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The Canning of Green Bananas. I. Processing Factors Affecting the Acidification of Hot Water Peeled Fruit.[1]

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ABSTRACT

Acidification of green bananas by blanching in hot acetic acid or citric acid solutions (160–190° F: 71–88° C) lowered the pH of the fruit at a much faster rate than dipping in the acid solutions at room temperature. A combination of blanching in hot acid solutions and canning in acidified brine proved to be an adequate acidification procedure when using either acetic or citric acids. However, acidification in the can with 2% salt brines acidified to .3–.35% citric acid proved to be the simplest procedure to lower the pH to a safe level for boiling water processing. Storage of acidified samples at room temperature resulted in negligible changes in the stabilization pH and on the pH of the solid portion, but at the end of a year of storage the fruit pH was always higher than the stabilization pH. The acidity of the green fruit affected the pH of the canned acidified product, which increased as the acidity of the raw fresh fruit increased. Unsalted canned bananas were higher in pH and lower in titratable acidity than samples packed in 2% salt brines.

INTRODUCTION

Green bananas have a pH ranging from 5.2 to 5.6, and therefore, for canning they must be thermally processed to meet the safety requirements of a low acid food. The heat treatment required to achieve commercial sterility at this pH produces an unmerchantable product due to the adverse changes in flavor, texture and color which take place during processing.

Many products like globe artichokes, white onions, cauliflower, Brussels sprouts, pimiento peppers, tomatoes and palmito, which cannot be retorted, are acidified to lower the pH to 4.6 or below in order that a thermal process at atmospheric pressure can be used for canning (5, 8, 10, 12).

The acidification process is based on the fact that the spores of

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Clostridium botulinum do not grow at a pH of 4.6 or lower and toxin formation does not occur (15, 17).

In the acidification of foods to be processed in hermetically sealed containers, acidification control is considered a critical process factor because of the hazards of *C. botulinum* resulting from an improperly acidified product (4). Many factors are known to affect the acidification process; among these are nature and stage of maturity of the product, acidification procedure, type of acid and packing media used, processing and storage (2, 3, 6, 8, 9, 10, 14, 16). For this reason, each product to be acidified must be carefully studied to determine the processing factors which affect the final equilibrium pH of the pack.

The main purpose of this study was to determine the feasibility of canning green bananas by acidification and boiling water processing to provide an additional outlet for this crop in Puerto Rico, and to determine the effect of the different processing factors on the quality and safety of the acidified canned bananas.

MATERIALS AND METHODS

Green fruits of the Montecristo cultivar were used in this study. The fruit, ranging in stage of development from three quarters to full, was purchased from a ripening plant. The fruit was either processed the same day it was purchased or stored at 45° F (7.26° C) until used.

To determine the effect of acid concentration, temperature and length of treatment on the pH of the fruit, the fruit was peeled by hand, cut in slices about 1–1½ in long and dipped in the acid (acetic or citric acids) solution for the length of time and at the temperature being tested.

To prepare the acid titration curve, 25 g portions of a 1:1 pulp dispersion in distilled water were titrated with .25% citric acid in 5 ml increments, determining the pH after each addition of acid solution.

Blanching studies were conducted in small pilot plant scale using a ratio of 1:20 fruit to blanching solution. The fruit was blanched in a small tank with the blanching solution controlled to the desired temperature by means of a pneumatic indicating temperature controller.

For all canning experiments the following procedure was used: The fruit was immersed in water at 94.4° C (200° F) for 30 minutes to inactivate the enzymes and to facilitate removal of the peel (13). Following the hot water treatment the fruit was cooled under running water and the peel removed by hand. The peeled fruit was sliced into 2.5 cm sections, inspected to discard blemished pieces. When using 303 cans, 9 oz (252 g) of the sliced fruit was used as filling-in weight. When using a 211 × 304 can, a filling-in weight of 5 oz was used. All 303 cans used in these studies were of plain tin (0.75 lb/tin/BB inside, .25 lb outside, with C enamel ends. The 211 × 304 cans were of F enamel throughout. Boiling

2% brine acidified to the desired level either with citric or acetic acid was added, the cans were exhausted in steam for 5 minutes and sealed. All lots irrespective of can size were processed in boiling water for 30 minutes and then cooled. The canned product was stored at ambient temperature which ranged from 85 to 90° F.

pH and acidity of fresh hand-peeled and/or hot water-peeled fruit was determined by standard AOAC procedures (7).

pH and acidity of the canned product were determined as follows: After a stabilization period ranging from 15 to 30 days at room temperature, a can was opened and the whole contents blended in a Waring Blendor for the determination of the stabilization pH and acidity (1). For measuring the acidified fruit pH and acidity, the fruit was separated from the brine by draining in a No. 8 standard screen. pH and acidity were determined separately on the drained fruit and brine. Usually all pH and acidity determinations were run in duplicate. To obtain average values for pH as for calculations involving pH measurements, pH values were converted to $[H^+]$ as specific acidity.

