OPTIMIZATION OF GUAVA JUICE AND POWDER PRODUCTION

CHETAN A. CHOPDA and DIANE M. BARRETT*

Department of Food Science and Technology

University of California Davis

Davis, CA 95616-8589

Running title: Guava Juice Processing Optimization

* Send correspondence to: Dr. Diane M. Barrett; University of California, Davis; One Shields Avenue; Davis, CA 95616-8589. Tel. (530) 752-4800; Fax: (530) 754-7677; E-mail: dmbarrett@ucdavis.edu

ABSTRACT

Enzyme treatment of guava puree was optimized for yield and clarity by first determining the most effective concentration, then varying both incubation time and temperature. Application of Pectinex Ultra SP-L® was optimal using 700 ppm enzyme for 1.5 hr at 50°C. Clarified guava juice was clearer (89.6%) when prepared using ultrafiltration (MW cut-off 40-60kDa) rather than plate and frame filtration (82.8%); however the latter was higher in both soluble solids and ascorbic acid. Clarified guava juice powders were made using freeze-drying, spray drying and tunnel drying. The freeze-dried product had superior quality; however the spray-dried product was stable and may be more economical. Sensory panelists ranked the cloudy juice prepared from aseptic guava puree highest, and there were no significant differences between the juices from pasteurized, clear nectar, freeze-dried puree powder or juice powder.

INTRODUCTION

Guava (*Psidium guajava* L.), which belongs to the Myrtaceae family, is a native of tropical America and grows well in tropical and subtropical regions. Guava fruit has a characteristic flavor, to which its acidity (pH 4.0 to 5.2) contributes (Jagtiani *et al.* 1988). It is a rich source of ascorbic acid, containing over 100 mg/100 g (Wenkam and Miller 1965). Most of the guava produced around the world is consumed fresh. Marketing of processed products such as puree, paste, canned slices in syrup or nectar is limited (Jagtiani *et al.* 1988). Clarified and cloudy guava juices are currently produced and may have greater market potential, but optimal process conditions for these products have not been determined.

The use of enzymes to maximize the yield of cloudy juice and promote clarification is uncommon in the production of guava juice. Commercial preparations containing pectinases, arabinase and cellulase may benefit guava juice production. Pectinase assists in pectin hydrolysis, which causes a reduction in pulp viscosity and a significant increase in juice yield. Pectin methyl esterase (PME) and polygalacturonase (PG) are pectinases which release carboxylic acids and galacturonic acid during enzyme treatment, which may lead to a decrease in the pulp pH (El-Zoghbi *et al.* 1992). Arabinase and cellulase convert araban and cellulose to soluble sugars that increase the soluble solids (SS). Arabinase also assists in eliminating the turbidity of juice caused by araban, which is visible only after 3-4 weeks of storage. There is an increase in the ascorbic acid content of guava juice following enzyme treatment due to release from the peel, which is a rich source (Askar *et al.* 1992).

Yield of cloudy juice is significantly affected by the temperature and time used for enzyme treatments. Increasing exposure time elevates yield but also causes a reduction in ascorbic acid content of the juice due to oxidation (Imungi *et al.* 1980). Immature fruits have a higher percentage of phenolics, which may affect the clarification process by preventing the settling of suspended solids or by hindering the activity of the enzymes used for extraction. Therefore, selection of fully ripe, firm yellow fruitwithout bruises is essential for processing.

A significant portion of the population prefers a grit-free, clear, haze-free guava juice. Clarified guava juice may be more acceptable to the general population, and may be used in the manufacturing of clear guava nectar or jelly, clear guava powder or a mixed fruit juice blend. There is also potential for use of an instant guava powder in formulated drinks, baby foods and other products. Transportation costs would be reduced significantly when shipping this product to distant markets. However, information about guava powders does not exist in the literature. Guava has delicate color and flavor properties and drying operations must be carefully designed to maintain these.

Several methods may be used for production of guava powder, but the most successful include freeze-drying, foam mat drying, spray drying and tunnel drying. Researchers have successfully used freeze drying to convert guava products into powder although freeze drying is known to be the most expensive method of drying. Very little literature is available on spray drying of guava products, but Muralikrishna *et al.* (1968) have reported difficulties in spray drying guava pulp. Maltodextrin products may serve as carriers and facilitate drying. Tunnel drying is well known to be the cheapest method of drying an acceptable quality powder.

The first objective of this study was to select the correct enzyme dosage and optimum treatment time and temperature for maximizing yield of cloudy juice and retaining ascorbic acid. At the same time, the cost effectiveness of the enzymes utilized was also of interest. A second objective was to evaluate the effect of both ultrafiltration and plate and frame filtration on the flux, turbidity, ascorbic acid retention and soluble solids (SS) content of clarified guava juice. The third objective was to prepare guava powders using freeze drying, spray drying and tunnel drying methods and evaluate the effects of drying on physico-chemical properties. A consumer preference test was conducted to determine the sensory quality of these clarified juice, cloudy juice and reconstituted juice products, and to compare products to those available in the market.

MATERIALS AND METHODS

Raw Materials

Guava puree made from the white fleshed variety ‘Allahabad safeda,' manufactured by Enkay Texofood Industries Limited (Valsad, Gujrat, India), was obtained in aseptically packed 20 kg bag-in-box containers.Pectinex Ultra SP-L® enzyme was obtained from Novo Nordisk Biochem North America Inc. (Franklinton, NJ) and ADM DMG 70®, a distilled monoglyceride, was obtained from Archer Daniels Midland Company (Decatur, IL). Three maltodextrin products, Maltrin 100®, Maltrin 500® and Maltrin 580®, and modified food starch powders Pure-cote B760® and Pure-cote B790® were obtained from the Grain Processing Corporation (Muscative, IA). Commercially manufactured (Nestle, Glendale, CA) cloudy pink guava nectar containing 18% juice was procured locally.

