PN-ABL-768 C5-208
78308

FINAL REPORT 1988-1991 JUNE 1992

SUBMITTED TO: U.S.-ISRAEL CDR-AID

TITLE: SUBTROPICAL AND TROPICAL FRUIT JUICES - ADVANCED TECHNOLOGY APPROACH FOR THEIR PRODUCTION THROUGH UTILIZATION OF MACERATING ENZYMES - IN DEVELOPING COUNTRIES.

PRINCIPLE INVESTIGATORS: N. Ben-Shalom, A. Levi, Rivka Pinto and Polet Shalom.
Department of Food Science A.R.O. Volcani Center, Israel

COLLABORATOR: Sandra Calderon and Sheron Thomas.
CITA, University of Costa-Rica, Costa-Rica

PROJECT NUMBER : 416-0239

GRANT NUMBER : C5-208

PROJECT DURATION : 1988-1991

REC'D IN R&D/R
AUG 4 1992

CC: CDIE+BOSTID

Table of Contents

1.	Executive Summary	2
2.	Research Objectives	3
3.	Methods and Results	4
3A.	Background	4
3A.I	Mango	4
3A.II	Papaya	8
3A.III	Guava	11
3B.	Experimental	15
3C.	Results and Discussion	20
3C.I	Israel	20
3C.I.1	Mango	20
3C.I.2	Papaya	27
3C.I.3	Guava	34
3C.II	Costa Rica	40
3C.II.1	Papaya	40
3C.II.2	Mango	50
3C.II.3	Guava	59
3C.III	Concentration of tropical fruits juices	62
4.	Changes in the pectin and the neutral sugars during fruit processing	65
5.	Some economical aspects of the tropical fruit juices marketing from developing to development countries	78
6.	References	80

1. EXECUTIVE SUMMARY

Taking in consideration the huge existing surplusses of tropical and subtropical fruits in the developing countries (DC) and in the least-developed onse (LDC), we studied the development of products and production methods of enzymatic maceration of Mango, Papaya and Guava, by commercial enzymes. Important quality characteristics (Q.C) of the fruits and the influence of the preparation and enzymatic maceration conditions, were assessed considering practical "Industrialization-Commercialization" of the developed processes. There is no doubt, that the fresh fruits (FF), characteristics, influence both the necessary pretreatments and enzymatic treatments needed for optimum yields and Q.C. of the final liquiform products - juices and concentrates.

Heat pretreatments (blanching, pasterization), were necessary, to prevent development of bitter taste in Papaya canned juice in Israel - on storage, while no bitterness was observed in the same juice, extracted from Costa Rica (C.R) varieties. Higher yields reaching more than 80% (on pulp basis), were obtained by maceration of non heat-pretreated, papaya in both countries. The non heat pretreated pasteurized papaya juice, was found significantly better in flavor, by a test panel in C.R. The best enzymatic treatment found was with Pectinex SP (or Pectinex 3xL), 150 ppm at 40°C-45° for 30-45 min, for Papaya acidified to pH 4.5, before maceration, Unacceptable astringency (which could not be prevented or removed), was observed in the enzymatically extracted Guava juices in C.R, while astringency problem was not observed in Israel. The maceration yield of Guava in Israel, was more than 80%, using 100 ppm Pectinex 3xL + 750 ppm Celluclast at 45°C for 120 min (on fruit basis).

Mango pulp had to be acidified in C.R. to pH 4.5, or lower, but in Israel the Mango was of pH lower than 4.5. Similar yields of about 60% juice (on a pulp basis), were observed in Israel - macerating with 150 ppm Ultrazyme only - for 60 min at 45°C, or a combination of Pectinex

3xL (150 ppm) with Celluclast (1000 ppm), at the same "time-temperature" conditions. Higher yields and better flavor, were observed macerating enzymatically, with 150 ppm Pectinex SP for 60 min at 45°C "non-heat pretreated", than "heat-pretreated" Mango in CR.
The above prepared fruit juices, could be concentrated to more than 65°Bx by vacuum evaporation, while concentration was studied also for enzymatically macerated Guanabana and Banana juices.

The above results are a considerable indication of the enzyme concentrations and conditions, needed for enzymatic maceration of tropical fruits, in general and the 3 fruits studied, in particular. More information is needed in order to pinpoint the best varieties (etc) and macerating conditions in each DC, leading to industrial application and feasibility assessment in different countries. More details are given in the full report, presented here.