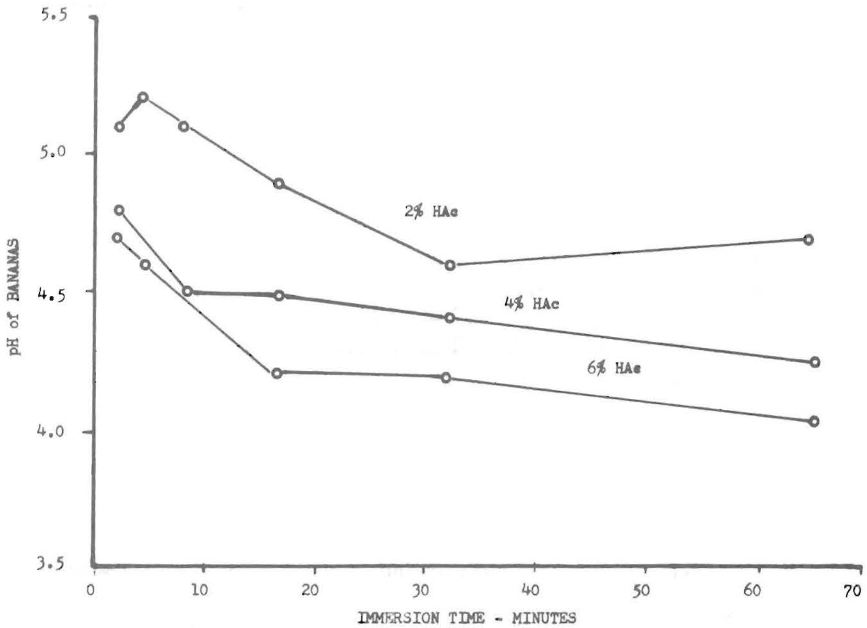

FIG. 1.—Changes in the pH of green bananas resulting from the acidification by dipping in acetic acid solutions at room temperature.

RESULTS AND DISCUSSION

ACIDIFICATION WITH ACETIC ACID

Figure 1 shows the effects of acid concentration and time of immersion on the pH of hot water-peeled green bananas acidified by dipping in acetic acid solutions at room temperature (80° F). In the 2% acetic acid solution, dipping for 6 minutes failed to lower the pH below 4.5. In the 4 and 6% solutions, the pH was lowered below 4.5 after dipping for 15 and 8 minutes, respectively.

Figure 2 shows the effect of time of immersion and temperature on the pH of the green bananas acidified by blanching in 4% acetic acid solution at temperatures ranging from 160 to 190° F. Blanching in the hot acid

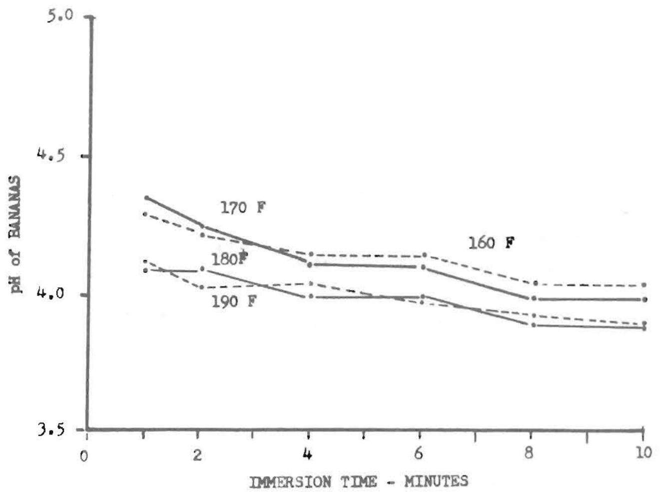

FIG. 2.—Changes in the pH of green bananas during blanching in acetic acid solutions.

solutions lowered the pH below 4.5 much more rapidly than by dipping at room temperature. Both an increase in the blanching temperature and dipping time resulted in a further lowering of the treated fruit pH. The change in pH resulting from any treatment effect becomes less as the pH approaches a value of 4. The acid titration curve for green bananas (fig. 3) shows that when the pH approaches 4 more acid is required to lower the pH than at higher pH values. This indicates a buffering effect near pH 4.0. This buffering effect would result in a levelling off of the pH of the treated fruit during acidification either at room temperatures or at a more elevated temperature, the pH of the acidified fruit tends to level off when the pH approaches 4.0.

