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FACTORS IN THE PROCESSING OF BANANAS [1]

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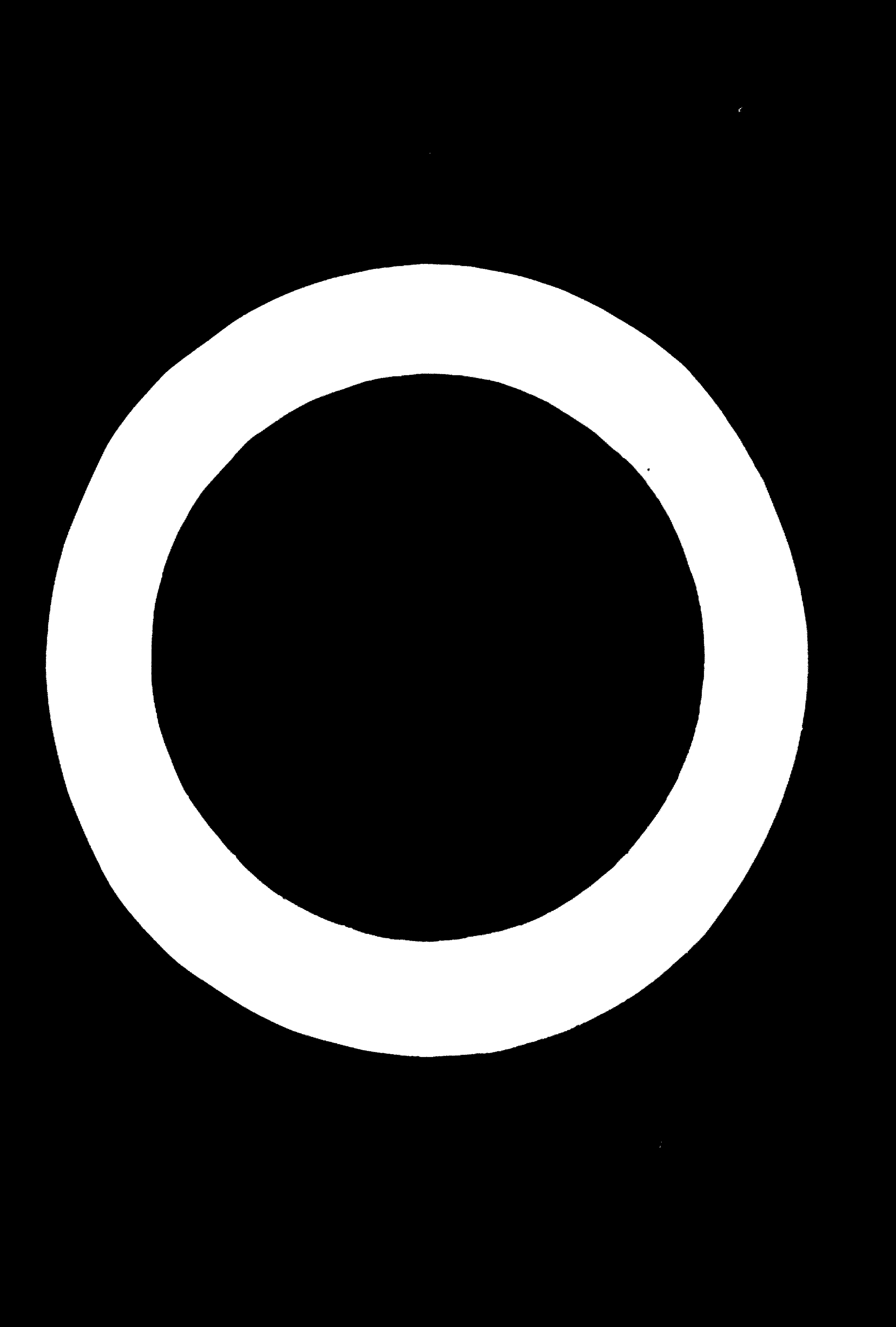

FACTORS IN THE PROCESSING OF BANANAS

A study prepared by C.O. Chichester, of the University of Rhode Island, Kingston, Rhode Island, USA, in collaboration with V.C. Sgarbieri, also of the University of Rhode Island, M. Hec, of the Instituto de Tecnologia de Alimentos, Campinas, Brasil, R. Moreira, of the Instituto Agronomico, Compinas, Brazil, and S. Leonard, of the University of California, Davis, California, USA

The almost universal appeal of the banana fruit has led to a large scale world utilization of the fresh banana. With the desirability of this fruit firmly established, its use in processed foods is rapidly expanding. Infant foods, ice cream mixes, and bakery products are but a few of the uses bananas have in formulated foods. In many cases the flavor component is but one of the characteristics which make the banana desirable as a component of other food products. Starch and soluble sugars play a role in its utilization as a component of food.