Laboratory reagents such as iodine, phenolphthalein, potassium iodide, metaphosphoric acid and the sodium salt of 2,6-dichlorophenol-indophenol were obtained from Sigma Chemical Company (St. Louis, MO). L-ascorbic acid, hydrochloric acid and sodium hydroxide were obtained from Fisher Scientific Company (Fair Lawn, NJ). Distilled deionized (DI) water was used in all experiments.

Processing

1. Enzyme treatment: Processing conditions are outlined in Figure 1. Enzyme treatment conditions were optimized in the laboratory prior to carrying out treatment at the pilot scale. Four hundred ppm of Pectinex Ultra SP-L® were added to guava puree in a Julabo 20B (Seelbach, Germany) water bath at five different temperatures, i.e. 35, 40, 45, 50 and 55°C. The optimum temperature for enzyme treatment was evaluated after inculbation for 1 hr and this temperature was used to estimate the optimum time and concentration for enzyme treatment. Guava puree was mixed with 300, 500 and 700 ppm Pectinex Ultra SP-L, and samples were removed at every 1, 1.5, 2 and 2.5 hr time interval. Part of this enzyme treated puree was immediately frozen using liquid nitrogen and stored at -80°C for ascorbic acid analysis. The remainder was heated to 80°C for 30 seconds to inactivate the commercial enzyme using a Cole Parmer hot plate (Model 51450 series, Vernon Hills, IL); thiswas used for other analytical measurements. All experiments were carried out in duplicate.

After determining the optimal process parameters in the laboratory, enzyme treatment was conducted in the Food Processing Laboratory of the Department of Food Science and Technology, using a 500 L steam jacketed vessel. To avoid further enzymatic hydrolysis, the enzyme treated puree was immediately stored at 4°C for no more than 12 hrs until further processing.

2. Centrifugation: The enzyme treated puree was centrifuged at 10,410 x g (8,000 rpm) for 8 minutes at 4-8°C in a RC-5C Model centrifuge from Sorvall Instruments, Dupont (Wilmington, DE), to remove the suspended material and aid in juice clarification. After centrifugation, the supernatant was filtered through cheesecloth and stored at 4°C for no more than 24 hrs until further processing. Centrifuged samples were filtered using either plate and frame or ultrafiltration.

3. Ultrafiltration: A SEPA® CF membrane cell, manufactured by Osmonics Inc. (Minnetonka, MN), was used to ultrafilter the centrifuged puree. The cell consisted of a RZ04 (molecular weight cut-off 40-60 kDa) membrane and an Enerpac hydraulic hand pump (Butler, WI) and operated under a pressure gradient of 250 psi. Feed material was recirculated through the system until a substantial reduction in permeate flux was observed.

4. Plate and frame filtration: The centrifuged juice was also clarified using a pilot scale plate and frame filtration unit and Micro-Media® filter pads manufactured by Ertel Engineering Company (Kingston, NY). Three filter pad grades M50 (retention 1 µ), M80 (retention 0.5 µ) and M90 (retention 0.25 µ) were compared and the system operated at a pressure of 15-20 psi. The clarified juice was stored at 4°C for no more than 48 hrs until further processing.

5. Pasteurization: Clarified juice was pasteurized using a plate heat exchanger (APV Model JRHE, Buffalo, NY). Juice was heated to 93°C and held for 48 seconds. One-gallon glass bottles were pre-sterilized in an autoclave and hot filled, followed by capping and inverting the bottle for 45 seconds to sterilize the lid. After cooling, bottles were stored at 4°C for 7 weeks before they were used in the final sensory test.

6. Concentration: Clarified guava juice was concentrated to 42°Brix using a 12 inch wiped film evaporator (Pfaudler Permutt Inc., Rochester, NY). Concentration was carried out at 146°C for 90 seconds under vacuum.

7. Freeze drying: Aseptic puree, clarified juice and clarified juice concentrate were freeze dried in a VIRTIS Model 50 SRC 5 (Gardiner, NY) freeze dryer. An approximately 1.5 cm thick, layer was placed on each tray and frozen overnight at -25°C; then the heating plate temperature was set to 46°C and the vacuum to 55 mTorr to initiate drying. After drying for 48 hrs, blocks of guava powder were removed from trays and ground in a heavy-duty food grinder (Oster, Mexico) and the fine powder was stored in plastic containers at room temperature.

8. Spray drying: Guava juice concentrate and diluted aseptic guava puree were spray dried using an APV Anhydro A/S laboratory size no.1 spray dryer (Attleboro, MA). A Bosch 1210 type atomizer (Scintilla SA, Switzerland) with the atomizer speed regulator set at 220 volts was utilized. The inlet temperature of the feed material was set to 160°C by adjusting the power supply with a 5 kW heating element. The outlet (product) temperature was set to 80°C by regulating the feed pump speed. Powder was separated from hot air by a cyclone separator and stored at room temperature.

Three different maltodextrin products, , Maltrin 100®, Maltrin 500® and Maltrin 580®, were added to the samples prior to spray drying. Based on the formula developed for spray drying an orange juice mix (Kramer, 1998), the following combinations were selected and blended using a hand mixer prior to drying:

i. 300 g clear juice concentrate + 285 g Maltrin 100®

ii. 300 g clear juice concentrate + 285 g Maltrin 500®

iii. 3000 g 4.7°Brix puree + 249 g Maltrin 580® + 48 g Maltrin 100® + 13 g Maltrin 500®

9. Tunnel drying: Puree was mixed with the following ingredients and placed on separate trays:

i. 117.1 g (20%) Pure-cote B790® + 585.5 g of puree + 146.38 g (25%) sugar

ii. 130 g (20%) Maltrin 580® + 650 g puree + 162.5 g sugar (25%)

iii. 117.1 g (20%) Pure-cote B760® + 585.5 g puree + 146.38 g (25%) sugar

Pure-cote and Maltrin provide flexible film-forming and adhesive properties to the puree. Concentrations of these ingredients were selected based on recommendations by the Grain Processing Corporation (1998). Sugar was added to improve retention of color and flavor and to improve drying characteristics of the final product (Askar *et al.* 1992).