Since in acidifying by blanching in hot acid solutions it is possible to lower the pH faster to the safe level of 4.6 required for processing, from a practical point of view, acidifying by blanching is more convenient than acidifying by dipping in acid solutions at room temperature. Since the effect of blanching temperature on the pH of the acidified fruit is not too pronounced (fig. 2), any blanching temperature from 170 to 190° F may be used when acidifying green bananas.

To acidify vegetables for canning three methods may be used: acidifying before canning by an acid dip or blanching in acid solutions; acidifying before canning as indicated above in combination with canning in an acidified brine; or acidifying in the can with acidified brine.

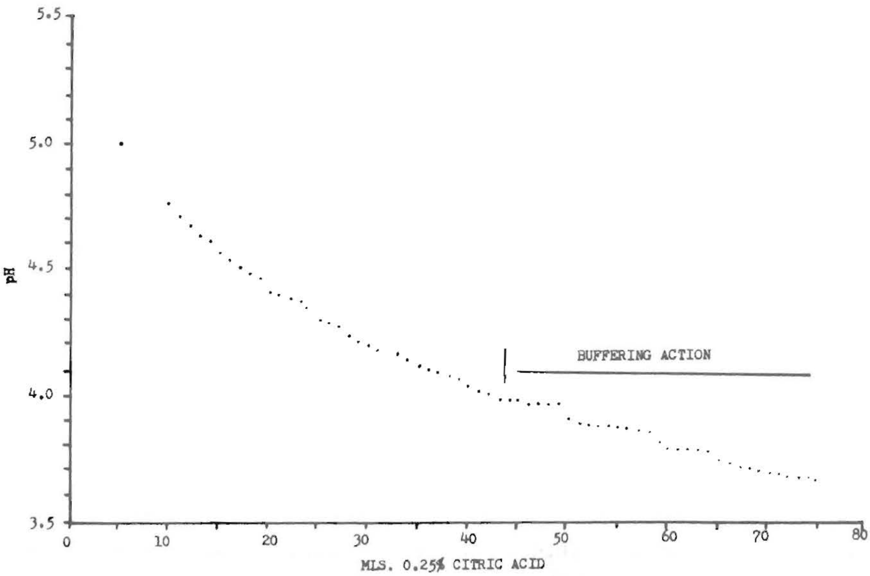

FIG. 3.—Acid titration curve of green bananas.

Table 1 shows the effect on the stabilization pH, as well as on the pH of the bananas and brine when green bananas were acidified by a combined method involving blanching for 5 minutes at 180° F in a 4% acetic acid solution and canning in a 2% salt brine acidified with acetic acid to a .5% acid content.

Although the pH of the fruit before canning ranged from 3.9 to 4.22, in all 4 lots processed, fairly uniform stabilization pH values resulted after storage for 2 months at room temperature. The pH of the acidified bananas was 4.1, which is a very safe pH for boiling water processing.

In the following tabulation the changes in pH observed during processing and storage when acidifying the green bananas by blanching in 4% HAc solution and canning in an acidified brine (0.5% HAc) are given:

pH of peeled bananas	5.12
pH of blanched bananas	3.88
Stabilization pH after storage for 60 days	3.90
pH of acidified bananas after storage for 60 days	4.00
pH of brine after storage for 60 days	3.95

Although the results of these experiments showed that green bananas can be properly acidified by blanching in acetic acid solutions and canning in an HAc acidified brine, further work on the acidification and canning of green bananas was carried out with citric acid because of the irritating effect of acetic acid fumes.

