice grade in 40° Brix and standard grade in 25° Brix syrup.

B. Freezing.

Addition of sugar or syrup and proportions used.

Since the beginning of the industry, fruit has been frozen with added sugar. Addition of sugar or sugar syrup during the preparation prior to freezing is mainly to protect the fruits from air. It also reduces the evaporation of volatile esters and other compounds which give fruits their characteristic aroma and flavor. According to Tressler and Evers (50) whole fruits and cut fruits are packed in dry sugar in the proportion of 2:1, 3:1, and 4:1 fruit sugar ratio, depending on the kind of fruit packed. Of these the most popular pack is 3:1.

The use of sugar solutions instead of dry sugar was introduced by Cruess, Overholser, and Bjarnason (16). They suggested the use of high, medium, and low syrup concentrations for different kinds of fruits. They pointed out that there was a slight difference between the concentration of syrup at which the flavor was best preserved and that at which the texture was best. This was later on proved by Joslyn (34). There is some difference of opinion among investigators as to the concentration of syrup that is best.

When syrups are used, Diehl, Weigand, and Berry (20) recommend a concentration of 50%. Syrups greater than 50% are not generally desired because they impart too sweet a taste and some undesirable fruit shrinkage may occur. Concentrations less than 40% do not have sufficient sugar to adequately protect the color and texture of fruits. Besides, the texture of fruits so packed tends to become soft.

Woodroof (56) states that syrup helps preserve the color and texture on both freezing and thawing since the film of sugar helps to eliminate air pockets that are so conducive to browning.

Use of anti-oxidants.

Several anti-oxidants which may act by reducing the free oxygen present in the syrup and the fruit tissues have been used. Hohl (30) reports that of these, ascorbic acid is used most widely at present in the packing of frozen fruit. In addition to preventing browning, ascorbic acid has a striking effect on retention of the natural fresh flavor and aroma.

The work done by the Hoffman-La Roche Company (29) shows that the ascorbic acid treatment has not been as successful, so far, in the dry sugar pack as in the syrup method. This is mainly because pockets of air within the container will cause a brown discoloration to develop around them, whereas in the syrup pack the air pockets are filled with liquid containing the protecting ascorbic acid. They recommend the addition of 150 to 180 mg. per pound of pack.

Bauernfeind and Siemens (4) recommend the addition of a minimum of 150 mg. of ascorbic acid per pound of finished pack, (3 to 4 parts of sliced fruit plus 1 part of sugar syrup by weight). The ascorbic acid is dissolved in the sugar syrup as shortly before use as possible and this syrup poured over the freshly cut fruit before the package is sealed and frozen. Other workers like Tressler and Clarence Du Bois (51) and Weigand (54) also recommend the use of 150 mg. per pound pack and state that the ascorbic acid could also be added directly to the fruit in dry powder form.

Sulphurous acid and its salts (the sulphites and bisulphites) are among the strongest and best known of anti-oxidants. It is a very strong inhibitor of browning and can be used in much smaller concentrations than ascorbic acid. Joslyn and Mrak (35) and Joslyn (36) report that unless used in concentrations of 50 to 75 p.p.m. browning will occur in the center portions of the fruit during freezing and also during thawing. According to Joslyn and Hohl (37), Tressler and Du Bois (51) sulphurous acids and sulphites have the disadvantage of bleaching the pigments of colored fruits and also have an objectionable and undesirable flavor which may be easily detected in concentrations above 25 to 50 p.p.m. in frozen fruits.

Another anti-oxidant which has received some attention in the literature is thiourea (thiocarbamide) known by the trade name Frulite according to Denny (17). Its use is not approved by the Food and Drug Administration because of its injury to humans. Besides, it adversely affects flavor.

The use of firming agents.

The effect of calcium compounds on plant tissues was studied by Kertesz (38) several years ago and a method for the calcium salts treatment of canned tomatoes was developed. The use of this method causes better retention of the original shape and firmness of the canned tomatoes by the addition of a minute quantity of calcium chloride to the can. Later on, Kertesz (39), Powers and Esselen (46), Esselen, Hart, and Fellers (21) made use of the firming quality of calcium salts on fruit tissue in the freezing of certain fruits which have a tendency to become quite soft and mushy when frozen. They found out that this tendency could be prevented by dipping the fruit in dilute solutions of calcium chloride, the strength of the solution and the dipping time depending upon variety, the condition of the fruit and the degree of firmness desired. According to Esselen, Hart and Fellers (22) a dipping time of five minutes in a 0.1% calcium chloride solution gave a very satisfactory product. They also indicate that concentrations from 0.03 to 1.5 % calcium chloride solution could be used. Hills et al (27) confirmed and extended these experiments and suggested vacuum impregnation to insure calcium penetration.

Freezing temperatures.

Since 1861, sharp freezing has been the most popular and widely used method of freezing. The freezing room was maintained at temperatures varying from 5°F. to -20°F. and no provisions were made for forced circulation of air, and the air within the room was allowed to circulate by convection. In present day practice the rooms are maintained at -10°F. to -20°F. or even lower. Since it takes 3 to 72 hours to freeze products, according to Tressler and Evers (50), depending upon their bulk, methods used and the facilities provided, this type of freezing was termed slow freezing. Hence this has been replaced by modern quick freezing.