Because of the wide utilization of the banana as a part of other foods, the development of stable concentrates, powders, or completely formulated food products offers significant possibilities for producing countries in the industrialization of bananas and banana products. The economics of producing a completely formulated food or a stable banana concentrate for secondary manufacturing are excellent, provided the instability of flavor and appearance can be overcome. As in many agricultural products, the initial utilization has been for fresh market and the varieties developed for this market may or may not be those which would yield the best industrialized product. The concentration of scientific effort has, in a like manner, been directed to the problems of a climateric fruit harvested before ripening and transported to the market where ripening is induced prior to or during distribution as a fresh product. Comparatively little effort has been diverted to the examination of varieties possibly more suitable for industrialization. Equivalently, the conditions for the processing and production of a stable industrializable product have been the subject of comparatively few investigations.

Information in these areas could lead to the development of a processing industry indigenous to the areas of production and significantly broaden the utilization of this uniquely tropical fruit. This, then, is an area like many others where the application of science and technology can lead to the development of a new industry in the semi-tropical or tropical countries.

As the banana is a climateric fruit, significant changes take place in its composition during the ripening period. In general, these changes are reflected in a marked increase in aroma and flavor attributable to an increase in volatile reducing substances and various alcohols and esters. Concurrent with the production of these desirable characteristics is an increase in polyphenol oxidase activity which makes the ripened fruit very susceptible to enzymatic darkening. There is also an almost quantitative change in insoluble carbohydrates (essentially starch) to soluble carbohydrates. This is accompanied by a drop in total acidity and a significant change in the amino acid pattern of the free amino acids.

The literature on changes that occur during the ripening of bananas is extensive (1, 2). Stewart and co-workers (3, 4) have made a comprehensive study of the composition of the banana plant, including some changes occurring in the fruit during ripening. The changes in tannins in the banana fruit during ripening were also studied by Barnell and Barnell (5). Wyman and Palmer (5a) reported on the organic acid changes during ripening. Numerous other changes associated with the climateric peak of respiration during the ripening have also been reported (6, 7, 8, 9, 10, 11). There have been extensive investigations of the changes in volatile substances, e.g., flavor compounds occurring during ripening and processing (12, 13, 14, 15, 16). However, there have been comparatively few studies relating to the differences in varieties. This area of investigation is of importance if one is to make a choice between varieties for a particular usage or to choose a variety for general processing or as a component in a particular formulated food material. There is no question that, in addition to varietal conditions, climatic and cultural modifications are of importance in the choice of a product for processing and utilization.

A major difficulty in the processing of bananas is their darkening upon exposure to oxygen. The ripe banana appears, in most instances, to present favorable conditions for enzymatic oxidation. In all instances, the enzyme responsible for this darkening and hence the unattractive appearance of non-inhibited products is the enzyme polyphenol oxidase. Palmer (17) suggested a mechanism for browning in bananas shown in Figure 1.

In this reaction scheme of browning, only the first step in the sequence is enzyme catalyzed, and the inhibition of this fast reaction will prevent the darkening of processed products subject to oxidation. At present, the necessary inhibition can be accomplished by one or more of four general procedures:

1) The heat denaturation of the enzyme (protein denaturation).

2) The utilization of a specific inhibitor of the enzyme.

3) The incorporation of anti-oxidants (reducing agents) which will reduce the quinone prior to its further reaction. If the anti-oxidant reduces the quinone to its original phenolic form as rapidly as it is produced by enzymatic oxidation, it will prevent the accumulation of intermediates and hence avoid the non-enzymatic sequences of reactions.

4) The elimination of oxygen from the environment which will eliminate the non-enzymatic darkening of the quinone.

In Figure 1 the points of intervention are thus concerned with the destruction of the enzyme responsible for the conversion of dopamine to the quinone, the inhibition of this enzymatic step, the reversal of the reaction, or the elimination of oxygen which is responsible for the subsequent reactions of the quinone.

Unfortunately, a specific inhibitor for the enzyme system which can be used in foods has not yet been discovered. The elimination of oxygen from the environment is practical in a container but, obviously, the processed product must be exposed to oxygen at some point in time and, hence, rapid darkening may occur when a container is opened or a product is exposed to oxygen and water. For example, non-inhibited freeze dried banana powder is an excellent product until it is rehydrated in the presence of oxygen. With this combination there is a rapid, almost instantaneous darkening. The amount of oxygen required for substantial darkening is extremely small; and it is very difficult, even in processed containers, to reduce the total oxygen tension to the point where surface darkening of a non-inhibited product will not occur.

At the present time, the most practical routes for the inhibition of the browning reaction are heat treatment and/or the use of anti-oxidants. The heat inactivation of polyphenol oxidase extracted from the variety Nanica (dwarf cavendish) is shown in Figure 2. The enzyme was incubated with 0.03 m catechol at pH 5.2 in the presence of a 0.1 m citrate-0.2 m phosphate buffer. The data indicates that inactivation is achieved in les. than one minute at 80°C.

