

CHALLENGES TO PROCESSING TROPICAL FRUIT JUICES: BANANA AS AN EXAMPLE

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Additional index words. browning, flavor.

Abstract. A significant percentage of many tropical fruit crops produced in Florida is unsuitable for the fresh market. This unmarketable fruit, currently discarded, could potentially be processed into valuable juices and/or other products. Research has addressed some of the processing and quality problems associated with the production of a clarified banana juice. The objective of the first study was to determine the best methods to reduce viscosity and prevent browning. A combination of pectinase, cellulase and hemicellulase was the most effective of all enzyme systems in reducing viscosity and improving filterability. Heating puree or whole bananas to 80C for 1-2 minutes, or the addition of 100 mg/liter potassium metabisulfite, were effective in limiting browning. The objective of the second study was to determine the effects of ultrafiltration and heating puree and/or juice on browning and sensory changes. A 10,000 mwco ultrafiltration membrane reduced browning in juice, but did not change the flavor. Heating puree to 90C inactivated polyphenoloxidase and reduced browning in juice. Heat pasteurization (90C) increased browning in all juices and altered the flavor if puree had not been heated. A combination of heating juice and puree had no more effect on flavor than pasteurization alone.

Interest in and demand for tropical fruits and vegetables continues to grow in the United States. As a result, the tropical fruit and vegetable industry in Florida continues to develop. The emphasis of this industry is on the fresh market, which is currently much more profitable than the processing market. However, a significant percentage of several important tropical fruit crops is unsuitable for fresh market sales, primarily due to various appearance defects. This fruit is usually very sound, and could potentially be used in processed products. The utilization of this un-suitable fruit may generate extra income for the grower or packer, and may help protect the integrity of the fresh market by reducing the temptation to sell this less desirable fruit on the fresh market.

There are many different tropical fruits that can be processed and many different products that can be produced. This is indeed one of the challenges, to find the best product for each tropical fruit. One of the most important products produced from fruits is juice, which could also be one of the most important products from tropical fruits in Florida. Although banana is not a major crop in Florida, it can serve as an excellent example of how to process a tropical fruit into juice.

Banana is a very important crop in many countries, but a large percentage of the crop is typically unsuitable for the fresh market since it is too mature for shipment (Koffi et al., 1991; Sims et al., 1994). Because bananas have a high sugar content and a recognizable, desirable flavor, high-value clari-

fied juices from these excess bananas could become valuable products from otherwise rejected bananas. Of the problems associated with banana juice processing, a high viscosity, problems with juice extraction (Dupaigne and Dalnic, 1965; Viquez et al., 1981;), and browning problems (Galeazzi and Sgarbieri, 1981; Mao, 1974) seem to be the most severe. Studies conducted recently at the University of Florida to address these problems associated with banana juice are summarized in this paper.

Material and Methods

Study 1 - Viscosity Reduction. Two stages of banana ripeness were studied: stage 3 (green turning yellow) and stage 7 (completely yellow and extensively speckled with brown). Bananas at stage 3 were purchased from a local fruit distributor and either immediately processed or allowed to ripen to stage 7. Bananas were manually peeled and pureed in a pulper fitted with a 0.40 cm screen. Six commercial enzyme formulations from Genencor (180 Kimball Way, South San Francisco, CA 94080) were added to 1 kg of puree in duplicate: Pectinol 80 SB (31 mg/kg), GC 917 (17 mg/kg), Cytolase 123 (200 mg/kg), Rhozyme 86L (300 mg/kg), Cytolase 104 (200 mg/kg), and Cytolase 219 (200 mg/kg). Table 1 shows the reported composition of these enzymes. The rates used were the average usage rate recommended for other fruits. The banana puree was incubated with the enzymes for 3 and 6 hr at 25C.

The viscosity was measured with a Thomas Stormer viscometer. The flow behavior index (n) was calculated from the data using the following Ostwald-de Waele or power equation: $T = K \times Y^n$ or $\log T = \log K + (n)(\log Y)$, where shear stress $T = 0.166 \times \text{weight (g)}$, shear rate $Y = 22.61 \times \text{rpm}$, and K = consistency coefficient. The flow behavior index (n) was calculated by taking the slope of the line from the plot of $\log T$ vs. $\log Y$. A higher flow behavior index indicates a less viscous sample under these circumstances.

The filterability of the puree was determined by the volume of juice from a 100 g puree sample that passed through Whatman #1 filter paper in 2.5 min using vacuum filtration (10 psi). All data were subjected to analysis of variance using SAS (SAS Institute, 1985), with Duncan's Multiple Range test at the 5% level used to separate treatment means. Data from the two maturities were analyzed separately.