TABLE 1.—*Stabilization pH and pH of acidified fruit and brine after storage for 2 months at 85 F (29.4 C). Green bananas blanched in 4% HAc and canned in 2% salt, 0.5% HAc brines*

Run No.	pH values		
	Stabilization	Bananas	Brine
1	3.92	4.10	4.00
2	3.92	4.18	4.00
3	3.92	4.18	4.00
4	4.00	4.10	3.98

ACIDIFICATION WITH CITRIC ACID

Figure 4 shows the changes in pH of green bananas resulting from dipping the fruit in 1 and 2% citric acid solutions at room temperature. In the 1% acid solution dipping for over 60 minutes failed to lower the pH to or below the safe value of 4.5. When dipping in the 2% citric acid solution, the pH dropped below 4.5 after dipping for 30 minutes. If figures 1 and 4 are compared, a 2% citric acid solution was more effective in lowering the pH of green bananas than a 2% solution of acetic acid. While the pH of the fruit acidified in a 2% HAc solution remained above 4.5 pH after 60-minute dip, the pH of bananas dipped at room temperature in a 2% citric acid solution dropped to values below 4.5 after a 30-minute dip.

Blanching green bananas in citric acid solutions resulted in a fairly rapid lowering of the pH. Figure 5 shows the effect of time of immersion and acid concentration on the pH of bananas blanched at 180° F (82° C). However, when blanching for 5 minutes, the pH of the green bananas dropped below the safe limit of 4.5 only in the 4% solution.

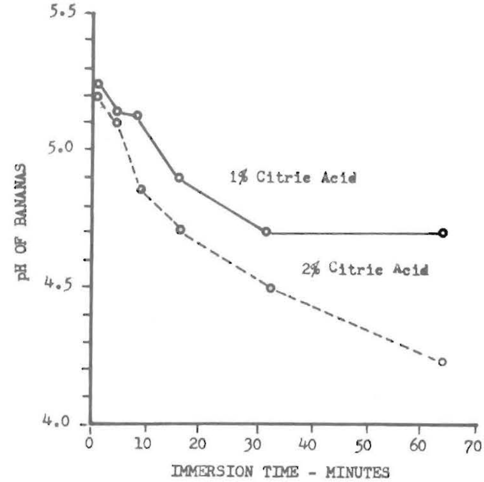

FIG. 4.—Changes in the pH of green bananas during acidification by dipping in citric acid solutions at room temperature.

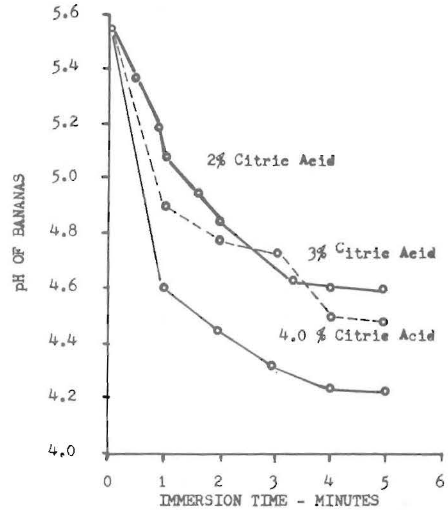

FIG. 5.—Changes in the pH of green bananas blanched at 180° F (82° C) in citric acid solutions.

Blanching temperature within a range of 140 to 190° F was found to have little effect on the pH of the blanched fruit. The effect of blanching temperature on pH is shown in the following tabulation. The bananas were blanched 3 minutes in a 2.9% citric acid solution.

TABLE 2.—*pH values for green bananas blanched at 180°F (82° C) in 1, 2, 3, and 4% citric acid solutions*

Dipping time	Acid concentration											
			1%			2%			3%		4%	
	pH of fresh bananas											
	—	5.20	5.42	5.0	5.48	5.50	5.30	5.30	5.30	5.50	5.20	5.50
	pH of acidified fruit											
Minutes												
1	4.58	4.86	5.00	4.52	5.10	4.85	4.70	4.50	4.50	4.80	3.95	4.6
2	4.58	4.78	4.90	4.52	4.85	4.80	4.55	4.40	4.32	4.65	3.95	4.45
3	—	4.70	4.82	—	4.68	4.70	4.50	4.20	4.32	4.60	—	4.32
4	4.48	4.68	4.78	4.45	4.62	4.65	4.32	4.10	4.22	4.53	3.85	4.25
5	—	4.60	4.75	—	4.62	4.60	4.30	4.10	4.22	4.50	—	4.25

Temperature		
°F	*°C*	*pH*
140	60.00	4.50
150	65.56	4.50
160	71.11	4.55
170	76.67	4.40
180	82.22	4.40
190	87.78	4.35

Irrespective of the blanching condition practiced, a fairly large variation in the pH of the acidified fruit was observed, as shown in table 2. In 4 lots blanched in 3% acid for 5 minutes the pH varied among the lots from 4.1 to 4.5. A more striking difference between two lots blanched in 4% acid is shown in table 2. For one lot blanched for 4 minutes the acidified fruit pH was 3.85, while the pH of the second lot blanched under similar conditions was 4.25. In replicated lots blanched under similar conditions, a variation among replicates of .22 pH unit was observed.