Pulp preparation from the fruits followed by enzymatic maceration decreased the alcohol insoluble solids content. Both galacturonic acid and neutral sugars decreased but the main changes were in the pectic substances. The pectolytic enzymes that we used during processing mainly hydrolyzed the pectin and much less the neutral sugars.
Using the enzymatic treatment we found degradation of the pectin all over the cell wall, a phenomena which was not observed before the treatment. This may be the main reason for improving juice extraction by this treatment.

2. RESEARCH OBJECTIVES

The main objective of this study was to develop enzymatic maceration methods, to be applied on "Industiral-Commercial" scale in developing countries, for production of tropical fruits liquiform products - juice and concentrate. We were (and are) aware of the importance of the different fruits' varieties, affecting the yields

and the quality characteristics of the final products. As the budget was limitted and different cultivation conditions - even in the same climatic region - may influence the fruits characteristics very significantly, detalled studies of the influence of varieties, have to be further studied in each developing country. Therefore, the main effort was was to find the optimum conditions and methods for development of tropical-fruits liquiform products at least, as a well justified indication for agroindustrial aplication of the results, after techno-economical feasibility assessement in each developing country. All that for practically "non-existant" products (juices, concentrates) on international and even national markets. Our opinion is that introducing the results to the developing countries (as we started in Costa-Rica - see appendix), will lead to the agro-industrial utilization of the results of our reaserch for the benefit of the respective agro-industries and the agriculture in countries of undernourished, underemployed vast papulation. This project was supported also by the research institutions of both Costa-Rica and Israel, mainly - the non-covered by CDR-salaries of the principal investigators and other supporting staff, the general services and non-supported infrastructure and maintenance, connected with the project.

3. METHODS AND RESULTS

3A. BACKGROUND

3A.I. Mango

The world estimated annual production of mango (*Mangifera indica* L.) fruit was already about 9,000,000 metric tons in the early 1970s (Bhatnagar and Subramanyam, 1973). According to Kay (1966), the real economic importance of the crop is in its local consumption, while the mango fruit ranks still rellatively low as an export crop. Acording to

Brekke et al., (1975), attempts at commercial processing of mango in Hawaii have been unsuccessful for a number of reasons, both technical and economical.

There are many mango varieties in the different growing regions - Africa, Asia South America etc. and the fruits are of various sizes, forms, color of peel and pulp, size of seeds, fibrousness, astringency, etc., but all have a typical (even if of different intensity) mango flavor. The seed weight is between 9 and 27% of the whole fruit in Hawaii (Orr and Miller, 1955), while in other countries the variability is even greater. A great part of the pulp remains attached to (and hard to remove from) the seeds, after manual - (using a knife), or mechanical - separation.

The skin color of mango is attributed mainly to anthocyanins, and the flesh color to carotenoids (Proctor and Greasy, 1969). The ascorbic acid (AA) content may vary between ca. 10 and 120 mg/ 100 g within different varieties (Brekke et al., 1975; Thomas, 1975). Similar wide variability was observed in total soluble solids (TSS) - 14.2 to 22.6^{o} Bx; pH - 3.7 to 4.2; acidity (mainly citric acid) - 0.21 to 0.47, etc. (Brekke et al., 1975). A pH of over 4.5 was observed in some mango varieties, (including these on Costa Rica - see further), therefore acidification of the mango pulp is sometimes needed, in order to be able to pasteurize the pulp (instead of sterilization) (Luh, 1980).

Pectic substances constitute a major component, contributing to the texture (fruit) and consistency (liquiform products) of mango. Protopectin decreases and soluble pectin increases, both significantly with the advance of the season. A significant relationship was found between the harvest date and the total pectin, its molecular weight and the viscosity of mango nectars prepared from those fruits (Saed et al., 1975a,b).

The major biochemical change in polysaccharide components during mango fruit maturation is the development of starch. An increase in

strach content from 1% to 12% was observed from fruit set to 16 weeks later (Luh, 1980). High polyphenols content of the fruit, associated with astringency, is also noted in mango fruits, but usually it decreases and astringency disappears during maturation and ripening (Luh, 1980).

Although starch and phenols decrease significantly during ripening (Fuchs et al., 1980), we assume that suitable analytical evaluation of these components, as well as of the pectic components, must be made, in order to assist in the specific selection of the available commercial enzymes (pectolytic, amyloytic) for mango maceration. Natural amylolytic enzymes are probably responsible for starch degradation upon ripening of mango (Fuchs et al., 1980; Tandon and Karla, 1968).