Study 2 - Browning Prevention. Several methods commonly used to prevent browning were tested in the production of clarified banana juice. Only bananas at maturity stage 7 were used in this study. The first method involved heating whole, unpeeled bananas for 11 min in 100C steam on a steam

Table 1. Enzyme preparation composition and amount used.

Enzyme preparation	Reported composition	Amount used (mg/kg)
Cytolase 219	Pectinase, cellulase, hemicellulase	200
Cytolase 104	Pectinase, cellulase, hemicellulase	200
Pectinol 80SB	Pectinase	31
GC 917	Galactomannanase	17
Cytolase 123	Cellulase, beta-glucanase	200
Rhozyme 86L	Alpha-amylase	300

blancher belt to reach an internal temperature of 85°C for 1-2 min. After heating, the bananas were peeled using a rolling pin and pulped as described previously. The puree was acidified to pH 4.0 using 20% citric acid to produce a high acid food. The puree was then cooled to room temperature, Cytolase 219 was added (200 mg/Kg) and the enzyme was incubated with the puree for 4 hr at 25°C for viscosity reduction.

Another heating method involved heating puree in a small steam kettle with constant stirring to 85°C. The puree was cooled to ca 25°C in ice water, acidified to pH 4.0 with 20% citric acid, and incubated for 4 hr with Cytolase 219. Two other treatments were the addition of potassium metabisulfite (100 mg/kg) or ascorbic acid (470 mg/kg) to puree immediately after the bananas were pureed. These rates of potassium metabisulfite and ascorbic acid have been reported to inhibit banana polyphenoloxidase (Galeazzi and Sgarbieri, 1981). The purees were acidified to pH 4.0 and incubated for 4 hr with Cytolase 219. A control with no heat treatment or additives was also acidified and treated with the enzyme in the same manner. All treatments were duplicated.

Following the enzyme treatment, a hydraulic press fitted with a press cloth was used to extract juice from the puree (4-6 kg batches). The puree was pressed at ca 400 kg/cm² for 12-15 min. The juice was then filtered to clarity through a series of cellulose pads coated with diatomaceous earth. The juice was then "sterile filtered" through a 0.45 µm cartridge membrane filter, potassium sorbate was added (200 mg/kg) as a further safeguard against microbial spoilage, and the juice was bottled into pre-sterilized 355-ml bottles. This method was adequate to prevent microbial spoilage without using heat pasteurization.

The color (degree of browning) of the juice was determined by measuring the absorbance at 420 nm in a spectrophotometer. For color stability assessment, potassium sorbate (250 mg/kg) was added to a 100 ml sample, the juice was covered with parafilm, and the color measured after 48 hr as described above.

Polyphenoloxidase (PPO) activity was determined by measuring the rate of increase in absorbance at 420 nm at 25°C in a Beckman DU-40 spectrophotometer. The incubation mixture contained 1 ml 0.5 M catechol, 1.9 ml 0.05 sodium phosphate (monobasic) buffer at pH 6.5, and 0.1 ml juice. PPO activity is reported as the unit change in absorbance per min per ml at 25°C.

All data were subjected to analysis of variance using SAS, with Duncan's Multiple Range test at the 5% level used to separate treatment means.

Study 3 - Color and Flavor Changes. Bananas at a maturity stage of 3 (turning yellow, green tips) were obtained from a local produce distributor and divided into two portions. One was processed immediately and the other was allowed to ripen to maturity stage 7 (completely yellow and speckled with brown spots) at ambient temperature (ca 25°C) before processing. Bananas from both maturities were peeled by hand, dipped in a 1% citric acid solution, and pureed using a paddle pulper fitted with a 0.40 cm screen. The puree was acidified to ca. pH 4.1 using a 50% citric acid solution, quickly heated to 90°C by pumping the puree through a scraped surface heat exchanger (25 psi steam), held for 30 sec in a holding tube, and quickly cooled to 50°C by pumping the puree through a second scraped surface heat exchanger cooled by chilled water. Another portion of the acidified banana puree was heated to only 50°C in a scraped swept surface heat ex-

changer, which is the optimum temperature for the enzyme treatment.