Only a few compounds are available which can be used in foods and which are capable of inhibiting the overall reactions involved in the polyphenol oxidase browning. Ascorbic acid can be used as a reducing agent which will lower the concentration of the quinone form but, in many cases, this compound will contribute to other non-enzymatic browning reactions which are accelerated by high temperatures or long storage times. Sodium bisulfite or sulfur dioxide will inhibit the polyphenol oxidase system at comparatively low levels. The inhibition of the oxidase reaction was studied in the same system described previously. Figure 3 shows the inhibition of banana polyphenol oxidase system by sodium bisulfite. The amount of darkening was measured at 420 mμ which reflects the subjective evaluation of browning. It is to be noted that 90 ppm of sodium bisulfite in the reaction completely inhibits browning. The inhibitary potency of a number of sodium bisulfite and other compounds was compared to ascorbic acid in the same system. The results are shown in Table 1. In the purified system, ascorbic acid displays a strong inhibiting effect at comparatively low concentrations. It must be stressed, however, that this is not a complete system and, since ascorbic acid can act in very many different ways, its effectiveness in a banana puree is not as dramatic as shown in the purified system.

An interesting compound which has been proposed for the inhibition of phenolic browning is cysteine. The inhibition of a polyphenol oxidase system by cysteine was studied by Walker (18, 19) who proposed the system shown in Figure 4 in which cysteine would combine with the quinone to form a cysteine phenolic complex. They suggested that the complex would be colorless and thus would effectively remove the active browning substrate from the total reaction scheme.

We have investigated this system and confirmed Walker's observation that cysteine was effective only if the thiol:phenolic ratio was greater than unity. Less than equimolar amounts of a thiol (in this case cysteine) did not prevent browning. At higher concentrations, however, the cysteine reacted with the phenolic compound to produce a red-colored complex which, while not brown, markedly altered the appearance of the product. We therefore would conclude that, although the cysteine might inhibit the primary browning reaction, it in turn acted as a secondary browner of a different type; and its overall contribution was not desirable.

As the normal banana ripens, changing from green to yellow, the oxalic acid content decreases and there is an increase in malic acid content. These changes are related to the sudden increase in respiration at this stage of ripening. It is significant that the pH of the ripe banana between 5.5 and 6.3 is very close to the pH optimum for the polyphenol oxidase enzyme. The pH activity curve of the polyphenol oxidase from bananas is shown in Figure 5. This complicates the problem of preventing browning, since the optimum pH for the activity of the enzyme coincides closely with that of the natural pH of the ripe banana. Additionally, as the banana ripens, there is a substantial increase in the activity of the enzyme system due to the decrease in the inhibitory compounds which are believed to be tannins. These two factors indicate the importance of a study of the relative contribution of the different factors in bananas to the reactions which might be expected during processing. Table 2 illustrates the relationship between some of the products of importance in browning and the ripening phenomenon. The various changes in composition account for the increase in activity of the enzyme system which is the cause of extremely rapid and intense browning when the ripe tissue is disrupted in contact with air.

The Nanica (dwarf cavendish) is the principal variety of banana harvested for commercial utilization in Brazil and yet, as cited earlier in this paper, it has certain characteristics which make it difficult to handle in an industrial sense. The principal problem is the very high activity of its browning system. Its desirable characteristics, however, are that it has excellent agricultural properties, e.g., good resistance to disease coupled with very desirable flavor characteristics. These properties make it an excellent variety for utilization as a fresh market product. From an industrial standpoint, however, its drawbacks make it difficult to handle; and it would therefore be desirable to modify these properties.

In many fruits and vegetables the industrialized products are made from different varieties than those used for fresh market purposes. For example, onions grown for fresh market have a very much lower total solids content than those grown for drying. A commercialized product made from the fresh variety would be of lower quality than that produced from specialized varieties. There is no reason to believe that bananas should be different than other fruits and vegetables. Future developments in the industrialization of banana products may well be dependent upon the introduction of varieties which, while retaining their organoleptic properties, will have modified properties to better suit industrialization.

In order to determine relative differences between banana varieties which are now available, ten varieties of bananas were studied during ripening. Changes in total acidity, ascorbic acid, total and soluble solids, carbohydrates, volatile reducing substances, and activity of the polyphenol oxidase system were measured. These varieties are shown in Figure 6 according to Simmonds and Shepherd (20).

Ripening conditions used in the intercomparison of the varieties were chosen to represent the best conditions for ripening of the two most widely cultivated varieties, e.g., Nanica and Nanicao. Although these conditions may not have been optimal for the other varieties studied, they were chosen as representative of normal ripening procedures. This, then, points to another area which requires study on an individual variety basis, that is, the optimum conditions for the ripening of any particular variety.

It was possible to group the ten varieties studied into three groups according to their ripening behavior and changes of their various constituents during ripening. The summation of some of the physical and organoleptic characteristics of these fruits after ripening is shown in Table 3. The results of all the analyses can be observed by inspection of Tables 4 and 5. A detailed analysis of the results shows a wide variability in behavior and the physical, chemical, and organoleptic characteristics of the different varieties when ripened under identical conditions.

Grossly, the ten varieties fall into three groups according to their ripening behavior and other characteristics:

1. Figo, Prata, and Branca, which ripened relatively faster and uniformly showing characteristically higher total acidity, higher ascorbic acid content, and reducing sugars. They were lower in volatile reducing substances and in polyphenol oxidase activity. These varieties showed also very weak aroma when ripe.