Ferris and Taylor (25) referred generally to quick freezing as the speed of freezing which would result in the product being completely frozen in approximately 90 minutes or less. Woodroof (57) defined it as a process which progresses through the body of the product at 0.3 cm. per minute or faster. Several methods are used in quick freezing, such as freezing by direct immersion in a refrigerating medium, by indirect contact with a refrigerant and freezing in a blast of cold air. Several patented processes were developed by workers like Zarotschenzeff (58), Birdseye (10), Finnegan (26), and others, each with advantages of its own. But the air blast system of freezing is the most common one in use today. The temperatures used vary from -10°F. to 0°F.

in the rooms. The rooms are equipped with large fans blowing directly on the goods or other positive air circulating systems.

C. Dehydration

Sun drying of bananas has been carried out to a limited extent in India and also in other tropical countries. According to Burns and Joshi (6) the sun dried whole product is superior to that artificially dried in a drying apparatus. Sun dried whole bananas of commerce are known as banana "figs" and they are dark in color and unattractive, but, according to Cruess (14), they have a pleasing flavor. The ripe fruits are peeled and are allowed to dry in the sun.

According to Savage and Arthur (48) and Anon (1) fruits just approaching the ripe stage are peeled, cut into halves lengthwise and subjected to 1 to 1.6% of sulphur dioxide for 15 minutes. The sulphured fruit is dehydrated at 120-125°F. for 18 hours and is then placed in boxes and allowed to "sweat" for 1-2 weeks. This has a slightly superior color than the ordinary sun dried product.

Preparation of banana products (3) is reported from Africa where banana figs, banana chips, and banana flour are manufactured. Bananas prior to drying are cut lengthwise and exposed to burning sulphur fumes for 20 minutes and are dried at 140°F. to a final moisture of about 20%. Banana chips are prepared by thoroughly drying "green" bananas. They are peeled by dipping in very hot water and dried, either whole or cut into pieces, to a final moisture of ten per cent.

Von Loesecke (53) reports on a method used commercially for spray drying of bananas. According to this method the green fruits are peeled by immersion in hot water, 186°F, for 4 to 5 minutes and then passed through a meat chopper. To get a light coloured product the peeled fruits are dipped in a 1 or 2 per cent sulphite solution before grinding. The slurry formed is passed through a colloid mill which grinds the slurry to a very fine consistency. This slurry which is atomized through an atomizer, meets the hot air, is dried and falls to the bottom of the drier. The loss in this method is very great, since a large portion of the slurry gets charred on the walls.

Another commercially used method is drum drying. This is more economical because by this method all the solids are recovered. The moisture content of the final product will vary from 3 to 6 per cent.

The National Industrial Banana Corporation, Puerto Cortes, Honduras, produces dried bananas (44) and also banana powder under the trade name "Sun ban." They claim to be the only producer in the world using the spray drier method of processing this product.

D. Brining and Salting

Brining is done with the object of preserving raw products by placing them in a weak or strong salt solution until they have undergone certain physical and chemical changes which prevent the growth of undesirable micro-organisms. This system of salting preserves them so that they can be used later and also permits the shipping of raw materials to distant places.

Investigators like Campbell (12), Le Fevre (41), have stressed the importance of carefully controlled salt concentration of the brine involved in salt stock production. They recommend an initial brine concentration of 30 salometer in cool weather and 32-33 sal. in warm weather. Campbell (12) observed that a low or weak brine favored rapid fermentation whereas a high or strong brine checked or retarded fermentation. Fabian and Erickson (24) investigated the influence of high and low salt in fermentation. With low salt treatment of 30 degree brine, acidity developed more rapidly and attained a higher value than with the high salt treatment of 40 degree brine. However, these authors point out that after about a month's time there is very little difference between the total acidity of the two brines. Le Fevre (41), on the other hand, reported appreciably greater acid formation in moderately strong brines of 32-40 degree than weak brines of 20 to 28 degree.

The work of Ivan D. Jones (31) shows that brines of low salt concentration favor the rapid formation of a relatively high amount of total titratable acid and the development of a low brine pH. Brines of increasingly higher initial salt content favor correspondingly retarded rates of acid formation and higher pH values. Experiments carried out by Fabian (24) and others on peas and green lima beans showed that peas and green lima beans could not be successfully preserved if they were allowed to ferment. Salt concentrations ranging from 30 to 90 salometer at 10 degree intervals were tried. If they were allowed to ferment their flavor was spoiled. Salt concentrations lower than 70 salometer, fermented the product in proportion to the amount of salt present. The acidity which developed gave the product an undesirable sour taste which did not disappear upon processing.

Jacobs (33) reports on brining of whole-kernel corn in 40, 60, and 80 degrees salometer brines. It was found that the color and texture were good and the flavor fair.

CHAPTER III

EXPERIMENTAL PART

A. Canning.

The author has not come across any literature on canning of bananas, though canning has been for many years one of the best methods of preserving fruits and vegetables. Certain varieties of plantain, i.e. green bananas, which are available only during certain seasons in India are consumed only after cooking. The cooking imparts a characteristic flavor which is preferred by the public, is lacking in the raw product. But such flavor is exclusively obtained by canning which involves cooking or processing. In spite of the fact that such cooking variety was not available in the market here, "Gros michel" the common variety was made use of. With this view in mind experiments were conducted and the effects of stage of ripeness of fruit, type and size of can, pH, processing time and temperature, and size of pieces have been studied.

(a) Proceedure.

In order to study the stage of ripeness of fruit for canning, experiments were conducted on green, hard ripe, and fully ripe bananas. The banana was washed thoroughly in water before separating them from the hand. In the case of green bananas, the skin was peeled by immersing them in hot water of 186°F. for 4 minutes. In the case of hard ripe and fully ripe bananas, the skin was peeled by hand. The stem and blossom ends were cut off to fit the length of the can. They were then canned both in heavy and light syrup in plain No. 2 (307 x 409) cans (12 ounces) after exhausting the cans for 10 minutes at 185°F.