The purees were then treated with 200 mg/kg Cytolase 219 for 1 hr at 45-50°C. The juice was separated from the residue using a rotary shaker screen (325 mesh screen). The juice was allowed to settle overnight at 2°C and then pad-filtered to clarity using a small plate and frame filter. The juice was filtered in two stages (coarse and fine pads) to achieve clarity. A portion of the juice that had been heated to 50°C (which still had PPO activity) was then ultrafiltered through a 30,000 or 10,000 mwco, spiral wound membrane (Amicon S1) using a Amicon model CH2 system. The juice was then hot filled at 90°C (pasteurized) into 200 ml juice bottles, sealed, inverted for 2 min, and cooled to 25°C in cold water. A portion of the juice was not pasteurized and kept at 2°C.

PPO activity and color of the juice were determined as described above. All color data were subjected to analysis of variance using SAS, and Fisher's least significant difference (0.05 level of significance) was used to separate means.

For sensory analysis, a series of triangle tests were used to determine if any overall flavor differences existed between the juices. All juices (25 ml) were presented to 17 or 18 panelists in black wine glasses to mask color differences. Panelists consisted of faculty and staff from the Food Science and Human Nutrition Department. Panelists were experienced in sensory evaluations, including banana juices, but were not specifically trained for these evaluations. Juices were served at ca. 7°C, and panelists evaluated the juices in private booths. Four triangle tests were conducted for each maturity level of bananas used, with 2 triangle tests conducted in the morning and 2 in the afternoon. All tests were conducted within 3 days of processing. The 4 triangle tests for each maturity of bananas consisted of:

- (1) puree heated to 50°C, non-pasteurized **vs.** puree heated to 50°C, pasteurized
- (2) puree heated to 90°C, non-pasteurized **vs.** puree heated to 90°C, pasteurized
- (3) puree heated to 50°C, pasteurized **vs.** puree heated to 90°C, pasteurized
- (4) puree heated to 50°C, pasteurized **vs.** puree heated to 50°C, ultrafiltered (30,000 mwco membrane), pasteurized

Results and Discussion

Study 1 - Viscosity Reduction. The effects of the enzymes on viscosity and filterability of puree from green bananas (stage 3) are shown in Table 2. Cytolase 219 (a mixture of pectinases, cellulase and hemicellulase) and Cytolase 104 (another mixture of pectinase, cellulase and hemicellulase) were the most effective enzymes in reducing viscosity of green banana puree (higher flow index) (Table 2). Pectinol 80 SB (a pectinase) was the next most effective enzyme. GC 917 (a galactomannanase), Rhozyme 86L (an alpha-amylase) and Cytolase 123 (cellulase and beta-glucanase) were much less effective, but did slightly reduce viscosity.

The two enzyme mixtures that were most effective in reducing viscosity, Cytolase 219 and 104, were by far the most effective in increasing filterability of green banana puree after all incubation times (Table 2). Pectinol 80 SB improved filter-

Table 2. Effect of enzyme treatment on the viscosity and filterability of green banana (stage 3) puree.

Enzyme treatment	Viscosity (flow index) ^z		Filterability ^y	
	3 hr	6 hr	3 hr	6 hr
Cytolase 219	0.563a ^x	0.670a	39a	48a
Cytolase 104	0.545b	0.636b	36a	49a
Pectinol 80SB	0.445c	0.506c	10b	17b
GC 917	0.284d	0.434d	3c	7c
Rhozyme 86L	0.278e	0.248f	1c	1c
Cytolase 123	0.256f	0.272e	1c	1c
Control	0.117g	0.214g	0c	0c

^xA lower value indicates a more viscous puree.

^yFilterability is defined as the ml of juice obtained from 100g puree following vacuum filtration (10 psi) for 2.5 min. through Whatman #1 paper.

^zMeans within a column followed by the same letter are not significantly different (Duncan's Multiple Range Test, 5%)

ability to a much lesser extent, but none of the other enzymes were effective, even though they did decrease viscosity somewhat. It appears that a significant reduction in viscosity is required to improve filterability.

A mixture of pectinase, cellulase and hemicellulase is much more effective than the pectinase or cellulase alone when used at these recommended rates. Green banana pulp contains considerable quantities of hemicellulose in addition to pectin and cellulose (Palmer, 1971; Barnell, 1943; Kayisu et al., 1981; Von Loesecke, 1950). The control had a high viscosity and could not be filtered at any incubation time, indicating that endogenous enzymes are inefficient in degrading the pulp. The alpha-amylase preparation had a minimal effect on viscosity and no effect on filterability even though green banana puree contains up to 20% starch (Wills et al., 1984). The presence of this high starch content apparently does not have a large impact on the viscosity or filterability if the puree is not heated. However, if green banana puree is heated, there is a tremendous increase in viscosity and gel formation (data not shown).