TABLE 3.—*pH values in the canned product resulting from a combined acidification treatment involving blanching in citric acid solution and canning with acidified brine*

Blanching treatment at 180°F (82° C)	pH of blanched bananas	Brine acidity	pH values for canned product		
			Stabilization	Bananas	Brine
		%			
3 minutes in 1% citric acid	4.80	0.2	4.32	4.50	4.39
		.3	4.21	4.32	4.23
		.4	4.15	4.25	4.13
3 minutes in 2% citric acid	4.65	.1	4.30	4.60	4.40
		.2	4.20	4.50	4.20
		.3	4.15	4.40	4.10
		.4	4.05	4.28	3.98
		.5	3.90	4.20	3.98

Because of the variation in the pH of the fruit acidified by blanching when a short blanch is used, there is the possibility that some lots may result with a pH higher than the safe limit of 4.6. Therefore, it was felt that, from the safety standpoint, it would be necessary to use an acidification treatment combining acidification of the fruit by blanching in acid solutions plus acidification in the can with acidified brines.

The results obtained from the acidification of the bananas in 1 and 2% citric acid solutions and canning in brine of varying acidity are shown by the data in table 3.

When blanching in 1% acid solution the pH of the acidified fruit before canning was 4.80. Canning in acid brine ranging in acidity from .2 to .4%

resulted in a stabilization pH well below the safe limit of 4.6. However, in the .2% acid brine the fruit pH after a stabilization period of about 2 weeks was 4.50. Considering the variations of over .2 unit previously observed among replicated lots of acidified fruit, the use of a .2% brine may result that in some lots the pH of the acidified bananas may exceed 4.6. Similar results were obtained when the fruit was blanched in 2% acid and canned in brines ranging in acidity from .1 to .5%. When brines of an acid content of .1 and .2% were used, although the stabilization pH was below 4.6, the fruit had a pH of 4.5 to 4.6. For both treatments the use of .3% acid brine would result in a safe pH for boiling water processing. Table 3 also shows that even though the pH of the blanched bananas differed in .15 pH unit, at a given brine acidity, both lots resulted with similar stabilization and acidified fruit pH. This suggested that acidification in the can alone would be an adequate process for the acidification of green bananas.

TABLE 4.—*pH values of green bananas acidified in the can with 2% NaCl brine ranging from .20 to .35% citric acid*

No. of replicates	Brine acidity	pH values for the canned product					
		Stabilization		Bananas		Brine	
		Range	Mean	Range	Mean	Range	Mean
	%						
12	0.20	4.00–4.40	4.27	4.05–4.49	4.36	4.00–4.44	4.29
12	.25	4.02–4.37	4.20	4.00–4.38	4.26	3.93–4.37	4.21
20	.30	3.73–4.23	4.04	3.82–4.29	4.12	3.80–4.30	4.03
21	.35	3.73–4.19	3.94	3.74–4.30	4.10	3.91–4.17	4.01

Table 4 summarizes the data from a large number of experiments in which acidification of green bananas was done in the can by the addition of a 2% acidified brine. In all experiments the brine was added near boiling temperature and the cans exhausted in a steam tunnel for 5 minutes. The temperature of the brine after exhausting averaged 170° F (77° C). Table 4 also shows that from the standpoint of the stabilization pH, the addition of brine of .2% acidity as citric lowered the pH to 4.40 (average value, 4.27). However the maximum pH reached by the fruit in the 12 lots processed was 4.49. Considering that it had been observed that replicated lots may vary by .22 pH unit, there is the possibility that the pH of the acidified fruit may exceed 4.6 if a brine of .2% acidity is used. The use of brines of .25% acidity gave lower fruit pH, but still too close to the safe value of 4.6. Brines of .30% acidity lowered the pH of the fruit to an average value of 4.12, with a range from 3.82 to 4.29. If the standard deviation is calculated from the data obtained from the 20 lots processed, the mean pH ± 2s[3] would range from 3.89 to 4.6. Therefore, based on the data available, the lowest brine acidity that should be used when acidifying bananas in the can would be .3%. Within this range of fruit pH the stabilization pH would be much lower and completely within the safe limits for boiling water processing. The use of a brine of .35% acidity would provide a wider pH range safety for boiling water processing (average, fruit pH 4.1, ± 2s = 3.87 to 4.34.)