Most of the processes used in the canning industry have been standardized by the National Canners' Association. Therefore it would be best if one of the standard processes used for similarly canned products be adapted for this particular product. The pH of fresh banana, which is approximately 5, falls within close range of asparagus. The process recommended for asparagus in No. 2 cans is 25 minutes at 240°F. Therefore this processing time would be perfectly suitable provided there are no adverse effects on color and texture of the product. Hence the cans were processed at 15, 25, and 30 minutes at 240°F. The cans were cooled in running water. The next day these cans were opened and examined. The results are given in tables 2, 3, and 4.

Table No. 2 Canned Green Banana (whole)

The pH of fruit was 4.8 and the vacuum varied from 12 to 13 inches.

°Brix	Time in min.	Tempera-ture	Texture	Color	Flavor
50	15	240°F.	tough	pink out-side and yellow near seed	no banana flavor
50	25	240°F.	tough	do	do
50	30	240°F.	tough	do	do
15	15	240°F.	tough	light pink outside and yellow near seed	insipid
15	25	240°F.	tough	pink out-side and yellow near seed	insipid
15	30	240°F.	tough	do	do

Table No. 3. Canned Hard Ripe Whole Bananas.

The pH of fruit was 5 and the vacuum varied from 12 to 13.5 inches.

°Brix	Time in min.	Temperature	Texture	Color	Flavor
50	15	240°F.	slightly tough	slightly pink	very little; slight astringent taste.
50	25	240°F.	do	pink	do
50	30	240°F.	do	pink	do
15	15	240°F.	slightly tough	slightly pink	almost insipid
15	25	240°F.	do	pink	do
15	30	240°F.	do	pink	do
			Cut pieces of 1" size		
50	15	240°F.	slightly tough	pink	very little; slight astringent taste.
50	25	240°F.	slightly tough	pink	do
50	30	240°F.	do	pink	do
15	15	240°F.	do	pink	insipid
15	25	240°F.	do	pink	do
15	30	240°F.	do	pink	do

Table No. 4. Canned Fully Ripe Banana.

The pH of fruit was 5 and the vacuum varied from 11 to 12.5 inches.

°Brix	Time in min.	Temperature	Texture	Color	Flavor
50	15	240°F.	whole*	slightly pink	good
50	25	240°F.	do *	pink	good
50	30	240°F.	do *	pink	good
15	15	240°F.	do *	slightly pink	poor
15	25	240°F.	do *	pink	poor
15	30	240°F.	do *	pink	poor
		Banana cut into 1" pieces			
50	15	240°F.	good	pink	good
50	25	240°F.	good	pink	good
50	25	240°F.	good	pink	good
15	15	240°F.	good	pink	good
15	25	240°F.	good	pink	good
15	30	240°F.	good	pink	good

* Center portion raw.

(b) Acid penetration.

It was found that the canned fruit regardless of the concentration of syrup used, had a pink color. The color increased as time of processing increased. Decreasing the time of processing less than that recommended by the National Canners' Association for a product of non-acid nature will not be safe from the public health point of view. Therefore other experiments were carried out by reducing the pH. If the pH of the fruit could be reduced to such a limit so that the product will have a final pH of 3.5, such as peaches, the processing time and temperature could be reduced accordingly. Citric acid was added to the syrup to lower its pH to 2 and fully ripe bananas were canned in this syrup both whole and cut pieces of 1" length. This required 10.4 g. of acid per 2 pounds of syrup. The processing time and temperature recommended for peaches in No. 2 can is 16 minutes at 212°F. after exhausting the cans for 8 minutes at 180°F. Therefore bananas were processed for 16, 20, and 25 minutes at 212°F. in order to study the effect on texture and color.

The cans were cooled in running water. These were opened after 8 days and examined. The results are given in table number 5. In all these cases the texture was good, but the ones cooked for 25 minutes had the color changed to pink. Those processed for 16 and 20 minutes had good texture and did not change in color.

Table No. 5. Canned Fully Ripe Banana with Added Acid.

pH of the syrup added is 2.0

°Brix	Time in min.	Temperature	Texture	Color	Flavor
50	16	212°F.	whole*	good	good but a little too sweet
50	20	212°F.	do *	good	do
50	25	212°F.	do *	light pink	do
45	16	212°F.	do *	good	good sugar acid blend
45	20	212°F.	do *	good	do
45	25	212°F.	do *	light pink	do
40	16	212°F.	do *	good	slightly acid
40	20	212°F.	do *	good	do
40	25	212°F.	do *	light pink	do

Cut pieces of 1" length.

°Brix	Time in min.	Temperature	Texture	Color	Flavor
50	16	212°F.	good	good	little sweet
50	20	212°F.	good	good	do
50	25	212°F.	good	light pink	do
45	16	212°F.	good	good	good sugar acid blend
45	20	212°F.	good	good	do
45	25	212°F.	good	light pink	do
40	16	212°F.	good	good	little acid
40	20	212°F.	good	good	do
40	25	212°F.	good	light pink	do

* Those canned whole: the fruit was not cooked well throughout, because the heat penetration was less even with 25 minutes cook.

Though 16 minutes cook was enough, 20 minutes cook was chosen as the processing time at 212°F. when 180°F. was the initial temperature of the product, since it did not change the color and also as a safety factor. The pH of the final product, fruit as well as syrup, was tested and found to be 3.5.

The different types of cans tried were: (1) plain tins, and (2) 'C' enameled cans. The former were chosen since it did not have any deleterious effect on the product in this short storage time of eight days.

(c) Discussion of results.