The effects of the enzymes on viscosity and filterability of puree from ripe (stage 7) bananas were slightly different than those for green bananas and are shown in Table 3. Although Cytolase 219 and 104 were generally the most effective in reducing viscosity, Pectinol 80 SB was nearly as effective at all incubations periods, and GC 917 was as effective as the other enzymes after 3 hr. The polysaccharide composition of bananas changes considerably during ripening, with a large decrease in hemicellulose (Palmer, 1971; Barnell, 1943) and starch (Wills et al., 1984), and smaller decreases in cellulose and pectin (Von Loesecke, 1950; Kayisu et al., 1981). Rhozyme 86L and Cytolase 123 were not effective in reducing viscosity of the puree.

Cytolase 219 and 104 were by far the most effective in improving filterability (Table 3) of ripe banana puree, as was the case with green banana puree. The Pectinol 80 SB and GC 917 also improved filterability, but not to the extent of Cytolase 219 and 104. The Rhozyme 86L and Cytolase 123 did not permit filtration of the juice. The green and ripe banana puree gave approximately the same amount of filtered juice (50 ml from 100 g) if treated with either Cytolase 219 or 104.

Study 2 - Browning Prevention. The juice obtained from the heated puree and sulfite treated juice were the lightest and least brown (as indicated by a lower abs. at 420 nm) of all the treatments initially (Table 4). The juice obtained from heat-

Table 3. Effect of enzyme treatment on the viscosity and filterability of ripe banana (stage 7) puree.

Enzyme treatment	Viscosity (flow index) ^z		Filterability ^y	
	3 hr	6 hr	3 hr	6 hr
Cytolase 104	0.492a ^x	0.643a	40a	42a
Cytolase 219	0.494a	0.642a	39a	43a
Pectinol 80SB	0.451ab	0.572b	18b	26b
GC 917	0.496a	0.488c	17b	20c
Rhozyme 86L	0.391c	0.410d	7c	7d
Cytolase 123	0.417bc	0.467c	8c	9d
Control	0.359c	0.408d	4c	5d

^xA lower value indicates a more viscous puree.

^yFilterability is defined as the ml of juice obtained from 100g puree following vacuum filtration (10 psi) for 2.5 min. through Whatman #1 paper.

^zMeans within a column followed by the same letter are not significantly different (Duncan's Multiple Range Test, p=0.05).

ed whole bananas and juice processed with ascorbic acid were also lighter than the control initially. After 48 hr of air exposure the sulfited juice had the lightest color and least amount of browning, followed by the heated puree juice and the juice obtained from heated whole bananas (Table 4). Ascorbic acid treated juice browned considerably when exposed to air and had similar color to the control.

Polyphenoloxidase (PPO) was very active in the juice treated with ascorbic acid and the control juice, but was inactivated completely by the sulfite and heating treatments (Table 4). Heating banana puree prior to juice extraction was the most effective method after sulfite treatment to inactivate PPO and ensure color stability. Heating whole bananas was very effective in inactivating PPO, which agrees with previous research by Mao (1974), but the color was comparatively unstable. This was apparently due to non-enzymatic browning, which could be due to migration of oxidizable compounds (such as certain phenolics) from the banana peel into the pulp during heating.

Study 3 - Color and Flavor Changes. Heating the puree to 90C inactivated PPO in both ripe and green bananas, while puree heated to only 50C still had PPO activity (data not shown). The level of PPO activity varied considerably between banana maturities, with the riper bananas having much greater activity. PPO activity in the riper banana puree and juice decreased substantially during settling of the juice at 3C overnight and pad filtration (data not shown). The filtered juice from less ripe bananas had no detectable PPO. The PPO was most likely associated with larger cell-wall components or tan-

Table 4. Effects of heat, bisulfite and ascorbic acid on the color and polyphenoloxidase activity of clarified juice from ripe bananas (stage 7).

Treatment	Abs at 420nm		Polyphenoloxidase activity ^y
	Initial	After 48hr	
Control	0.289a ^x	0.357a	3.42
Heat-whole bananas	0.153b	0.206c	0
Heat-puree	0.115c	0.148d	0
Bisulfite (100mg/kg)	0.090d	0.130e	0
Ascorbic acid (470mg/kg)	0.121c	0.308b	5.10

^xMeans within a column followed by the same letter are not significantly different (Duncan's Multiple Range Test, p=0.05).