2. Nanica, Nanicao, and Ouro, which characteristically showed a low acidity, low ascorbic acid, a very strong aroma, relatively high content

of volatile reducing substances, and very high polyphenol oxidase activity. It is interesting to notice that in Nanica and Nanicao the polyphenol oxidase becomes more active as the fruit ripens, whereas in the variety Ouro the activity is high in the green fruit and remains the same throughout the ripening period. This could be due to different types of phenolics in the green fruits of Ouro since in all others the relatively lower polyphenol oxidase activity in the green fruits seems to be due to the inhibitory action of phenolic substances. During ripening in most fruits the low molecular weight astringent phenolics (such as Leucoanthocyanins) transform into less soluble, high molecular weight, non-astringent phenolic compounds (21) which are less inhibitory to the enzyme activity (22).

3. Caru-Rexa, Caru-Verde, Leite, and Maca, which resemble group two in some chemical aspects but typically show less aroma and much less enzyme activity. For instance, the variety Leite showed a lower total sugar content but a high proportion of reducing sugar, which resembles the reducing sugars content of the varieties of group one. Maca also exhibits high acidity which brings it closer to the varieties of group one. The varieties Caru-Rexa, Caru-Verde, and Leite all showed low acidity and a high content of volatile reducing substances, which makes them similar to the varieties of group two; however, they exhibited at the same time relatively low polyphenol oxidase activity. In these varieties aroma and volatile reducing substances do not seem to be directly correlated since, in spite of the high volatile reducing substances, the aroma is comparatively weak.

The general trend of the changes in acidity and carbohydrates for all varieties was similar to what has been described in the literature. An interesting feature concerns the total acidity of ripening bananas; the acidity increases from harvest (green) to a maximum, one or two days before the best eating quality is reached (yellow-green) and then start to decrease, reaching the low level of the green fruit when it becomes soft-ripe. This increase in acidity during ripening might be of great physiological significance to the ripening phenomena because it coincides with the start of the climateric peak of respiration when several enzymes have been shown to become very active (23, 24). This is also of technological significance because at this point the fruits exhibit the best physical and chemical properties for processing. Wyman and Palmer (5a) have shown that oxalic acid makes up about 50% of the total acidity, malic acid 35%, and citric acid 10% in the green bananas. During ripening both the malic and citric acid peaks increased three to four fold, and oxalic acid drops to about 60% of its original value. The net result is a doubling of organic acidity in the ripe fruit, with malic acid comprising about 65% of the total, citric 20%, and oxalic acid 10%.

From this data it is obvious that dissimilar varieties display major differences in composition and that their constituents may change in concentration in diversified manners during ripening. In general, however, the flavor characteristics of the various varieties appear to be related to starch content or to their aroma and total sugar content. Interestingly enough, some varieties have a high astringency even when ripe. Their phenolic or tannin content does not decrease as it does in most varieties. This has been observed in chilled fruit or fruit taken from infected plants. The high astringency, however, in these does influence the activity of the polyphenol oxidase system since it may very well cross-couple with the ability of the enzyme to show its maximum activity. From the technological viewpoint, the most important varieties display a very high content of reactive phenolics, particularly dopamine (8 μg/g pulp) and a very high polyphenol oxidase activity. These characteristics make them the most difficult to process commercially and retain the natural color, aroma, and taste. Other varieties, because of their lower enzyme activity, may be considerably easier to process; however, they do lack the aroma characteristics of the fresh varieties. There is no reason, however, to believe that these two characteristics are necessarily genetically coupled and, therefore, there would seem to be a good possibility of developing varieties with comparatively low browning potential but with high aroma and flavor characteristics. A high content of ascorbic acid might very well accompany the production of such a variety.

It is thus apparent that a great deal more information must be accumulated on varietal differences, pre- and post-harvest physiology and biochemistry of the banana fruit in relation to proper handling and processing methods. The development of this information will promote an indigenous industry in the banana-producing regions of the world which will allow a significant development of industrialization uniquely adapted to this important agricultural product. The development of a technology based upon a raw material developed for another use is always fought with difficulty. It is difficult in some cases and, in most, economically impossible to significantly modify the technology to handle a less-suitable raw material if a possibility exists of developing a raw material better suited to its end use. This, in turn, points to the necessity of maintaining a close liaison between the food technologists and production agriculturists. Attacking the problem from the raw material standpoint as well as the technological standpoint it is possible, in most cases, to produce a finished product of superior characteristics as economically as possible.

With the high world demand for banana and banana-based products, the export potential of the banana-producing regions may be suitably enhanced by the development of a unique technology coupled to a modified agricultural input.

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TABLE 1. INHIBITION OF ENZYMATIC BROWNING BY REDUCING SUBSTANCES*

Compounds	mm in reaction mixture 5	10	15	20	25	100
Ascorbic acid		x				
Cysteine				x		
Glutathione				x		
Sodium Bisulfite					x	
Sodium Sulfite						x

*The data represents the concentration of different compounds (reducing agents) required to completely stop browning at 420 mμ for 10 minutes.