In the case of banana canned whole the heat penetration, as evidenced by cooked texture, was found to be less than that cut into small pieces, regardless of the time of cook used. In small pieces there was no change in texture throughout the product, whereas in whole bananas the central portion was much more firm than the outside, indicating lack of cook.

Both in the case of whole as well as the cut pieces high temperature caused change in color. The higher the temperature and longer the time, the deeper was the color.

When high concentration of syrup, viz. 50° Brix, was used the product was found to be too sweet. But when 15° Brix syrup was used the product was almost insipid. Hence medium syrup, 45°

Brix was chosen as best since it gave a product with good sugar acid blend. (Table 5.)

The experiments described above show clearly that bananas before they are fully ripe are not fit for canning purposes, like the cooking varieties of plantain, if a product of good texture, color and flavor are to be obtained. Since the fruit falls under the non-acid group, lower temperatures cannot be used for processing unless acidified with some edible acids. It is also obvious that a canned banana product having good color, flavor and texture can be obtained if properly acidified with some edible acid and processed for 20 minutes at 212°F. when the initial temperature is 180°F.

B. Freezing.

(a) Objectives.

This work was undertaken to prepare a frozen banana product having good flavor, color, texture and general acceptability. In this work only a few factors like stage of ripeness, sugar and syrup ratio, effect of blanching, use of anti-oxidants like sulphite dips and l-ascorbic acid, and firming agent were studied. Experiments on these and their results are described below so that further work can be done on them by those interested. The results given below and the conclusions drawn are based on 4 days storage only.

(b) Proceedure.

Fruits of different stages of ripeness such as green tipped, all yellow or hard ripe, and fully ripe were taken. They were washed thoroughly in water before they were separated from the hands. They were then peeled by hand and cut into slices of approximately 3/16" to 4/16" thickness. One batch was blanched in steam for 3 minutes. They were then packed with dry sugar having a fruit to sugar ratio of 4:1, 3:1, 2:1, 1:1, and also without sugar. After mixing with sugar the fruit was put in cellophane bags encased in waxed cardboard boxes, of 1 pound size, heat sealed and frozen in about four hours at $0^{o}F.$ with a fan blowing air onto the product. After four days they were allowed to thaw, about six hours being required, and examined for color, texture, and flavor. The results are given in tables 6, 7, and 8.

It was found that the sugar solution formed on contact with the surface of the fruit settled to the bottom of the package, carrying with it the undissolved sugar. This left the upper portion of the fruit exposed, thus limiting the preservative effects of sugar. Since this could be eliminated if sugar solutions are used, other experiments were carried out with sugar syrups of different concentrations on fully ripe bananas. The fruit, after slicing, was packed in syrups of 60, 50, and 40 degrees Brix. Syrups were used in the proportion of 3:1, fruit to syrup ratio. The results are tabulated in table number 9.

Since it was found that the color of banana turned brown one hour after thawing, anti-oxidants like sulphur dioxide and l-ascorbic acid were used. In the case of sulphur dioxide the banana slices were dipped in 0.3 per cent and 0.4 per cent solutions of potassium meta-bisulphite for three and four minutes respectively. They were then packed with 50 Brix syrup having a fruit to syrup ratio of 3:1. After 4 days they were examined after thawing. The results are given in table number 10. In the case of l-ascorbic acid, the banana slices were packed in 1 pound packages with 50 Brix syrup having a fruit to syrup ratio of 3:1 (12 ounces of fruit

Frozen Bananas---Green Tipped.

Table No. 6. No Blanch

Fruit: Sugar	Color	Texture	Flavor	General Acceptability	Remarks
No Sugar	brown	soft and slimy	insipid	worst	All had astringent taste. Color darkened as exposure to air increased.
4:1	brown	soft	astringent	poor	
3:1	brown	fair	do	poor	
2:1	fair	fair	do	poor	
1:1	fair	fair	do	poor	fruit slightly shrunk
Blanched for 3 minutes in steam					
No Sugar	dark	firm	poor	worst	Fruit became mushy while mixing with sugar.
4:1	dark	firm	poor	poor	
3:1	dark	firm	poor	poor	
2:1	dark	firm	poor	poor	
1:1	dark	firm	poor	poor	Darker near seed. Had a better color than the rest but not better than unblanched one.

Frozen Bananas

Table No. 7. Hard Ripe Fruit. No Blanch.

Fruit: Sugar	Color	Texture	Flavor	General Acceptability	Remarks
No sugar	brown	slimy	poor	worst	All had astringent taste.
4:1	slightly brown	soft	astringent slightly	poor	Color darkened as period of exposure to air increased.
3:1	fair	fair	do	poor	
2:1	fair	fair	do	poor	
1:1	fair	fair	do	poor	Slight shrinkage in fruit.

Frozen Bananas

Table No. 8. Fully Ripe Fruit. No Blanch.

Fruit: Sugar	Color	Texture	Flavor	General Acceptibility	Remarks
No sugar	brown	slimy	insipid	worst	No astringency. Flavor increases as concentration of sugar increases to 2:1. Above that the flavor is masked by sugar. Color darkened after 1 hour.
4:1	light brown	fair	fair	fair	
3:1	fair	fair	good	v.fair	
2:1	fair	fair	good	v.fair	
1:1	fair	fair	sweet	fair	

Frozen Bananas

Table No. 9. Packed in Syrup. Fully Ripe.