The tunnel dryer was a batch type and air temperature was maintained by a steam control system (Foxboro, MA). A thin layer of each solution was spread on cheesecloth and placed over a wire mesh tray, which was placed in the tunnel dryer for drying. The air temperature which flowed parallel to the breadth of the trays was set at 70°C for the first 2 hrs of drying, then was reduced to 60°C. After drying was complete, at approximately 12 hrs as judged by the appearance, flakes of dried guava puree were collected and stored at room temperature.

Analytical Methods

All analytical measurements were carried out in duplicate.

Total ascorbic acid, moisture content and total titratable acidity were determined according to the methods described by Askar *et al.* (1993). Total ascorbic acid was calculated titrimetrically using the sodium salt of 2,6-dichloro-phenol-indophenol. Moisture content (% moisture w/w) was measured using a vacuum oven (Hythermco, Model 6002, Hydor Therme Corporation, Pennsauken, NJ), which operated at 100°C and 26 inches of Hg pressure. The pH was measured using a Beckman Zeromatic SS-3 (Fullerton, CA) pH meter, along with an Orion glass electrode (Model # 91-03, Boston, MA). Powder samples were evaluated for pH by mixing 10 g powder with 50 g DI water at 18°C. Measurement of total titratable acidity was conducted using a standard 1% phenolphthelein solution, titrated against 0.1 N NaOH to pH 8.1; the result was expressed as grams of anhydrous citric acid per 100 g of sample. Degrees Brix was measured using an RFM 80 digital refractometer (Bellingham Stanley Ltd., England) with automatic

temperature correction. Ten g of powder were mixed with 50 g deionized (DI) water and this solution was filtered, if necessary.

The color of the puree, juice and powder samples was measured using a Minolta colorimeter, Model CR-200 (Ramsey, NJ) and expressed as L*a*b. Pectin was detected according to the qualitative method suggested by Novo Nordisk (1998). Ten ml of acidified ethanol (1 ml of 37% HCl in 100 ml of 96% ethanol) was mixed with 5 ml of filtered puree and after slowly inverting the tube 2 or 3 times, the nature of flocculation was observed after 15 minutes. Percent yield (w/w) was calculated by weighing the supernatant obtained by centrifuging the enzyme treated puree. The presence of starch was tested by the iodine test (Novo Nordisk, 1998), for which an iodine solution was prepared by adding 1 ml iodine and 10 g potassium iodide to 1 liter water. A ten ml sample was heated to above 80°C and cooled to room temperature. One ml of iodine solution was gently poured over the top layer of the sample without mixing and the color change at the interface was observed. Turbidity (clarity) was measured using the percent transmission mode in the Shimadzu UV-VIS scanning spectrophotometer (Model # UV-2101 PC, Kyoto, Japan) (Chan and Chiang 1992). Viscosity was measured with a Brookfield viscometer (Model LVT, Stoughton, MA) using spindles # 2 and # 3 (Askar *et al.* 1992).

Juice and powder samples were analyzed for aerobic plate count (APC) and yeast and mold counts. All microbial tests were conducted by Silliker Laboratories (Modesto, CA). Plate count agar was used for the APC with 10^{-2}-10^{-4}-10^{-6} serial dilutions, and potato dextrose agar along with an antibiotic additive was used for yeast and mold count analysis with 10^{-1}-10^{-2}-10^{-4} dilutions.

Sensory Analysis

The optimum dilution for each juice sample was first determined in informal sensory tests. Preference ranking tests were conducted for both the preliminary and final sensory tests, using a consumer panel. For all the juice samples, the final °Brix was adjusted to 11° using cane sugar. Eight to ten responses were collected for each preliminary sensory test. Fifty ml of juice (5-8°C) was served and five juice concentrations were presented during each serving. Final sensory tests were conducted in

sensory booths with controlled illumination. For these tests, 45 responses were collected, and the serving order was determined using the balanced-block design suggested by Stone and Sidel (1993). In the second half of each test, commercial cloudy pink guava nectar containing 18% juice (Nestle, Glendale, CA) was presented and consumer panelists were asked to compare it with their most preferred sample.

Statistical Analysis

All processing experiments and analysis of the samples were run in duplicate. Analysis of variance was calculated using the standard ANOVA procedure. Sensory ranking data was analyzed using the Basker Table and the Friedman test (Lawless and Heymann 1998). All data were analyzed at a 5% probability level. Significant differences between the means were estimated using Duncan's multiple range tests.

RESULTS AND DISCUSSION

1. Enzyme treatment optimization: Of the five temperatures evaluated, the 50°C incubation temperature yielded the maximum °Brix, ascorbic acid content, % yield and titratable acidity in the enzyme treated puree without resulting in a significant loss in guava flavor. The same temperature and enzyme were used by Hodgson *et al.* (1990) however El-Zoghbi *et al.* (1992)found the highest activity of this enzyme at an incubation temperature of 40°C.

As enzyme concentration and incubation time increased, a gradual increase in °Brix and titratable acidity observed along with a decrease in pH and viscosity (Table 1). Similar results were obtained by Imungi *et al.* (1980), Askar *et al.* (1992) and Brasil *et al.* (1995). The main criteria for optimizing concentration and incubation time were viscosity reduction, percent yield and ascorbic acid retention in the puree. Reduction of viscosity aids in the formation of fine spray during concentration and spray drying. Significantly higher yields of clarified juice were obtained using 700 ppm enzyme for 1.5 hrs (Table 1). When the control sample was centrifuged, it produced a cloudy supernatant while enzyme-treated puree produced a clear juice. Except for samples treated with 500 ppm enzyme at 2.5 hr and 700 ppm at 1.5 and 2 hr, the ascorbic acid content in all samples was less than that in the control. In these samples, ascorbic acid was released from cells due to pectin breakdown, however simultaneous oxidative degradation of ascorbic acid exceeded its rate of release. In the exceptional concentrations stated above, the situation was reversed.All enzyme treatments resulted in a negative starch test, indicating a lower initial starch content in the puree.