Reaction Mixture: 50 ml

Substrate concentration	0.02 M Catechol
Enzyme extract	0.20 ml
Inhibitor concentration as specified	
Made to volume with 0.1 M citrate, 0.2 M phosphate buffer, pH 6.0, temperature 30°C.	

TABLE 2. CHANGES IN THE COMPOSITION OF BANANA (VARIETY NANICA) ON RIPENING

Days in Ripening Room	pH	Pulp/peel ratio	Total Acidity o/o Malic Acid	Ascorbic Acid mg/100g	Total Solids g/100g	Soluble Solids g/100g	Insoluble Carbohydrate (starch) g/100g
0 (harvest)	5.60	1.23	0.325	8.24	25.65	3.25	19.91
4	4.90	1.26	0.576	9.30	25.49	15.20	10.44
6	5.00	1.49	0.500	11.63	25.32	18.25	3.72
8	5.25	1.74	0.512	11.04	23.43	19.60	0.99
12	5.55	2.00	0.402	9.30	21.33	19.00	0.52

*Stage of Ripeness

0 (harvest) - hard green
4 days - green yellowish
6 days - yellow with some green
8 days - yellow (eating ripe)
12 days - yellow flecked with brown (overripe)

TABLE 2. CHANGES IN THE COMPOSITION OF BANANA (VARIETY NANICA) ON RIPENING (cont.)

Days in Ripening Room	Total Soluble Sugars g/100g	Reducing Sugars g/100g	Volatile Reducing Substances meq/100g	Crude Protein N x 6.25	Polyphenol oxidase*(PPO) Klett units/g
0 (harvest)	0.43	0.19	0.130	1.20	280
4	8.07	5.77	0.986	1.11	450
6	13.30	6.65	1.106	1.12	850
8	17.00	7.75	1.016	1.01	1200
12	15.00	8.50	0.912	1.12	1520

*Unit of activity = Amount of enzyme that produces a change of one Klett unit per minute under the conditions of the assay.

TABLE 3. CHARACTERISTICS OF SOME VARIETIES OF BANANAS DURING RIPENING

Days in Ripening Room	Variety Common Name	Firmness	Color of Peel	Aroma Characteristic of Ripe Fruit	Astringency
At harvest	Ouro (gold)	hard	light green	absent	strong
	Caru-Rexa	hard	purple	absent	less strong
	Caru-Verde	hard	light green	absent	less strong
	Prata (silver)	hard	dark green	absent	strong
	Branca (white)	hard	dark green	absent	strong
	Figo (fig)	hard	light green	absent	less strong
	Nanicao (giant cavendish)	hard	dark green	absent	strong
	Nanica (dwarf cavendish)	hard	dark green	absent	strong
	Leite (milk)	hard	light green	absent	less strong
	Maca (apple)	hard	light green	absent	strong
3 days	Ouro (gold)	hard	green-yellow	absent	less strong
	Caru-Rexa	firm	reddish-purple	weak	weak
	Caru-Verde	hard	green	absent	less strong
	Prata (silver)	firm	yellow-green	very weak	weak
	Branca (white)	firm	yellow	very weak	weak

TABLE 3. CHARACTERISTICS OF SOME VARIETIES OF BANANAS DURING RIPENING (cont.)

Days in Ripening Room	Variety Common Name	Firmness	Color of Peel	Aroma Characteristic of Ripe Fruit	Astringency
3 days	Figo (fig)	firm	yellow-green	very weak	weak
	Nanicao (giant cavendish)	firm	light-green	absent	less strong
	Nanica (dwarf cavendish)	firm	green-yellowish	absent	weak
	Leite (milk)	hard	green-yellowish	absent	weak
	Maca (apple)	firm	green-yellowish	weak	strong
5 days	Ouro (gold)	firm	yellow	weak	weak
	Caru-Rexa	firm	reddish	weak	very weak
	Caru-Verde	firm	yellow-green	weak	weak
	Prata (silver)	firm	yellow	very weak	absent
	Branca (white)	firm	yellow	very weak	absent
	Figo (fig)	firm	yellow	very weak	very weak
	Nanicao (giant cavendish)	firm	yellow-green	weak	very weak
	Nanica (dwarf cavendish)	firm	yellow-green	weak	very weak
	Leite (milk)	firm	yellow-green	weak	weak
	Maca (apple)	firm	yellow	more strong	weak

TABLE 3. CHARACTERISTICS OF SOME VARIETIES OF BANANAS DURING RIPENING (cont.)

Days in Ripening Room	Variety Common Name	Firmness	Color of Peel	Aroma Characteristic of Ripe Fruit	Astringency
7 days	Ouro (gold)	firm	yellow	weak	absent
	Caru-Rexa	firm	reddish	weak	absent
	Caru-Verde	firm	yellow	weak	absent
	Prata (silver)	firm	yellow	very weak	absent
	Branca (white)	little soft	yellow	very weak	absent
	Figo (fig)	little soft	yellow	very weak	absent
	Nanicao (giant cavendish)	firm	yellow	more strong	absent
	Nanica (dwarf cavendish)	firm	yellow	strong	absent
	Leite (milk)	firm	yellow	weak	absent
	Maca (apple)	firm	yellow	more strong	weak
10 days	Ouro (gold)	firm	yellow with brown speckle	strong	absent
	Caru-Rexa	soft	reddish	weak	absent
	Caru-Verde	little soft	yellow	weak	a'sent
	Prata (silver)	soft	yellow with brown spots	very weak	sent

TABLE 3. CHARACTERISTICS OF SOME VARIETIES OF BANANAS DURING RIPENING (cont.)