Of particular concern in the processing of acidified products is the time required by the solid portion to equilibrate its pH with that of the packing medium to the value required for boiling water processing.

TABLE 5.—*Changes in pH in canned green bananas stored at 85–90°F (29.4–32.2° C) for 35 days*

Storage time	pH values of canned product		
	Stabilization	Bananas	Brine
Days		*Brine acidity—0.3% citric acid*	
0	4.00	—	—
1	4.00	4.38	4.05
5	4.12	4.22	4.12
11	4.22	4.41	4.28
19	4.21	4.32	4.23
27	4.27	4.35	4.33
35	4.17	4.29	4.18
		Brine acidity—0.4% citric acid	
0	4.00	—	—
1	3.92	4.22	3.92
5	4.00	4.18	4.05
11	4.12	4.30	4.18
19	4.15	4.25	4.13
27	4.12	4.27	4.27
35	4.08	4.22	4.11

Table 5 shows the changes in pH observed in two lots of canned green bananas acidified with .3 and .4% acid brine, during storage at 85° F (29.4° C) for a period of 35 days. During this time the changes in the stabilization pH in the sample canned in 0.3% brine show a trend to increase, while the pH of the solid portion showed a trend to decrease. The pH of the brine follows the same trend as the stabilization pH. In the .4% brine, the changes in pH observed were negligible. In the course of these studies it was observed that the higher the acidity of the brine the more quickly the pH equilibration took place.

Storage of the acidified canned samples at 45° F (7.2° C) for a period of 14 days resulted in higher stabilization and fruit pH than those

[3] s = standard error.

observed in samples of the same lots stored at 85° F (29.4° C) for the same length of time. At 85° F (29.4° C) the solid portion pH came closer to the stabilization pH than in the samples stored at 45° F (7.2° C).

Table 6 summarizes the data obtained from shelf life studies in which two lots of acidified bananas were stored at 85° F (29.4° C) for 1 year. In both samples the change in stabilization pH during this period was negligible. The fruit pH remained nearly the same throughout storage but always higher than the stabilization and brine pH. Supran et al. (16) reported that after 15 months of storage the pH of the solids of acidified pimiento peppers was usually higher than the pH of the liquor in the cans. Flora et al. (3) found that the pH of processed pimientos did seem to creep upward during storage. Thus the behavior of the acidified green bananas during storage is similar to that of pimiento peppers.

When acidifying green bananas for canning, the fact that the fruit

TABLE 6.—*Changes in pH in canned green bananas stored at 85–90 F (29.4–32.2 C) for a year*

Storage time		pH value of canned product					
Lot A	Lot B	Stabilization		Bananas		Brine	
		Lot A	Lot B	Lot A	Lot B	Lot A	Lot B
Days	*Days*						
0	0	3.89	3.99	—	—	—	—
3	5	3.85	4.00	4.06	4.16	3.96	4.01
16	24	3.90	4.09	4.02	4.18	3.90	4.08
90	95	4.21	3.94	4.19	4.07	4.20	3.96
185	172	3.93	3.99	4.03	4.10	3.95	3.98
264	276	3.95	4.09	3.98	4.23	3.92	4.17
365	365	4.05	4.00	4.10	4.16	4.08	4.00

does not reach at any time during storage the equilibrium, pH should be taken into consideration when choosing the brine acidity to be used. This further substantiates the previous conclusion that a brine of an acidity lower than .3% as citric should not be used when the acidification is done by addition of the acid to the container.

The level to which the pH of the acidified fruit is lowered by a brine of a given acidity within certain limits, will depend on the ratio of solids to liquid in the can. In the course of this work most of the samples were canned in 303 cans with a fill-in weight of 9 oz. (270 g). To determine the effect of fill-in weight on the pH a series of samples were prepared varying the solid content from 8 oz. (240 g) to 10 oz. (300 g). The results of these tests are included in table 7. Increasing the fill-in weight from 8 to 10 oz. (240 to 300 g) resulted in the following increases in pH values: stabilization pH—.3; fruit pH—.2; and brine—.22. Therefore, from the data in table 7 it can be concluded that a change in fill-in weight of about 1 oz. (30 g) will not have a significant effect on the stabilization and fruit pH, and will therefore not affect the safety of the product unless the fruit pH lies too close to the safe value of 4.6.