Mango fruits are harvested at optimum maturity, but are usually subjected to artificial ripening in order to assure the optimum and relatively uniform eating ripeness, needed for the production of mango products (Luh, 1980).

Polyphenolase (PPO), peroxidase and other naturally occurring enzymes, which can cause off-flavors development and color deterioration, are present in the edible portion of the mango. Peroxidase activity is present at all stages of maturity and the enzyme is apparently bound to the insoluble particiles of the fruit tissue, while PPO is found particularly in the exocarp (Brekke et al., 1975; Luh, 1980). Naturally occurring pectolytic enzymes activity (PE, PG), which could to a certain extent contribute to the maceration, is probably parallel to undesirable enzymatic activity (of the above enzymes). Therefore, peel removal and heat inactivation were applied during the prepartion of mango pulp for enzymatic maceration (Brekke et al., 1975).

Lye and steam peeling were studied (Brekke et al., 1975) for the preparation of various liquiform products of different mango varieties. Optimum lye peeling of var. 'Haden' in Israel was achieved

by dipping the fruits for 5-6 min in 20% boiling NaOH solution, followed by washing under tap water sprays (A. Levi, 1982 - unpublished data). On the other hand, Brekke et al., (1975) concluded that removal of the peel before pulping is not necessary for the production of high-quality mango puree. In some plants for preparation of mango-based baby food, special machinery is used to remove the seeds and peel, after steaming of the mango, but sometimes very low yields are observed with fibrous varieties, because of unsufficient removal of the pulp attached to the seeds (A. Levi, 1975 - unpublished data). The process for preparation of canned or frozen puree and nectar includes the following basic preparatory steps: washing, sorting, blanching (or not), disintegration and removal of seeds, pulping, finishing, de-aeration (Siddapa and Bhatia, 1955; Sanches-Nieva et al., 1959; de Leon and de Lima, 1966; Brekke et al., 1975). The pulpy products are usually pasteurized directly or after acidification (if the pH is relatively high) and then hot filled in cans, or frozen. According to Brekke et al., (1975), either enamel or plain tin lining is satisfactory for color stability of canned mango nectars. Mahadevia et al., (1974) reported that ascorbic acid and its degradation product, furfural, act as accelerators of can corrosion, when added to mango nectar. Due to the above, suitable enameled cans were used for the clarified juices and concentrates.

Several publications on the preparation of the so-called mango "juice" exist, but these "Juices" are based on pulp dilution with water, sugar syrup, etc. therefore they are nectars. Ascar et al., (1981) described the concentration of mango "juice" by several methods. In order to obtain good quality mango juice they recommended freeze concentration (too expensive?), or separation of pulp from serum by centrifuge, vacuum concentration of the serum, and then combination of the pulp with the concentrated serum, in order to obtain mango flavor (complicated and expensive). Aroma deterioration is observed during vacuum concentration of whole mango "juice". Most

of the mango aroma compounds are usually attached to the insoluble particles of the pulp. Vacuum treatment of mango puree resulted in a "flat" taste, according to Huntor et al. (1974).

Adding selected pectolytic enzymes - for mango maceration - to a "cloudy" free flowing juice, resulted in a typical mango-flavored product in our case. This relatively low viscosity juice was also concentrated by conventional vacuum evaporator to a high degree of concentration (above 65°BX). The lack of typical flavor can be overcome by "cut-back" addition of non-concentrated fully flavored juice, before the hot filling, being the "cut-back" a standard method in the citrus juices industry, for natural flavoring of high quality citurs concentrates.

3A.II. Papaya

Papaya (Carica papaya) is a tropical fruit with a definite development potential (Luh et al., 1980). Many varietites of papaya different in size, shape, color, etc., are grown mainly in tropical, developing countries. In Australia papaya is one of the major components in canned tropical fruit salads for export, but only small quantities are used in making mixed fruit drinks (Luh et al., 1980). In other words, even if there is a large production of papaya, only very few products, and in limited quantity, are marketed locally or exported.