Days in Ripening Room	Variety Common Name	Firmness	Color of Peel	Aroma Characteristic of Ripe Fruit	Astringency
10 days	Branca (white)	soft	yellow	very weak	absent
	Figo (fig)	soft	yellow	very weak	absent
	Nanicao (giant cavendish)	soft	yellow with brown spots	strong	absent
	[illegible]a (apple)	little soft	yellow	[illegible] strong	absent

TABLE 4. RIPENING CHARACTERISTICS OF SEVERAL CULTIVARS OF BANANAS

Common Names and Genotypes	Days in Ripening Room	Pulp/Peel Ratio	pH	Total Acidity (%Malic)	Ascorbic Acid mg/100g	Total Solids g/100g	Soluble Solids g/100g	Starch g/100g	Total Sugar g/100g	Reducing Sugar g/100g	Volatile Reducing Substances meq/100g	Protein %N x 6.25	Polyphenol Oxidase μ/3
Ouro (gold) Genotype AA	0	1.82	5.15	0.239	21.70	33.68	---	21.16	2.93	0.44	0.266	1.09	1250
	5	3.04	4.55	0.336	13.32	30.66	22.36	4.50	16.21	5.50	---	1.00	1250
	10	3.98	5.40	0.187	8.48	29.82	25.00	3.85	16.67	8.01	1.036	1.07	1170
Nanicao (giant cave dish) Genotype AAA	0	1.58	5.25	0.269	13.45	27.43	0.78	---	0.26	0.19	0.130	1.20	280
	5	1.89	4.70	0.373	7.99	25.71	20.20	1.90	13.37	8.33	1.106	1.12	850
	10	1.98	5.55	0.212	5.93	22.07	19.40	1.84	14.24	7.46	0.912	1.12	1520
Caru-Rexa Genotype AAA	0	2.02	5.20	0.292	15.62	26.12	3.32	20.62	0.93	0.08	0.222	1.01	0
	5	2.54	4.95	0.342	5.72	23.67	18.36	1.99	14.86	4.31	1.306	0.98	450
	10	2.52	5.35	0.385	4.28	22.40	18.36	1.09	13.37	3.74	0.800	1.13	930
Caru-Verde Genotype AAA	0	1.56	5.20	0.254	13.02	26.56	2.92	20.90	0.24	0.13	0.130	1.13	50
	5	2.07	4.55	0.410	7.10	26.07	17.40	2.32	13.37	4.13	1.198	1.10	520
	10	2.51	5.45	0.209	3.39	22.00	19.16	1.14	14.93	2.79	0.932	0.96	850

TABLE 5. RIPENING CHARACTERISTICS OF SEVERAL CULTIVARS OF BANANAS

Common Names and Genotypes	Days in Ripening Room	Pulp/ Peel Ratio	pH	Total Acidity (%Malic)	Ascorbic Acid mg/100g	Total Solids g/100g	Soluble Solids g/100g	Starch g/100g	Total Sugar g/100g	Reducing Sugar g/100g	Volatile Reducing Substances meq/100g	Protein %N x 6.25	Polyphenol Oxidase u/g
Leite (milk) Genotype AAA	0	1.55	5.30	0.284	18.22	28.64	3.30	22.00	1.30	0.40	---	1.00	---
	5	1.39	5.40	0.254	7.99	28.38	20.20	4.35	12.07	9.48	1.126	1.01	600
	10	2.07	5.30	0.312	4.28	26.87	22.36	0.95	11.84	10.47	0.706	0.91	600
Maca (apple) Genotype AAB	0	1.89	5.50	0.401		32.36	6.24	7.83	3.83	1.51			196
	4	2.20	4.50	0.588		31.74	24.52	3.36	17.69	12.77			336
	6	2.58	4.60	0.495		30.23	25.00	2.43	20.72	15.13			350
Figo (fig) Genotype ABB	0	1.26	5.80	0.187	39.92	31.89	1.56	24.30	1.09	0.16	0.138	1.18	15
	5	1.25	4.90	0.475	19.76	29.88	19.04	6.35	14.21	10.48	0.462	1.17	45
	10	2.24	5.00	0.313	11.87	26.97	19.40	2.43	16.82	12.97	0.438	1.10	190
Prata (silver) Genotype ABB	0	1.59	5.15	0.224	26.04	31.24	0.92	25.92	0.18	0.17	0.138	1.04	8
	5	2.41	4.38	0.569	15.98	29.30	22.36	4.78	13.50	11.12	0.500	0.92	80
	10	2.56	4.52	0.480	11.02	26.70	21.32	1.50	11.48	9.08	0.644	0.92	130
Branca (white) Genotype ABB	0	1.24	4.90	0.381	21.70	26.90	3.32	23.48	1.25	0.84	0.278	1.18	2
	5	1.63	4.50	0.511	6.21	25.94	19.72	2.30	13.89	9.01	1.066	1.17	7
	10	2.11	4.70	0.343	5.08	22.09	18.12	1.13	10.09	9.56	0.788	1.09	83