Syrup Used	Color	Flavor	Texture	General Acceptability	Remarks
60° Brix	good	good	fair	good	Too sweet.
50° Brix	good	good	fair	good	In all three the color of fruit became brown 1 hour after thawing.
40° Brix	good	v.fair	fair	v.fair	

Frozen Bananas

Table No. 10. Anti-oxidant: Sulphite Dips

% Sulphite Solution	Time of Dip	Color	Texture	Flavor	General Acceptability	Remarks
0.3	3 min.	good	soft	SO_2	poor	*
do	4 min.	good	soft	do	poor	
0.4	3 min.	good	soft	do	poor	
do	4 min.	good	soft	do	poor	

* All had sulphur dioxide taste. But there was no change in color even two hours after thawing.

and four ounces of syrup). Quantities of 75, 100, 150, and 200 milligrams of l-ascorbic acid were added to each packet, after dissolving it in a very small quantity of water. The packets were at once heat sealed. After sealing, the packets were turned upside down and quick frozen at 0°F. in a blast of air. The results are given in table number 11.

It was found that the fruit had a slightly soft texture on thawing. In order to improve the texture of the fruit, a firming agent, viz. calcium chloride, was used. In one batch of experiments different quantities of calcium chloride were added directly to the package along with 150 milligrams of l-ascorbic acid prior to freezing. The amounts of calcium chloride used were 100, 200, 300, 400, and 500 milligrams per pound of the product. The results are given in table number 12.

In another series of experiments banana slices were dipped in 0.2 per cent and 0.3 per cent solutions of calcium chloride for 10 to 15 minutes. The banana slices were then packed with 50 Brix syrup and 150 milligrams l-ascorbic acid per pound package. The packets were turned upside down and quick frozen. They were kept frozen for four days before they were thawed and examined. The results are tabulated in table number 13.

The product obtained with 10 minutes dip in 0.2 per cent and 0.3 per cent calcium chloride solution was fairly satisfactory. This experiment was repeated and samples of the two treatments

Frozen Bananas

Table No. 11. Use of Anti-oxidant: l-Ascorbic Acid.

Mg. of Added l-Ascorbic Acid	Color	Texture	Flavor	General Acceptability	Remarks
control	slightly brown	fair	fair	poor	*
75 mg.	fair	fair	fair	fair	
100 mg.	good	fair	good	good	
150 mg.	v.good	fair	v.good	v.good	
200 mg.	v.good	fair	slight acid taste	poor	

* When 200 mg. of l-ascorbic acid was added the acid taste could be detected. With these with 75 mg. the color changed to brown 1 hour after thawing. Others retained the color even 2 hours after thawing.

Frozen Bananas

Table No. 12. Use of Dry Calcium Chloride.

(150 mg. of l-ascorbic acid added to each package.)

Mg. of Calcium Chloride	Color	Texture	Flavor	General Acceptability
control	good	fair	fair	fair
100	good	fair	fair	fair
200	good	v.fair	slightly bitter	poor
300	good	v.fair	do	poor
400	good	v.fair	do	poor
500	good	v.fair	do	poor

Frozen Bananas

Table No. 13. Calcium Chloride Dip for 10 Minutes.

(150 mg. l-ascorbic acid added to each package.)

Calcium Chloride Concentrations Used	Syrup	Color	Texture	Flavor	General Acceptability
no calcium chloride	50 Brix	good	fair	good	fair
0.1% calcium chloride	do	good	fair	good	fair
0.2% calcium chloride	do	good	good	good	good
0.3% calcium chloride	do	good	good	good	good
Calcium chloride dip for 15 minutes					
no calcium chloride	do	good	fair	good	fair
0.1% calcium chloride	do	good	fair	good	fair
0.2% calcium chloride	do	good	good	good	good
0.3% calcium chloride	do	good	good	good	good

were compared with a control by the official taste panel of the Food Technology Department. The samples were judged to be good in flavor and appearance but too sweet (50° Brix). There was a preferance for the calcium chloride treated samples because of slightly improved texture. Though the bananas were found to be a little too sweet for ordinary eating purposes, they could be well utilized for prepared products such as pies, bakery products, and baby foods.

(c) Conclusions on freezing experiments.

Stage of ripeness. From the above experiments it was obvious that the best stage of ripeness for freezing was when the banana was fully ripe. Partially ripe or hard ripe bananas had an astringent taste which is common with unripe bananas.

Effect of blanching. Banana blanched in steam for three minutes was difficult to handle and became mush when mixed with sugar. Though there was slight firming in texture of banana during blanching, while freezing and thawing the product became dark in color. The color difference was more noticeable and darker at the seed portion, while, in the case of unblanched banana, no such change was noticed, and there was no difficulty in handling the fruit.

<u>Effect of dry sugar pack.</u> It was found that in dry sugar pack the sugar solution formed on contact with the surface of the fruit settled to the bottom of the package. While settling down, the undissolved sugar was also carried along with it. As a result of this the fruit was exposed to the air and oxidative changes , which caused the darkening of the product. In the case of 1:1 ratio of fruit to sugar there was slight shrinkage in fruit. It was also found that the flavor of banana increased in the case of dry sugar pack as the concentration of sugar increased to 2:1. Above this ratio the product was too sweet in taste and the flavor was masked by sugar.

<u>Effect of sugar syrup pack.</u> The sugar syrup used in one pound pack (4 ounces) was enough to cover the fruit when 12 ounces of fruit were used. The complete coverage given by the syrup protected the fruit from changing the color during freezing and thawing. But after the fruit had been thawed and left in pans for one hour the color changed to brown. Fruits packed with 60 and 50 degree Brix had very good flavor of banana, though the one packed with 60 Brix was found to be too sweet. In the case of those packed in 40 Brix the flavor seemed to have lost a little. In all cases the syrup had more flavor than the pieces.