An enzyme treatment of 700 ppm concentration for 1.5 hrs was determined to be the most efficient and economical. A cost comparison showed that enzyme treatment at 300 ppm concentration for 1 hr resulted in 78.5% recovery of input cost as compared to an 83.9% recovery from a 700 ppm treatment for 1.5 hr. The latter was sufficient to degrade pectin and starch completely and to obtain very high ascorbic acid retention. Ascorbic acid retention, percent yield and viscosity values from the 700 ppm treatment for 2 hrs were not significantly different ($p<0.05$) from those treated 1.5 hr. Therefore, a

treatment of 700 ppm for 1.5 hr was selected to minimize the cost, processing time and potential flavor losses during incubation.

Hodgson *et al.* (1990) selected an enzyme treatment of 0.2% w/w (2000 ppm) Pectinex Ultra SP-L® for 2 hr. Imungi *et al.* (1980), reported a treatment of 400 ppm of Pectinex® (Ferment Ltd., Switzerland) for 1.5 hr; Brasil *et al.* (1995) selected 600 ppm of Clarex-L superconcentrate® (Miles-Brasil Ltd., Brazil) for 2 hr and Askar *et al.* (1992) used a treatment of 400 ppm Ultrazyme 100® (Ciba Giegy Ltd. Switzerland) for 2 hr. In all cases, either enzyme concentration or incubation period was determined first, with the remaining factor determined experimentally. The current study is the first in which a complete study of incubation time and enzyme concentration was performed.

If higher enzyme concentrations are utilized, the increased enzyme cost and significant losses in ascorbic acid content may not justify the increased yield of guava juice. The optimized enzyme treatment was found to be very economical. In this treatment, $18.55 worth of enzyme applied to 1 ton of guava puree resulted in an increase in juice production worth $132.10.

2. Clear juice and concentrate production: Centrifugation removed most of the insoluble particles from the puree, but there remained some colloidal particles that caused turbidity in the juice. This turbidity was effectively removed by filtration either through the plate and frame filter or ultrafiltration (UF). In plate and frame filtration, °Brix and percent transmission results indicated that a fraction of the soluble solids and a majority of the substances responsible for turbidity in the centrifuged puree lie within the 0.5µ and0.25µ particle size range. Moreover, it was observed that the smallest pore size filter pads (M90, 0.25µ) cdid not completely remove the color of the juice. Chan and Chiang (1992) found optimum clarity (85% transmission at 650 nm) after treating puree with pectinase and holding the 30% puree solution with 2000 ppm bentonite for 10 minutes. The M80 filter pads were sufficient to achieve clarity in the guava juice (83% transmission) similar to what was determined by Chan and Chiang (1992). UF juice was clearer with 90% transmission, as compared to 83% for plate and frame filtered juice.

The plate and frame filtered juice retained more soluble solids and contained 5.8% more ascorbic acid than the UF juice (Table 2). Greater loss in ascorbic acid with UF may have been due to higher

temperature in the feed material and more oxidative losses during the turbulent flow through the system. During UF, concentration polarization on the membrane surface, which led to formation of a fouled layer, was responsible for a gradual decline in the permeate flux with time. Chan and Chiang (1992) and Constenla and Lozano (1997) found similar reductions in permeate flux during UF of centrifuged guava puree and apple juice, respectively. Based on the higher flux rates for plate and frame filtration at all times and sufficient clarity obtained using M80 filter pads, plate and frame was selected for pilot scale processing. However, on an industrial scale, ultrafiltration may be more economical, resulting in a superior clarified juice. Moreover, it can be used to cold-sterilize juice, eliminating the heat treatment step which causes a significant loss in sensitive flavor compounds.

High temperature and incorporation of oxygen in the plate heat exchanger were primarily responsible for the significant loss of ascorbic acid (45%) in pasteurized juice (Table 2). The application of vacuum during heat treatment could improve ascorbic acid retention significantly. Brasil *et al.* (1995) also recorded an increase in the °Brix and color index during pasteurization, along with a 27.4% loss in ascorbic acid . Evaporation of water was responsible for an increase in SS content and a slight darkening of the juice.

After the clarified juice was concentrated, the following increases were found: 4.7 fold in °Brix, 3.9 fold in titratable acidity and 4.2 fold in ascorbic acid content (Table 2). While concentrating their partially clarified guava juice, Hodgson *et al.* (1990) reported the following increases: 3.9 fold in °Brix, 4.03 fold in titratable acidity and 4.18 fold in ascorbic acid content. In concentrating cloudy guava juice to 41°Brix, Sandhu and Bhatia (1985) also reported these increases: 3.7 fold in °Brix, 3.55 fold in titratable acidity and 3.5 fold in ascorbic acid content. Final ascorbic acid contents, as reported by Hodgson *et al.* (1990) and Sandhu and Bhatia (1985), were higher than those obtained in this study, e.g., 867 mg and 849.82 mg per 100 g concentrate, respectively.

Although the juice was at a higher temperature for a longer time in the falling film evaporator as compared to the pasteurization process, less ascorbic acid deterioration was reported, primarily due to the

the use of vacuum and therefore avoidance of oxidative deterioration. Askar *et al.* (1992) reported a 30% loss in ascorbic acid after pasteurizing clear guava juice and a 60% loss after concentrating clear guava juice.