In later studies several lots of green bananas were acidified in 211 × 304 cans. Since the use of these smaller cans resulted in a change in the solid to brine ration, a number of tests were conducted to determine proper acidification procedures for these can sizes. The results obtained are summarized in table 8.

The results of these tests show that to assure that the pH of the acidified fruit lies always below the safety level of 4.6, the acidity of the brine should not be lower than 0.3%, as for the larger 303 can size.

TABLE 7.—*Variations in the pH of canned green bananas with fill-in weight*

Fill-in weight		pH of canned product		
		Stabilization	Bananas	Brine
oz	*g*			
8.0	226	3.93	4.19	4.05
8.5	230	4.09	4.28	4.12
9.0	235	4.19	4.32	4.19
9.5	268	4.23	4.39	4.27
10.0	284	4.18	4.35	4.03

TABLE 8.—*Effect of brine acidity on the pH of green bananas canned in 211 × 304 containers*[1]

Brine acidity as citric acid	Drained weight	Volume of brine	pH of canned product	
			Stabilization	Bananas
%	*g*	*ml*		
0.25	137.5	92.0	4.38	448
.30	131.0	99.5	4.28	4.35
.35	136.5	94.5	4.15	4.30

[1] Fill-in weight 142 g (5.0 oz. pH measurements made after 30 days of storage at 85°–90°F (29.4–32.2°C).

Besides the effect of brine acidity and processing variables on the pH of the acidified bananas, the acidity of the green fruit was found to affect the pH of the acidified product also. A significant correlation (0.5) was found between fruit acidity and the pH of the acidified product in bananas canned in brine of .30, .25 and .20% acidities as citric acid.

This relationship between fruit acidity and acidified fruit pH was expected from the results obtained from experiments to determine the buffer capacity of green bananas. In the following tabulation the relationship of fruit acidity to the volume of 0.5% citric acid required to lower the pH of 100 g of pureed fruit to 4.1 is given:

Fruit acidity	*Volume of acid*
%	*ml*
.19	95
.15	85
.13	60

These results indicate that the buffer capacity of green bananas vary with the acidity. Fruits with higher acidity have a higher buffering capacity. Therefore, the variation in acidity of the fruit will result in variations in the pH of the acidified bananas, which may affect the safety of the product if the stabilization pH is too close to the safe limit of 4.6.

TABLE 9.—*Effect of NaCl on the pH and titratable acidity of canned green bananas stored at 85–90 F (29.4—3.2 C) for 30 days*

Replicate	Packing medium		Homogenized can contents		Drained solids		Liquid portion	
	A[1]	B	A	B	A	B	A	B
				pH				
1	2.32	2.70	4.05	4.45	4.13	4.45	3.79	4.52
2	2.23	2.62	3.95	4.28	4.03	4.28	3.85	4.35
3	2.18	2.56	3.79	4.25	3.92	4.17	3.79	4.26
			Titratable acidity as % anhydrous citric acid					
1	0.30	0.30	0.34	0.24	0.28	0.23	0.30	0.25
2	.40	.40	.39	.28	.36	.26	.37	.28
3	.50	.50	.49	.34	.47	.32	.45	.35

[1] A = 2% NaCl acidified brine; B = Salt free citric acid solution.

The pH of the acidified fruit was found to increase linearly as the acidity of the raw green fruit increased. This linear relationship was found to be highly significant conforming to the following equation: $Y = 0.2642 - .1351\ X$, where Y is the pH of the acidified fruit as H^+ and X the acidity of the raw fruit as percent anhydrous citric acid.

The variations in the pH of the acidified fruit with the acidity of the raw bananas may explain in part the variations observed in pH among lots of fruits acidified by blanching in acid solutions or by the addition of acidified brines to the container.

Since both the pH and acidity of green bananas was found to vary with maturity, in commercial operations where the stage of maturity of the fruit harvested is rarely controlled, variations in the pH of the acidified fruit can be expected from lot to lot of processed fruit. To assure that the pH of the acidified product after stabilization is lower than the limiting pH of 4.6, the brine acidity should be maintained low enough to provide a safety margin to account for the unexpected variations in pH.