✓ <u>Effect of anti-oxidants.</u>

✓ <u>Sulphite dips.</u> Fruits dipped in sulphite solutions of 0.3 per cent and 0.4 per cent for 3 and 4 minutes respectively retained their color even two hours after thawing. The texture of the fruit became slightly soft. In general all had sulphur dioxide taste and no banana flavor.

<u>l-ascorbic acid.</u> Those treated with 100, 150, and 200 milligrams of l-ascorbic acid per pound package had very good color, while those with 75 milligrams, though retaining the color after thawing, became slightly brown after one hour. Fruit in which 200 milligrams was added, the acid taste could be detected. Since 150 milligrams of added l-ascorbic acid retained the color and flavor well, this quantity was taken as the optimum.

<u>Effect of firming agent.</u>

<u>Dry calcium chloride.</u> When 100 milligrams of dry calcium chloride was added to one pound package there was no appreciable change in texture of banana slices. Addition of more than 100 milligrams of calcium chloride, though improving the texture had a deleterious effect on flavor. Hence it is evident that addition of dry calcium chloride is not advisable if a product of good flavor is desired.

<u>Effect of calcium chloride dip.</u> Dipping of banana slices in 0.1 per cent calcium chloride solution, both for 10 and 15 minutes did not have any appreciable change in the texture of the product. But when the concentration was increased to 0.2 per cent and 0.3 per cent calcium chloride, there was definite change in texture. Between 0.2 per cent and 0.3 per cent of calcium chloride,

increasing the time of dip from 10 to 15 minutes did not have any significant change in texture. It was noticed that the central core of each slice was firmer than the surroundings. Probably a higher concentration and longer time dip might improve the texture more. A definite conclusion cannot be made at this stage, as more work on this line is needed.

It is clear from the above experiments that a frozen banana product having good flavor, color and texture and general acceptability can be obtained, by subjecting the banana slices to a 10 minute dip in 0.2 per cent calcium chloride solution and addition of 150 milligrams of l-ascorbic acid per pound package and four ounces syrup prior to freezing.

C. Dehydration

(a) Objectives.

The dehydration of bananas was studied only with certain factors, such as effect of blanching, sulphuring, sulphite dips, and drying temperatures. Since there are so many variables, the results are only indicative and the author does not pretend to give hard and fast conditions for the dehydration of banana. The optimum conditions for each variable must be obtained under the prevailing conditions with specific equipment.

(b) Procedure.

Ripe bananas were washed thoroughly in water before they were separated from the hands. They were then peeled by hand, trimmed to discard blemishes and bruised portions, and cut into cross-slices of approximately 2/16" to 3/16" thickness. The slices were spread on wire mesh trays and the following treatments were given:

1. No treatment.
2. Blanched in steam for 1 minute and not sulphured.
3. Blanched in steam for 5 minutes and not sulphured.
4. Sulphured for 30 minutes in fumes of burning sulphur.

5. Blanched in steam for 1 minute and sulphured in fumes of burning sulphur for 30 minutes.

6. Blanched in steam for 5 minutes and sulphured in fumes of burning sulphur for 30 minutes.

The treated material was dehydrated with single pass hot air flowing across the trays in a cabinet dehydrator of the Food Technology Department, which is provided with automatic controls for temperature and humidity. A temperature of 165°F. dry bulb, and 94°F. wet bulb, was used in this experiment so that an absolute humidity of 129.5 grains per pound of dry air is maintained throughout the drying period. This particular amount of absolute humidity was maintained in order to represent the absolute humidity conditions in southwestern part of India (Travancore State).

The first trial run was made and the product was dehydrated to a final moisture content of 7 per cent in $5\frac{1}{2}$ hours. The product obtained had brown colour regardless of the different treatments given. Since the brown colour was due to long drying period, other runs were carried out to have a moisture content of 15 per cent in the final product. The drying temperatures were maintained the same and a product of 15 per cent moisture was obtained in $3\frac{1}{2}$ hours. The per cent moisture was determined by the toluene distillation method. The products obtained were graded according to percent natural colour by the author. The results of the various treatments are given in table number 14.

Table No. 14.

Dehydration Pretreatments: Blanching & Sulphur Dioxide.

Treatment	% Natural Color	General Rating	Remarks
Sulphured for 30 min.	95	Excellent	(drying time
Sulphured for 30 min.	94	v.good	(
Sulphured for 30 min.	93	v.good	(3½ hours
Blanched 1 min. and sulphured 30 min.	92	good	do
Do	91	good	do
Do	90	good	do
Sulphured for 30 min.	89	v.fair	(drying time
Blanched for 1 min. & sulphured for 30 min.	88	v.fair	(5½ hours
Blanched 1 min. and no sulphuring	87	poor	(drying time
Do	85	poor	(3½ hours
No treatment	80	v.poor	do
Do	80	v.poor	do
Do	80	v.poor	do
Do	77	v.poor	drying time 5½ hours
Blanched 1 min. and no sulphuring	75	v.poor	drying time 3½ hours
Blanched 1 min. and no sulphuring	75	v.poor	drying time 5½ hours
Blanched 5 min. and sulphured 30 min.	Translucent	v.poor	(drying time
Blanched for 5 min. and no sulphuring	do	v.poor	(both 3½ & 5½ hours.

Another set of experiments to determine the effects of sulphuring for 240 minutes instead of 30 minutes, and also dipping in 1 per cent potassium meta-bisulphite solution having a pH of 3, by addition of citric acid, for periods of 2 minutes, 5 minutes, 8 minutes, and 10 minutes, was conducted. The material, after these treatments, was dehydrated at the same temperature, viz. 165°F. dry bulb, and 94°F. wet bulb, to a final moisture content of 15 per cent. Banana slices after dipping in potassium meta-bisulphite solution became very soft and mushy. On dehydration the slices adhered to the trays so tightly that they had to be removed with a knife. The results of the above experiments are given in table number 15.