^yActivity is expressed as the increase in absorbance at 420nm per ml of juice per minute.

Table 5. Effects of fruit maturity, heat and ultrafiltration on the color of banana juice.

Treatment ^a	Absorbance at 420nm		
	Before pasteurization ^b	After pasteurization ^b	After Storage (10 mo. at 24C)
<u>Ripe</u>			
90C	0.085c ^x	0.112c	0.281b
50C	0.351a	0.426a	0.432a
50C-UF 30,000	0.367a	0.402a	0.446a
50C-UF 10,000	0.290b	0.319b	—
<u>Green</u>			
90C	0.114b	0.134b	0.471a
50C	0.134a	0.210a	0.445a
50C-UF 30,000	0.127a	0.215a	0.462a

^aPuree was heated to either 90C or 50C, enzyme treated, strained to extract juice, settled overnight, pad-filtered, and then not ultrafiltered or ultrafiltered through a 30,000 or 10,000 mwco membrane.

^bPasteurization was hot-fill at 90C.

^xMeans within a column and fruit maturity followed by the same letter are not significantly different (Fisher's lsd, p=0.05).

nins that precipitated or were removed during settling and/or filtration. Other researchers (Palmer and Roberts, 1967; Young, 1965) have indicated that banana PPO and other enzymes are associated with or bound to cell wall components and/or tannins, especially in less ripe bananas.

Ultrafiltration of ripe banana juice through a 30,000 mwco membrane only slightly reduced PPO activity, but ultrafiltration through a 10,000 mwco membrane removed all PPO activity (data not shown). Banana PPO fractions reportedly have molecular weights of 30,000 or greater (Galeazzi et al., 1981). However, the mwco of these membranes is nominal, not absolute, and other characteristics of macromolecules such as shape may influence retention by the membrane. The 10,000 mwco membrane effectively retained PPO and eliminated enzymatic activity.

Banana juice (especially juice from riper bananas) from puree heated to 90C was much lighter (less browning, lower absorbance at 420 nm) (Table 5) than juice heated to 50C, which was due to inactivation of PPO and less enzymatic browning. Ultrafiltration of juice through a 30,000 mwco membrane had no effect on color, regardless of maturity (Table 5). The 30,000 mwco membrane did not remove PPO when present, nor did it remove any of the brown color compounds. However, ultrafiltration of the riper banana juice through a 10,000 mwco membrane did significantly reduce the brown color as well as remove PPO.

Pasteurization of the juices at 90C (hot fill) increased browning in all juices, but the difference between the treatments remained the same (Table 5). Enzymatic activity in the puree caused much more browning overall than did heat pasteurization. All the pasteurized juices browned during storage at 24C for 10 months, but juices from the less mature bananas browned to a greater extent and had similar color as juices from more mature bananas after storage. Juice from the riper bananas that had been heated to 90C as puree browned during storage but remained much lighter than similar juice that had been heated to only 50C as puree. In contrast, the less ripe banana juice heated to 90C as puree browned extensively during storage and had similar color as juices heated to 50C

Table 6. Effects of heating puree, juice pasteurization and ultrafiltration on sensory differences (triangle tests) between banana juices.

Comparison ^a	Total/Correct ^a
<u>Ripe</u>	
50 NP vs. 50 P	18/12*
90 NP vs. 90 P	18/9 NS
50 P vs. 90 P	18/9 NS
50 P vs. 50 P + UF	18/7 NS
<u>Green</u>	
50 NP vs. 50 P	17/12*
90 NP vs. 90 P	17/8 NS
50 P vs. 90 P	17/5 NS
50 P vs. 50 P + UF	17/4 NS

^a50 NP = puree heated to 50C, non-pasteurized juice; 50 P = puree heated to 50 C, pasteurized (90°C) juice; 90 NP = puree heated to 90C, non-pasteurized juice; 90 P = puree heated to 90C, pasteurized (90C) juice; 50 P + UF = same as 50 P, but juice was ultrafiltered through a 30,000 mwco membrane.

^bTotal observations/Correct observations, * indicates significant at the 0.05 level, NS indicates not significant.

as puree. There was insufficient quantities of the juice ultrafiltered through the 10,000 mwco membrane to submit to storage.

Triangle sensory tests indicated that there were no significant differences in flavor between the pasteurized and non-pasteurized juice from puree heated to 90C (Table 6). These juices had a cooked banana flavor according to the panelists, and heat pasteurization of juices that had already been heated to 90C did not significantly change the flavor. There was no difference in flavor between the pasteurized juices that had been heated to 50C and 90C as puree, either. These juices also had a similar cooked banana flavor, which indicates that heating the puree causes as much flavor change as heat pasteurization (hot-fill). Ultrafiltration did not significantly change the flavor of juice, either. Results were the same for juices from both maturities.