4. Freeze drying: During freeze drying, rupture of cells in the guava puree may have induced the elution of cell contents, which caused an increase in SS content and titratable acidity and a reduction in the pH of the powder (Table 3). Soluble solids After freeze drying clear juice and concentrate, a reduction in the SS content was observed which may be due to a reduction in the amount of acids present in the feed material. A reduction in titratable acidity and an increase in the pH after freeze drying clear guava products indicates that acids were lost during the process. Askar *et al.* (1992) also reported a noticeable loss in total titratable acidity after freeze drying guava puree. The oxidative losses in ascorbic acid following freeze-drying were approximately 12% in powder made from puree, 19% in clear juice powder and 15% in concentrate powder. Askar *et al.* (1992) reported a 15% loss of ascorbic acid when freeze drying pasteurized guava puree.

The increase in L* (brightness), a* (redness) and b* (yellowness) values following production of guava puree powder (Table 3) was most likely a result of non-enzymatic browning during freeze drying, which produced a darker product. Askar *et al.* (1992) also obtained a darker freeze-dried pasteurized guava puree. Both powders produced from clear juice and concentrate were higher in L* value with lower a* and b* values, indicating a less intense color as compared to the original. The clear juice and concentrate were high in sugar and low in particulates, allowing forsatisfactory puffing which was responsible for the lighter color and shiny nature of the powders. These powders were very hygroscopic in nature and powder removed from the trays was difficult to grind; whereas the puree powder was easy to grind and the least hygroscopic. To reduce the hygroscopicity of these powders, 0.5% sodium aluminosilicate can be added (Askar *et al.* 1992). All three powders were very porous in nature and could be reconstituted instantly with room temperature water. The reconstituted liquid prepared from clear juice powder was quite turbid (71% transmission), whereas that made from concentrate powder was clearer

(82% transmission). Soluble pectins in the clear juice may have aggregated during freeze drying and may be responsible for a slight turbidity in the reconstituted clear juice powder.

5. Spray Drying: During initial trials of spray drying clear juice, no powder was collected due to the low solids content of the feed. Therefore, the higher solids guava puree and guava juice concentrate were selected for spray drying. Spray drying was difficult due to high sucrose content and burn-on the equipment resulting from the high temperatures used. When Maltodextrin was added to the concentrate, it formed a film around the solids in the feed that facilitated production of a non-hygroscopic, free flowing, flour-like powder. All the powders produced by spray drying were bright white in appearance irrespective of the color of the feed material.

There was no significant difference ($p<0.05$) between the L*a*b* values for powders prepared using different maltodextrin products. Muralikrishna *et al.* (1969) reported production of a grayish white powder after spray drying guava puree without an additive. The spray-dried powders produced in this study were extremely stable at room temperature and could be reconstituted after blending with room temperature water. However, the reconstituted drinks made from concentrates were not clear, because the maltodextrin concentration exceeded the 30% solids limit suggested for making a clear solution (Grain Processing Corporation, 1998).

The moisture content of all the spray-dried powders was lower than that of the freeze-dried powders (Table 4). Similar results were obtained by Muralikrishna *et al.* (1969) who had a final moisture content of 2.24% in the spray-dried powder. There was an increase in °Brix and total titratable acidity and a decrease in pH following drying, which may be the result of concentration accompanied by release of sugars and acids from maltodextrin during drying. Ascorbic acid was lost during drying as a result of the high temperatures and oxidation. The average loss of ascorbic acid was around 21%. Muralikrishna *et al.* (1968) found a similar loss of 19.1% ascorbic acid content in spray dried guava puree. Although M-100 and M-500 maltodextrin products are chemically the same, a better retention of ascorbic acid and soluble solids was observed with M-100. The finer structure of M-100 particles provided a more uniform coating

of the feed solids during spray drying, giving better protection from thermal and oxidative losses than M-500.

6. Tunnel drying: Tunnel drying is one of the least expensive methods of drying food materials. However, no literature is available on tunnel drying guava puree using any modified food starch or maltodextrin products. This drying method was very slow, requiring approximately 12 hrs to completely dry the product. During tunnel drying, a significant increase ($p<0.05$) in titratable acidity and decrease in pH was noticed in all the powders (data not shown). There were no significant differences in °Brix or titratable acidity of the powders that could be related to particular characteristics of the additives. After tunnel drying, the average loss of ascorbic acid was approximately 30%, which was higher than freeze drying (15%) or spray drying (21%). Tunnel dried powder containing Maltrin 580® maltodextrin was darker in appearance as compared to powders prepared using Pure-cote B760® and Pure-cote B790®, which may be attributed to better coating provided by the maltodextrin product. All the powders were golden yellow in color, but were difficult to remove from the cheesecloth covering the drying trays and difficult to grind. Approximately 5 minutes were required to completely reconstitute with room temperature water.

7. Microbiological tests: Freeze-dried concentrate powder had an Aerobic plate count (APC) of 5.3×10^5 APC/g as compared to the spray-dried concentrate powder with 9.7×10^4 APC/g, which could be attributed to the high temperatures achieved during spray drying. Spray-dried puree powder had relatively higher APC and yeast and mold counts as compared to the aseptic puree (e.g., 1.5×10^4 vs. 1.5×10^2 APC/g). This may be due to the use of the M580 additive, which is reported to have a maximum standard plate count (SPC) of 100/g and a yeast and mold count of 50/g. Yeast and mold counts were relatively low in all samples and did not pose any threat to the safety of the drinks.

8. Sensory Tests: During the preliminary sensory tests for aseptic puree and pasteurized clear juice, concentrations of 35% and 55% (w/w) powder, respectively, were found to be optimum. This difference in concentration indicates the significant loss of flavor due to clarification. Spray-dried powder from

puree was rejected because of a medicine-like off-flavor. This may be due to the addition of maltodextrin products at a higher concentration than desirable from a sensory standpoint.

Nectars were prepared by adding water and sugar to adjust to a final 11 °Brix product. Commercial guava nectar containing 18% juice was an exception; its final °Brix was 14.4°. Nectar made from freeze-dried clear juice contained the most ascorbic acid (50mg/100g), primarily due to the higher percentage of juice used in the final drink; whereas, the commercial nectar contained the least ascorbic acid (10mg/100g).