In order to investigate the possibilities of using a higher temperature for drying and also to note its effects on the final product, another experiment was conducted. A starting temperature of 180°F. dry bulb and 100°F. wet bulb was used for the first one hour of the drying period and then lowered to 165°F. dry bulb and 94°F. wet bulb. Drying was done over a period of 2 3/4 hours with a final moisture content of 15 per cent. It was found that the product obtained was similar in colour to that dried at 165°F. The results are given in table number 16.

Table No. 15. Dehydration Pretreatment: Bisulphite Dips.

Treatment	% Natural Color	Sticking	General Rating	Drying Time	Moisture
Sulphured for 240 min.	95	slight	excellent	$3\frac{1}{2}$ H.	15 %
2 min. dip in 1 % potassium meta-bisulphite solution	do	v.bad	do	do	do
5 min. do	do	do	do	do	do
8 min. do	do	do	do	do	do
10 min. do	do	do	do	do	do

Table No. 16. Effect of High Drying Temperature.

Treatment	Color	Sticking	Drying Time in Hours	Moisture %
No treatment	brown	slight	2 3/4	15
Sulphured for 30 min.	excellent	do	do	do
Sulphured for 240 min.	excellent	do	do	do
Blanched for 5 min. & no sulphuring	translucent	bad	do	do

(c) Discussion of results.

It was fairly clear from the results of the different experiments that ripe bananas dehydrated without any treatments had very poor colour regardless of their moisture content, temperature or drying time.

Effects of blanching, and blanching and sulphuring. Ripe bananas blanched for 1 and 5 minutes gave a poor product as far as colour and flavor are concerned. Those blanched for 1 minute and sulphured for 30 minutes gave a very fair product. But those blanched for 5 minutes and sulphured for 30 minutes gave a very poor product and stuck badly to the wire mesh trays. Since the slices were small the product was almost cooked during steaming and hence had a cooked taste. The product also was translucent in appearance. Hence, blanching is not recommended as a pretreatment in dehydration of ripe bananas.

Effect of potassium meta-bisulphite solution dip. Dipping the slices in 1 per cent meta-bisulphite solution having a pH of 3 for as short a period as 2 minutes definitely improved the colour of the product. But the pieces became so soft and mushy after the dip that they stuck tightly to the trays. Additional work should be done before any definite conclusions can be made.

Effect of sulphuring in fumes of burning sulphur.

Subjecting the slices to fumes of burning sulphur in a chamber for 30 minutes and 240 minutes gave an excellent product having a light lemon color. Sulphuring for 240 minutes duration did not have any significant improvement, as far as colour of the product was concerned, over those sulphured for 30 minutes. Samples sulphured for 240 minutes had a stronger sulphur taste then those sulphured only for 30 minutes, but no more than sun dried peaches and apricots, which are sulphured before drying.

Use of higher drying temperature. Use of higher drying temperature during the first hour of drying did not have any deleterious effect on the final product. Thus one can reduce the time of drying, which would increase the output per day, with given equipment.

D. Brining & Salting.

(a) Objectives.

Preservation of food by brining and salting has been one of the oldest and cheapest methods. The study on preservation of bananas by salting and brining has been carried out on both green and ripe fruit in order to compare which of them gives a better product. Green cooking variety banana is produced in large quantities in India and during certain seasons of over production the majority of it is wasted. In order to investigate the possibilities of salting and brining of green and ripe bananas and storing for future use, a survey has been made on a comparative basis.

(b) Procedure.

Bananas were washed in water thoroughly to remove dirt and other foreign materials. Both peeled and unpeeled bananas were used. Green bananas were peeled by dipping them in 186°F. hot water for 4 minutes. Ripe ones were peeled by hand. One batch, each, of whole, cut pieces of approximately 2 " length, peeled and unpeeled bananas were put in 20, 40, 60, and 100 salometer salt brine. Another batch was dry salted with 1:1, 1:2 and 1:4 salt to fruit ratio by weight. They were stored for 3 weeks. They were then examined and the results are given in tables 17, 18, 19 and 20.

(c) Discussion of results.

Whole ripe versus whole green bananas in brine. Whole bananas, both ripe and green, put in different concentration of brine, retained their color of both skin and pulp exceptionally well. On peeling, ripe ones had a disintegrated surface, which was absent in the case of green ones. The texture of ripe bananas became so spongy and soft that they lost the rigidity and shape of banana after peeling. But the green ones had a firm texture and retained their shape. In either case the taste was too salty, even after soaking in water for five hours. A significant difference in pH was noticed in the brine of ripe bananas than in green ones, indicating, thereby, formation of lactic acid from sugar of ripe bananas. As the concentration of salt increases, the action of lactic acid bacteria is inhibited and the acid formed is less.

Cut peeled banana versus whole unpeeled. From tables 17, 18 and 19 it is clear that formation of acid is more when brined without skin, both in the case of green as well as ripe ones. It seems that the skin acts as a barrier. In India even the green skin is used in certain vegetable preparation. Since the presence of skin does not seem to jeopardize the preservative action when higher concentrations of brine are used, the removal of skin does not seem to be a necessity.

Table No. 17. Whole Unpeeled Green Bananas in Salt Brine.

Initial Salometer Reading of Salt Brine	Final pH	Color	Texture	Taste	Final Salometer Reading
20	4	good	firm	poor	14
40	4.5	good	firm	poor	36
60	5	good	firm	poor	54
100	6.5	good	firm	poor	88

Taste was too salty even after 5 hours of soaking in water and hence banana flavor could not be detected.