There was a significant difference in flavor between the non-pasteurized and pasteurized juice from puree that had been heated to 50C (Table 6). The non-pasteurized juice had very little cooked banana flavor and was described as a "fresher banana flavor" by most panelists as compared to the pasteurized juice. Sterile filtration and aseptic packaging of the juice would likely preserve the fresh banana flavor, but poor color due to enzymatic browning in the puree could remain a problem.

Conclusions

Mixtures of pectinase, cellulase and hemicellulase were effective in reducing viscosity and improving the filterability of puree from both green and ripe bananas. Heating whole bananas or puree to 80-90°C, or the addition of 100 mg/liter potassium metabisulfite, effectively inhibited browning of clarified juice. A 10,000 mwco ultrafiltration membrane, but not a 30,000 mwco membrane, removed all PPO activity, reduced the brown color in the juice, and did not change the flavor of pasteurized juices. Heat pasteurization (hot fill at 90C) increased browning in all juices and changed the juice flavor (more "cooked" flavor) if the puree had not been heated to 90C. Overall, heat pasteurization had less effect on juice browning than enzymatic activity in the puree.

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Proc. Fla. State Hort. Soc. 107: 319-322. 1994.

MARKET DEVELOPMENT STRATEGIES FOR SELECTED TROPICAL FRUITS

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Abstract. Hurricane Andrew caused a major disruption of the tropical fruit industry in Dade County. Approximately one-third of the avocado acreage, two-thirds of the limes and nearly 40% of the mangos were lost. Competitive pressures that were building prior to the hurricane may prevent acreage of these crops from reaching pre-storm levels. As a result, there appears to be heightened interest in mangos and minor fruit crops, which include carambola, specialty bananas, mamey sapote, lychee, guava, papaya, annona (atemoya and sugar apple), longan, and passion fruit. Marketing increased volumes of these minor fruit crops at a profit may be a challenge. This paper discusses various ways of developing commercial markets for these exotic fruits by targeting specialty produce wholesalers and retail chains in major U.S. markets where large numbers of Hispanics and Asians reside. Unique packing, shipping, and promotional needs associated with marketing these specialty fruits are also discussed.

In order to better understand the changes in the tropical fruit industry caused by Hurricane Andrew, the Florida Agricultural Market Research Center at the University of Florida is conducting a multifaceted study of the tropical fruit industry. Interviews have been conducted with 245 tropical fruit growers and produce buyers of 75 retail supermarket chains, with interviews of packers, shippers, and specialty produce wholesalers within the industry to be completed. This paper will focus only on the preliminary results of our retailer interviews.

Retailer interviews were conducted to achieve the following objectives: (1) To identify consumer market segments and geographic areas that afford the greatest marketing po-

tential for exotic fruits, (2) to obtain retailers' feedback on the current marketing environment for these fruits, and (3) to obtain retailers' suggestions for market development activities for tropical fruit.

In 1992, Hurricane Andrew destroyed much of Dade County's tropical fruit industry. Lime, avocado, and mango acreages in particular were devastated, prompting some growers to replant with more exotic species of tropical fruits. Production of these exotics without adequate market development could depress future prices to growers.

Materials and Methods

The study focuses on 10 tropical fruits identified by boardmembers of the Florida Tropical Fruit Growers' Association as having the greatest potential for economic success in South Florida. The fruits selected by the boardmembers are carambola (star fruit), specialty bananas, guava, papaya, mamey sapote, passion fruit, lychee, annona (sugar apple & atemoya), mango, and longan. Because the list includes two types of annona, the total number of fruits is eleven.

Preliminary discussions with tropical fruit growers and shippers in South Florida revealed that Hispanics and Asians constitute viable markets for many tropical fruits because of their familiarity with these items and their propensity to buy them when available. Accordingly, the 25 largest Hispanic and Asian markets were identified using U.S. Census data available on CD-ROM. Markets were defined as geographic regions with well-established food distribution patterns, as designated by Progressive Grocer's *1994 Marketing Guidebook*. Detailed ethnic population statistics for Hispanics and Asians by country-of-origin were derived for each market area (Table 1).

Each market area examined included a much greater geographical area than the city by which it is referenced. For example, the Boston market encompasses the city and all