Fig. 1 [illegible]

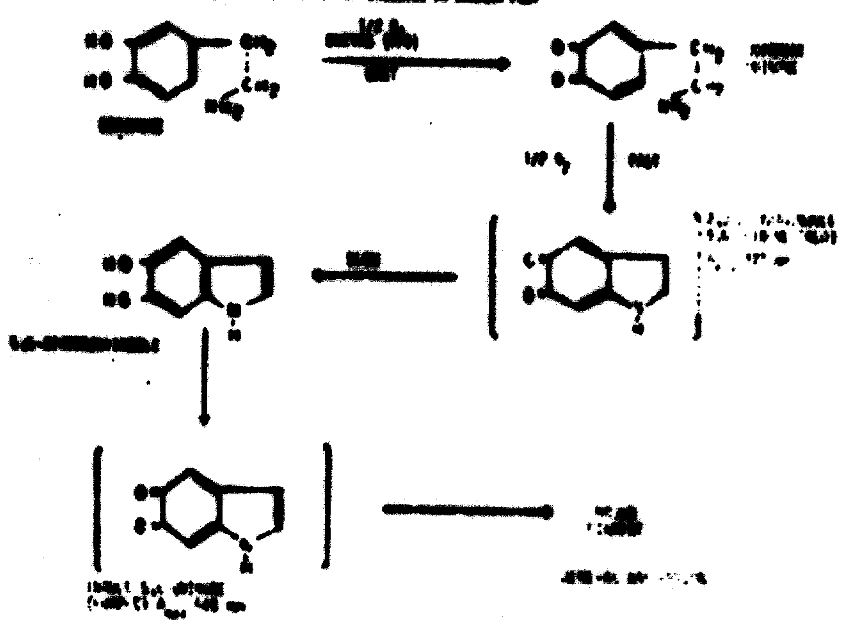


Fig. 2
HEAT INACTIVATION OF POLYPHENOL OXIDASE

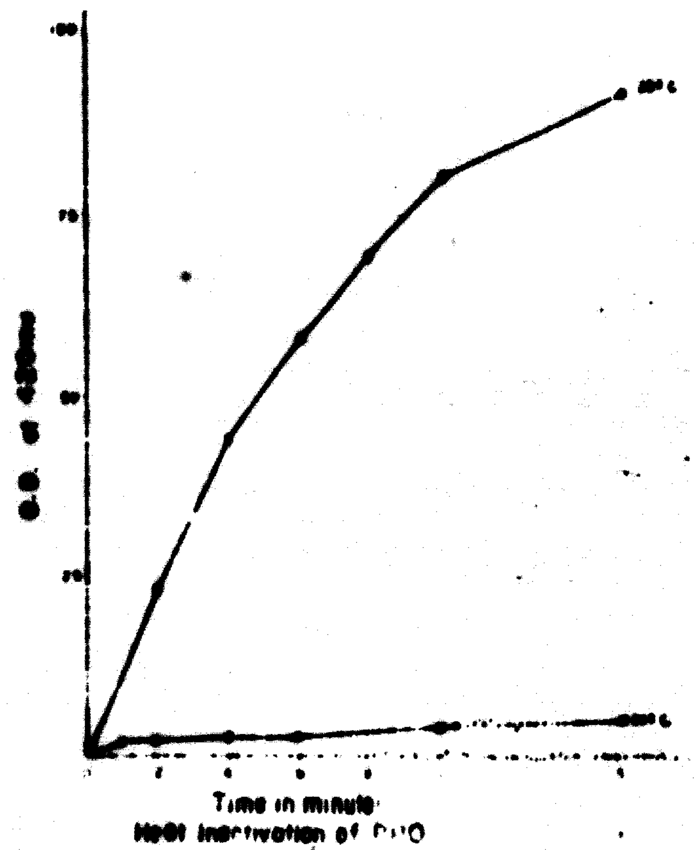
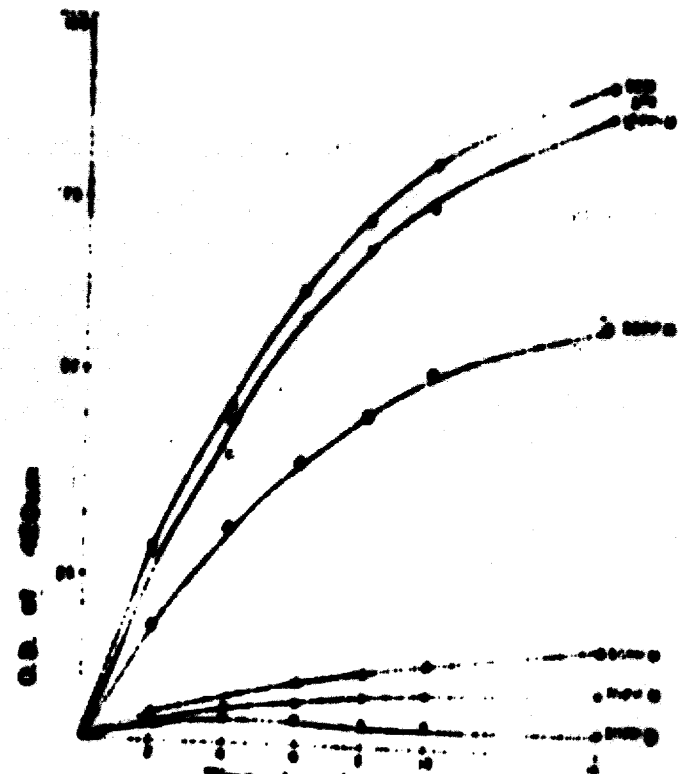