Table No. 18. Whole Unpeeled Ripe Bananas in Salt Brine.

Initial Salometer Reading of Salt Brine	Final pH	Color	Texture	Taste	Final Salometer Reading
20	3.4	good	spongy	slightly acid	15
40	3.8	good	do	do	35
60	4.5	good	do	do	53
100	5	good	do	do	80

The taste was too salty and no banana flavor could be detected even after soaking in water for 5 hours. When peeled the surface of banana had a disintegrated appearance.

Table No. 19. Cut Peeled Pieces in Salt Brine.

Kind	Initial Salometer Reading	Final pH	Color	Texture	Taste	Final Salometer Reading
Green	60	4.3	good	firm	slightly acid	50
do	100	5.6	do	do	no taste	75
Ripe	60	4.3	do	spongy	slightly acid	55
do	100	4.8	do	do	too salty	80

Table No. 20. Cut Peeled Pieces in Dry Salt.

Kind	Proportion of Salt to Fruit	Final pH	Color	Texture	Taste
Green	1:1	6.6	good	firm	too salty
do	1:2	5	good	firm	do
do	1:4	5.5	dark	firm	do
Ripe	1:1	6.5	good	spongy	do
do	1:2	5.2	good	do	do
do	1:4	4.8	dark	do	do

The salt solution formed in contact with the fruit was not enough to completely cover in the case of 1:4 and hence the fruit that was exposed became dark. But those inside the salt solution retained good color. Shrinkage in size, in the case of 1:1 and 1:2, salt to fruit ratio.

Dry salting. It has been found that the salt solution formed on contact with the fruit settled to the bottom, carrying with it the undissolved salt. This left the upper part exposed, as the solution formed was not enough to cover completely the entire product.

This caused the product to turn dark. Those well immersed in salt solution had a good natural color, but caused shrinkage in size. The texture of green bananas remained firm, while that of ripe became spongy and soft, regardless of the proportion of dry salt to fruit added.

The above experiments show that green bananas could be stored for future use in brine, either peeled or unpeeled, without undergoing any appreciable change in texture, color and shape. The banana flavor is lost in all cases. This is not serious where bananas are to be used for cooking since green cooked bananas have no banana flavor even when cooked fresh. Since green bananas are always cooked with addition of salt during preparation of vegetable dishes, the presence of salt is not objectionable. Dry salting requires a large amount of salt to cover the entire product, which shrinks the product, and also is uneconomical. Ripe bananas do not give a satisfactory product.

CHAPTER IV

SUMMARY AND CONCLUSIONS.

This work has led to the preparation of canned, frozen, and dehydrated banana products having good color, flavor, texture, and general acceptability. The work has proved to be a first step in the direction of preparation of such products, especially in the case of the canned and frozen product.

There are several varieties of bananas grown in the tropical countries. The selection of particular varieties best suited for the different processes should be made by experimentation. Since "Gros michel" is the only variety available in the market here, the processes surveyed had to be limited to this particular variety.

With bananas canned and processed at 240°F., because of their non-acid nature, any safe time of cook changed their color and texture regardless of the size of pieces, and concentration of syrup used. All those canned in 45 degrees Brix syrup, after proper acidification with citric acid to pH 2, to give a final pH of 3.5 in the processed product, and cooked for 20 minutes at 212°F. had good color, texture and general acceptability. The processing time (20 minutes) and temperature (212°F.) were adapted from the standard processes for similar products (peach) suggested by the National Canners' Association. Number 2 plain cans were used.

The best frozen product was sliced bananas subjected to a 10 minute dip in 0.2 per cent calcium chloride solution and addition of 150 milligrams of l-ascorbic acid per pound package, including 4 ounces of 50° Brix sugar syrup, prior to freezing. This gave a product having good color, flavor, texture and general acceptability. The product was found to be a little sweet for ordinary eating purposes, but could be well utilized in prepared products such as pies, bakery products and baby foods. Addition of different quantities of dry calcium chloride salt to each one pound package, though improving the texture, gave a product having a slight bitter taste. Blanching of the fruit prior to freezing made difficult the handling of the product.

In dehydration, the work was mainly based on atmospheric conditions in southwestern part of India (Travancore), with a mean annual temperature of 86°F. and a mean absolute humidity of 129.5 grains per pound of dry air. The air entering the dehydrator was maintained as far as possible the same as that which could be obtained in Travancore. Banana slices of approximately 2/16" to 3/16" thickness, subjected to 30 minutes of sulphur dioxide fumes prior to drying gave an excellent product having a light lemon yellow color when the final moisture content was fifteen per cent. Sulphuring for 240 minutes duration did not have any significant improvement in color over that sulphured for 30 minutes. Use of higher drying temperature of 180°F. during the first hour of drying did not have any deleterious effect on the product, proving that a higher temperature could be used. This shortened the drying time from approximately $3\frac{1}{2}$ hours to 2 3/4 hours.

The work on salting and brining green bananas was carried out in order to investigate the possibilities of storing green and ripe bananas for future use, on a comparative basis. This proved that green bananas peeled or unpeeled could be stored in strong brine without fermentation and any bad effects on color, and texture.

In this survey of experimentation on various methods, attention was paid only to certain important factors and the results and conclusions derived are based on a short storage period. Hence more work in this direction is necessary and could be carried on by those interested. Yet it is obvious from the results of the experiments, especially in the case of canned and frozen bananas, that a product resembling the fresh fruit in color, texture and flavor could be obtained.

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