The majority of the sensory panelists (84%) had tasted guava fruit or drink before, and 78% liked its taste. Most panelists preferred cloudy guava nectar, because they perceived it as a more natural product. Ranks assigned by each panelist were totaled for every sample and termed rank total (Table 5). Reference to the Basker table and the Friedman test (Lawless *et al.* 1998) showed no statistically significant difference ($p<0.05$) between the rank totals of clear pasteurized nectar, nectar prepared from freeze-dried clear juice powder and puree powder. This indicated minimal flavor loss during freeze drying. Most panelists thought that the sweetness and flavor of their preferred samples was just right. Panelists considered the flavor of nectar made from freeze-dried puree to be weak. Sixty-six percent of the population preferred their favored sample rather than the commercial nectar, primarily due to flavor and sweetness differences. Overall, except for the commercial nectar, 71% of the panelists were either very satisfied or satisfied with the guava products and only 5% disliked them. The remainder of the panelists expressed a neutral opinion. These results for clear juice products, however, are in contrast to the findings of Askar *et al.* (1992). They reported a significant loss of quality in clear guava juice and found it unacceptable to consumers. This may be due to a difference in the sensory method used by Askar *et al.* (1992) or to the more diverse ethnicity of consumers participating in this study.

CONCLUSIONS

The commercial enzyme Pectinex Ultra SP-L® was successfully applied to guava puree. Enzyme concentration, incubation time and temperature were optimized at 700 ppm, 1.5 hr and 50°C, respectively,

resulting in a 51% reduction in viscosity, 13% increase in ascorbic acid content and 18% increase in yield of a clearer juice. The enzyme application also helped to clarify the juice.

In terms of clarity, guava juice prepared using UF was clearer with 89.6% transmission, as compared to 82.8% for plate and frame filtered juice. However, plate and frame filtered juice retained more soluble solids, contained 5.8% more ascorbic acid than the UF juice and had higher flux rates at all times.

This was the first reported attempt to produce clarified guava juice powder. Freeze drying produced the best quality guava powder in terms of ascorbic acid and flavor retention, though it was quite hygroscopic in nature. Spray drying produced an extremely stable powder at room temperature with a minimum moisture content of 3%. Tunnel drying produced dried flakes that were extremely difficult to remove from trays and difficult to grind. Although the quality of tunnel dried powder was inferior, the addition of maltodextrin resulted in better color retention in the final powder. Because freeze drying is an expensive method to apply commercially, spray drying may be the best alternative for producing guava powder.

Seventy-one percent of consumer sensory panelists most preferred the cloudy juice prepared from aseptic guava puree. However, there was no significant difference among responses for juices prepared from pasteurized, clear nectar; freeze-dried puree powder and freeze-dried, clear juice powder.

ACKNOWLEDGEMENTS

We would like to thank Drs. R. Paul Singh and Thomas Rumsey of the Dept. of Agricultural and Biological Engineering, UC Davis, for technical assistance with this project.

REFERENCES

ASKAR, A., EL-SAMAHY, S.K. and ABD EL-SALEM, N.A. 1992. Production of Instant Guava Drink Powder. Confructa-Studien *36* (5-6), 154-161.

BRASIL,I.M., Geraldo A.M., RAIMUNDO, W.F. (1995) Physical-chemical changes during extraction and clarification of guava juice. Food Chemistry *54(4)*, 383-386.

CHAN, W.Y. and CHIANG, B.H. 1992. Production of Clear Guava Nectar. Int J Food Sci & Technol *27*:435-441.

CONSTENLA, D.T. and LOZANO, J.E. 1997. Hollow Fibre Ultrafiltration of Apple Juice: Macroscopic Approach. J Food Sci & Technol *30*(4):373-378.

EL-ZOGHBI, M., EL-SHAMEI, Z. and HABIBA, R. 1992. Effect of Enzyme Application on Some Properties of Guava Puree. Fruit Processing *2*(7):106-108.

GRAIN PROCESSING CORPORATION. 1998. Technical Bulletin: Pure Cote® Corn Starches in Aqueous Film Coating.

HODGSON, A.S., CHAN, H.T., CAVALETTO, C.G. and PARERA, C.O. 1990. Physical-Chemical Characteristics of Partially Clarified Guava Juice and Concentrate. J Food Sci *55*(6):1757-1761.

IMUNGI, J.K., SCHEFFELDT, P. and SAINT-HILAIRE, P. 1980. Physico-Chemical Changes During Extraction of Clear Guava Juice. Lebensm Wiss. +. Technol *13*:248-251.

JAGTIANI, J., CHAN, H.T. and SAKAI, W.S. 1988. *Tropical Fruit Processing*, Academic Press, San Diego.

KRAMER, M.E. 1998. Application Scientist, Grain Processing Corporation, personal communication.

LAWLESS, H.T. and HEYMANN, H. 1998. Sensory Evaluation of Food: Principles and Practices, Chapman & Hall and International Thompson Publishing, New York.

MURALIKRISHNA, M., NANJUNDASWAMY, A.M., and SIDDAPPA, G.S. 1969. Guava Powder Preparation, Packaging, and Storage Studies. J Food Sci & Technol *6*:93-98.

NOVO NORDISK. 1998. The Production of Clear, Stable Juices and Concentrates: Guidelines for Processing and Quality Control.

SANDHU, K.S. and BHATIA, B.S. 1985. Physico-Chemical Changes During Preparation of Fruit Juice Concentrate. J Food Sci & Technol *22*:202-206.

STONE, H. and SIDEL, J.L. 1993. *Sensory Evaluation Practices*, Academic Press, San Diego.

WENKAM, N.S. AND MILLER, C.D. 1965. Hawaii Agricultural Research Station, Bulletin 135.