Table 9 shows the effect of the use of salt (NaCl) on the pH and titratable acidity of acidified green bananas. Unsalted canned bananas were found to be higher in pH and lower in titratable acidity than the corresponding samples packed in a 2% brine. Sapers et al. (14) observed this effect of salt on the pH and titratable acidity of canned tomatoes, and attributed the change to the Debye:Huckel effect.

RESUMEN

Un estudio se llevó a cabo para determinar la viabilidad de enlatar guineos verdes acidulándolos para bajar su pH a menos de 4.6, de modo que los envases se pudiesen esterilizar a presión atmosférica en agua hirviendo.

Se ensayaron tres métodos de acidulación: inmersión de rodajas de guineos en soluciones de los ácidos acético y cítrico a temperatura ambiente; escaldado en soluciones de estos ácidos y luego envasados en una salmuera acidulada; y acidulación en la misma lata usando salmueras aciduladas con ácido cítrico.

En todos los experimentos de acidulación, los guineos se preparanon en la misma forma: la fruta verde se sumergió en agua a 200° F (93° C) por 30 minutos para inactivar su sistema enzimático y facilitar el mondarlos. Se pelaron a mano y la fruta se cortó en pedazos de alrededor de I pulgada (2.5 cm) de largo. El procedimiento de enlatar fue el siguiente: la fruta ya acidulada parcialmente o sin acidular se envasó a mano en latas 303 ó 211 × 304, a razón de 9 onzas (270 g) y onzas (150 g), respectivamente. Se añadió la salmuera hirviendo manteniendo las latas por 5 minutos en un túnel de vapor antes de cerrarlas. Las latas luego se mantuvieron en agua hirviendo por 30 minutos y luego se enfriaron a temperatura ambiente antes de almacenarlas.

Se probó que la acidulación de los guineos verdes por inmersión a temperatura ambiente tanto en una solución de ácido acético al 2, 4 y 6% y de ácido cítrico al 1 y 2% no fue práctica, pues requería un tiempo de inmersión demasiado largo para bajar el pH de la fruta a menos de 4.6. Sin embargo, la escaldadura probó ser un método eficaz de acidulación, pudiéndose bajar el pH de la fruta en pocos minutos a temperatura que fluctuó entre 160 a 190° F (71–88° C) en soluciones de ácido acético al 4 y 6% de ácido cítrico al 3 y 4%. Los cambios en el pH de la fruta durante este tratamiento fueron menos pronunciados al acercarse el pH a 4.0, lo que se atribuyó a que a este pH la fruta presenta una acción amortiguadora.

El guineo verde acidulado por una escaldadura de 5 minutos a 180° F (82° C) en una solución de ácido acético al 4% y luego envasado en salmuera de un 2% de sal y 0.5% de HAc resultó con un pH de estabilización de 4.1, el cual no sufrió cambios apreciables durante dos meses de almacenamiento a temperatura ambiente.

Cuando los guineos verdes se escaldaron en soluciones de ácido cítrico al 1 y 2% y luego se enlataran en salmuera al 2% de sal y .3% de ácido cítrico, se obtuvo un producto enlatado con un pH de estabilización de alrededor de 4.1. Cuando se bajó la acidez de la salmuera a menos de .3%, el pH del producto enlatado resultó ser más alto de lo deseable, aproximándose a 4.6.

Los estudios de almacenamiento a temperatura ambiente con fruta acidulada por adición al envase de salmuera acidulada demonstraron que durante un período de almacenamiento de un año ocurrieron pocos cambios en el pH de estabilización, en el pH de la fruta y en el pH de la porción líquida. El pH de la fruta acidulada resultó ser siempre más alto que el de estabilización de la porción líquida durante el período de almacenamiento estudiado. El almacenamiento de este producto a una temperatura de 45° F (7.2° C) resultó en valores pH de estabilización y de la fruta más altos que en los lotes similares que se almacenaron a 85° F (29.4° C).

La acidez de la fruta fresca indicó una correlación significativa con el pH de la fruta enlatada, aumentándolo al aumentar la acidez de la fruta.

El uso de sal en la salmuera causó una reducción en el pH del producto enlatado y aumentó significativamente la acidez. La fruta enlatada sin sal resultó con un pH más alto y una acidez más baja.

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