Fig. 3

INHIBITION OF POLYPHENOL OXIDASE BY SODIUM SULFITE



Chemical inactivation of PPO

Fig. 4 ROLE OF CYSTEINE AND ASCORBIC ACID IN PHENOLIC BROWNING.

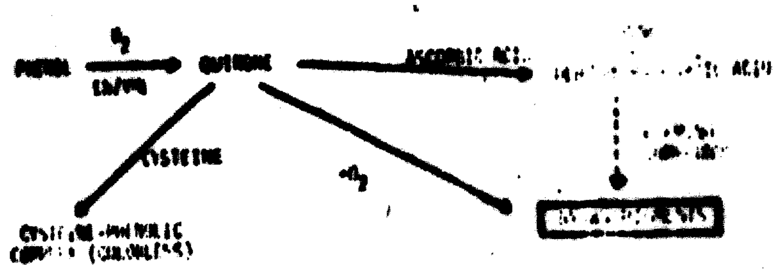


Fig. 5
ACTIVATION OF POLYPHENOL OXIDASE vs. pH

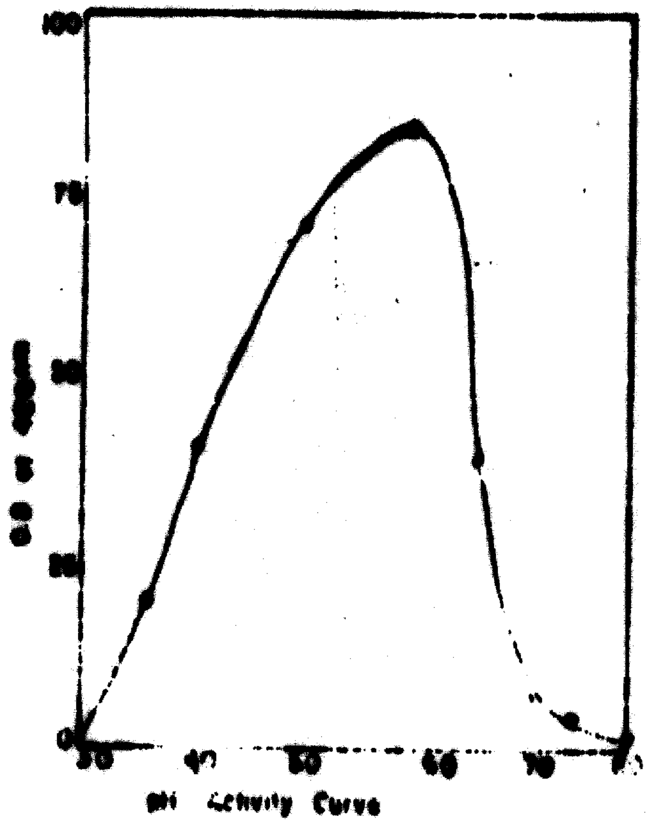
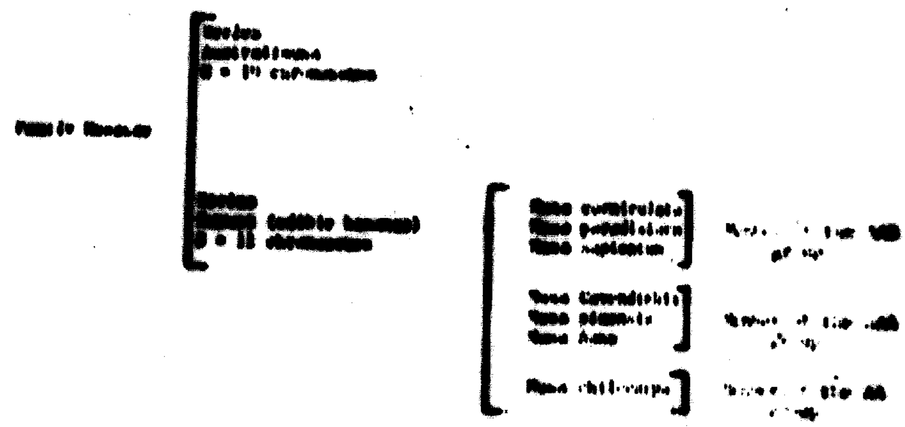


Fig. 6
BANANA VARIETIES STUDIED



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