FIGURE LEGENDS

Figure 1. Flow diagram of guava puree processing.

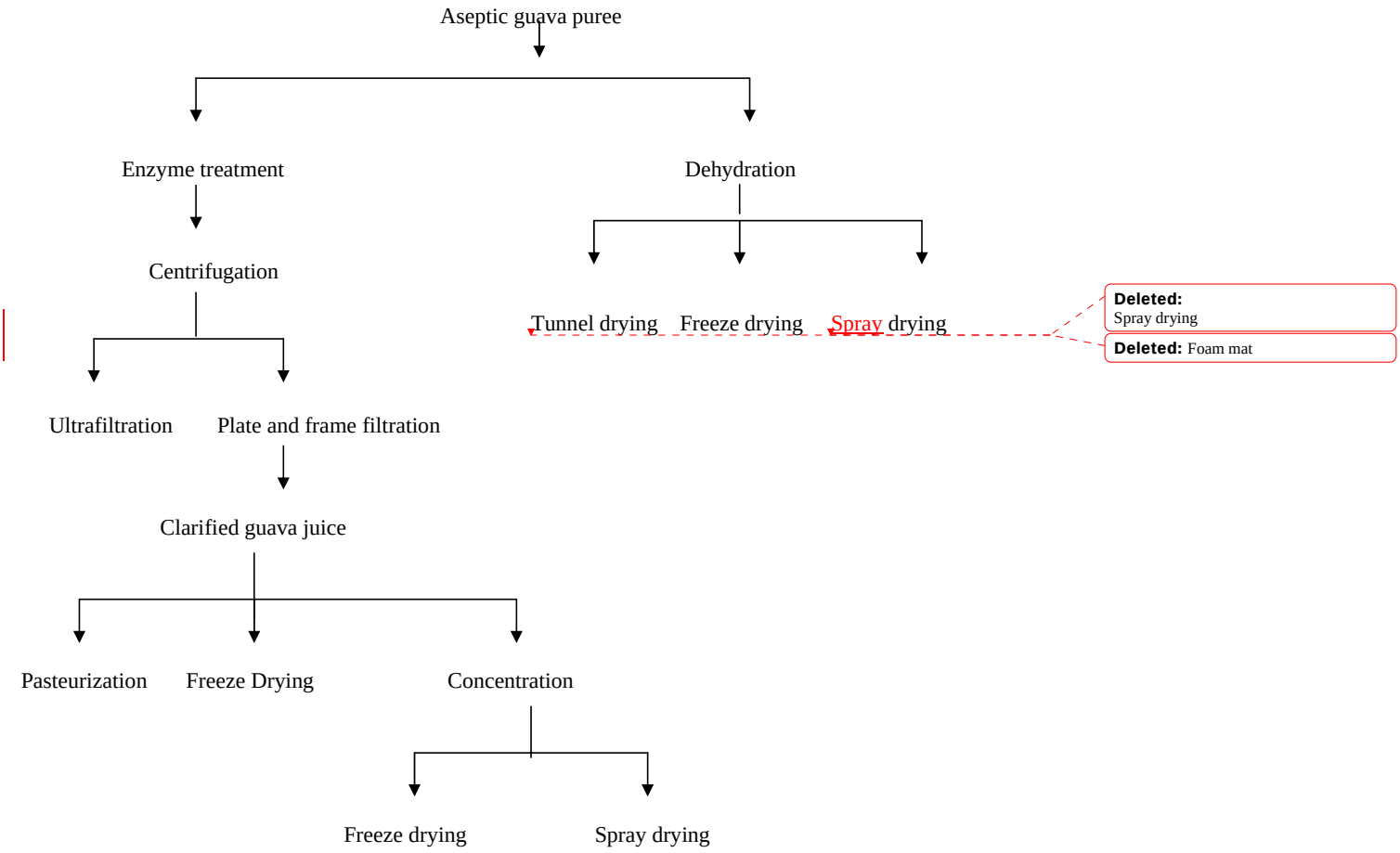
Aseptic guava puree
Enzyme treatment
Dehydration
Centrifugation
Tunnel drying
Freeze drying
Spray drying
Deleted: Spray drying
Deleted: Foam mat
Ultrafiltration
Plate and frame filtration
Clarified guava juice
Pasteurization
Freeze Drying
Concentration
Freeze drying
Spray drying

Table 1.
Effect of enzyme concentration and incubation time on guava puree[1].

Enzyme Concentration (ppm)	Incubation time (hr)	°Brix	pH	T.A. (g citric acid / 100 g)	Viscosity[2] (cps)	% yield[2]	AA[2] (mg ascorbic acid / 100 g)	Pectin (+/-)	Starch (+/-)
Control	0	8.8	3.91	0.52 ±0.03	1582.7^{h} (±25.03)	72.38^{a} (±0.72)	120.00^{def} (±4.55)	+	+
300	1.0	9.1	3.87	0.54 ±0.01	1362.7^{g} (±24.47)	79.16^{b} (±0.57)	109.13^{bc} (±4.32)	+	-
	1.5	9.1	3.83	0.55 ±0.04	1260.7^{fg} (±21.84)	80.07^{bc} (±0.21)	105.58^{ab} (±5.15)	+	-
	2.0	9.2	3.80	0.57 ±0.03	1109.3^{ef} (±24.18)	80.74^{bcd} (±0.26)	102.02^{a} (±3.21)	+	-
	2.5	9.2	3.77	0.58 ±0.02	982.7^{de} (±13.86)	81.17^{bcde} (±0.23)	115.19^{cd} (±4.18)	-	-
500	1.0	9.1	3.84	0.56 ±0.01	1146.0^{ef} (±19.80)	81.73^{cdef} (±0.44)	110.17^{bc} (±5.05)	+	-
	1.5	9.2	3.78	0.58 ±0.01	1007.7^{de} (±12.87)	82.54^{defg} (±0.05)	115.08^{cd} (±3.15)	+	-
	2.0	9.2	3.74	0.60 ±0.05	927.7^{cd} (±13.25)	83.35^{efgh} (±0.11)	119.35^{def} (±2.27)	-	-
	2.5	9.3	3.71	0.63 ±0.03	791.0^{bc} (±12.73)	83.82^{fghi} (±0.12)	123.61^{ef} (±4.13)	-	-
700	1.0	9.1	3.78	0.58 ±0.03	889.3^{cd} (±5.16)	84.19^{ghij} (±0.20)	117.22^{de} (±3.51)	+	-
	1.5	9.2	3.74	0.60 ±0.01	774.3^{bc} (±6.08)	85.43^{hij} (±0.10)	135.56^{g} (±5.26)	-	-
	2.0	9.3	3.70	0.63 ±0.02	642.7^{ab} (±5.80)	85.76^{ij} (±0.11)	138.42^{g} (±3.25)	-	-
	2.5	9.3	3.68	0.65 ±0.01	526.0^{a} (±10.47)	86.11^{j} (±0.08)	125.56^{f} (±4.20)	-	-

[2] Values represent the average of duplicate analytical measurements.
[2] Means with the same letter are not significantly different ($p<0.05$)

Table 2.
Physico-chemical changes during production of clear juice and concentrate[1].

Sample Name	°Brix	pH	T.A. (g citric acid/100 g)	AA content (mg ascorbic acid / 100 g)	% transmission (650 nm)
Raw Puree	9.2	3.85	0.51 (±0.01)	138.7 (±4.61)	turbid
Enzyme treated puree	9.6	3.67	0.59 (±0.01)	158.4 (±6.87)	turbid
Centrifuged puree	9.4	3.75	0.55 (±0.00)	149.4 (±5.55)	67.9 (±0.14)
Plate and frame filtered juice	8.9	3.80	0.52 (±0.00)	138.6 (±4.53)	82.8 (±0.05)
UF juice	8.7	3.80	0.52 (±0.00)	131.0 (±4.69)	89.6 (±0.01)
Clear juice (pasteurized)	9.0	3.75	0.53 (±0.01)	76.2 (±5.46)	78.3 (±0.03)
Concentrate	42	3.50	2.05 (±0.01)	552.4 (±6.91)	56.6 (±0.12)

[1] Values represent the average of duplicate analytical measurements.

Table 3.
Changes in guava puree, clear juice and concentrate during freeze drying[1].

Sample	pH	°Brix[2]	T.A.[2] (g citric acid/ 100g)	AA[2] (mg ascorbic acid / 100g)	% moisture	% transmission (650 nm)	L*	a*	b*
Raw puree	3.85	50.6	2.84 (±0.08)	770.56 (±7.81)	82.0 (±1.02)	turbid	70.78 (±2.13)	-2.55 (±0.15)	18.30 (±1.02)
Raw puree powder	3.80	55.6	3.26 (±0.00)	679.42 (±19.25)	4.5 (±0.05)	turbid	76.81 (±3.00)	5.51 (±0.17)	30.36 (±0.81)
Clear juice	3.60	89.0	5.20 (±0.09)	1386.00 (±27.12)	90.0 (±0.87)	82.8 (±0.01)	26.72 (±1.91)	4.58 (±0.08)	36.66 (±0.75)
Clear juice powder	3.75	87.6	4.81 (±0.03)	1117.54 (±41.70)	5.0 (±0.04)	70.7 (±0.03)	84.90 (±2.85)	2.15 (±0.11)	24.77 (±0.99)
Concentrate	3.50	89.4	4.36 (±0.10)	1175.32 (±25.39)	53.0 (±0.91)	56.6 (±0.03)	38.75 (±1.54)	4.58 (±0.09)	36.55 (±0.70)
Concentrate powder	3.55	88.8	4.04 (±0.02)	996.67 (±45.92)	4.0 (±0.02)	82.0 (±0.01)	85.80 (±2.15)	1.77 (±0.18)	25.95 (±0.57)

[1] Values represent the average of duplicate analytical measurements.
[2] Expressed on a dry weight basis.

Table 4.
Changes in guava puree and concentrate due to spray drying.[1]

Sample	°Brix[2]	pH	T.A.[2] (g citric acid /100 g)	AA [2] (mg ascorbic acid/100 g)	% moisture	L*	a*	b*
M-100 concentrate	59.9	3.70	0.97 (±0.01)	403.98 (±4.28)	30.5 (±0.01)			
M-100 powder	104.1	3.50	1.62 (±0.02)	321.17 (±3.98)	3.0 (±0.00)	96.91 (±0.09)	-1.34 (±0.11)	8.06 (±0.17)
M-500 concentrate	59.4	3.70	0.95 (±0.02)	398.45 (±3.80)	30.5 (±0.00)			
M-500 powder	103.1	3.50	1.64 (±0.00)	309.45 (±2.25)	3.0 (±0.00)	96.23 (±0.12)	-1.28 (±0.08)	9.70 (±0.21)
M-580 diluted puree	14.4	3.70	0.58 (±0.01)	145.30 (±1.17)	55.0 (±0.01)			
M-580 powder	99.0	3.50	1.76 (±0.01)	114.79 (±2.19)	3.0 (±0.00)	95.39 (±0.10)	-1.00 (±0.08)	8.95 (±0.11)

[1] Values represent the average of duplicate analytical measurements.
[2] Expressed on a dry weight basis.

Table 5.
Sensory comparison of guava juices prepared by different methods.

Juice type	Number of panelists ranking as most preferred	Rank Total[1]
Aseptic guava puree	32	68[a]
Pasteurized guava juice	5	121[b]
Freeze-dried clear juice powder	5	130[b]
Freeze-dried guava puree powder	3	131[b]

[1]Means with the same letter are not significantly different at $p<0.05$ using the Basker table and the Friedman test.