Except when harvested for the extraction of papain, papaya fruits are havested mature but not ripe. Several methods for artificial ripening are mentioned in the literature, but in most developing countries the fruits are left to ripen under ambient humidity and temperature conditions. Peleg and Gomez-Brito (1974) used external color as a maturity index. The peel color of unripe mature papaya is green and changes gradually during ripening to yellowish-orange, depending on variety, etc. (Levi, A. et al., 1985). The flesh (pulp)

color of the unripe papaya is yellowish-green and turns to yellowish-orange or deep orange during the ripening period (Rodrigues and de George, 1972). This coloration of the pulp is caused by various carotenoids, beta-carotene (provitamin A) being one of the main ones (Chan et al., 1975). Wide variability of carotenoids content - as beta-carotene - was found within the same variety as well as between different varieties. The total carotenoids content in some Israeli papaya varieties was between 1800 and 2200 µg/100 g edible portion on a dry matter basis (Levi et al., 1985).

The edible portion of the ripe papaya constitutes 60-80% of the fruit (Khedkar et al., 1980; Levi et al., 1985). The rest of the fruit - peel, seeds, central cavity liquid - must be removed before using the papaya for fresh consumption or for food production purposes, because of its strong "off-flavors", including the very bitter taste of the seeds (Khedkar et al., 1980). The dry matter of the papaya flesh varies between 10 and 15%. Wide variability was also observed in the content of TSS, acidity, pH, sugars, etc. The pH of the papaya flesh varies between 4.5 and 5.65 (Nath and Ranganna, 1981); therefore, acidification of its pulp is needed for pasteurization (instead of sterilization) purposes. Acidification and heat treatments are recommended also for prevention of gellification and development of unpleasant off-flavors and odors due to enzymatic or microbial acitivty (Chan et al., 1973). Chan et al., (1973) found butyric, hexanoic and octanoic acids and their methyl esters in purees in which natural enzymes present were not inactivated by acidification and heat. A pungent sulfur-like odor also evolves, especially if the puree is prepared from green papaya (Luh, 1980).

Pal et al., (1980) found that the ascorbic acid (AA) content of fresh papaya pulp varies between ca. 46 and 126 mg/100 g. Levi et al. (1985) found 70 to 113 mg/100 g AA in Israeli papaya varieties, while Baqar (1980) reported AA contents between 18 and 180 mg/100 g in 12 commercial varieties. Naturally occurring pecotlytic enzymes, such as

pectineserase (PE) and polygalacturonase (PG) (Chan et al 1975B), affect the textural-structural properties of the papaya and its products. Gellation of papaya puree due to PE activity is an important problem facing a processor. The formation of gels may be prevented by application of heat and acidification (Brekke et al., 1973, 1976). Natural invertase, which hydrolyses the non-reducing sugars to glucose and fructose (50% - within 2-3 min), after the tissue is pulped, increased the probability of non-enzymatic browning of processed papaya products during high-temperature treatments or prolonged storage (Chan and Kwok, 1975). Therefore, also the invertase must be inactivated very rapidly.

Based on the above, we assumed that undesirable enzymatic inactivation (steaming of whole fruit, or immediate heat-treatment after papaya disintegration) must be considered prior to enzymatic maceration. Pulp acidification (before or after heat-inactivation) was also needed - for prevention of undesirable off-flavors' formation and of gellification, and pH regulation for the optimum maceration by commercial enzymes.

Brekke et al. (1977) published an operating manual for processing of frozen papaya puree. The most important unit operations recommended are: ripening (natural); steaming (whole fruit); slicing and crushing, pulping; fast acidification (to pH 3.4-3.6); heat-treatment (for enzymic inactivation) - followed by immediate cooling and freezing in polyethylene bags. The puree may be used for preparation of nectars. Neither plain tin nor enamel-lined cans affected canned papaya nectar quality during up to one year of storage at 12.8°C (Brekke et al., 1976).

Chan et al (1975) studied quality characteristics of papaya puree (11.5-13.5° Brix) and concentrates (2.4- to 3.0-fold). The puree was treated with 0.05 to 0.2% pectic enzyme (Pectinol 10 M, Rohm and Hass), at 50-56°C, for 1.2 to 2.0 hours, in order to reduce its consistency - before vacuum concentration in a Centritherm evaporator.

Even with this treatment, the consistency of the resulting concentrated puree may have been too high for further concentration, (which we indeed achived - after the maceration and centrifugal separation).

Our objective was to apply "new", (recently available), commercial enzymes, which would macerate the papaya pulp to a much greater extent, reducing in parallel its viscosity, to result in a free-flowing pulp. This pulp, after removal of fibrous particles (by finishers, etc.), was further separated to fine-pulp and cloudy papaya juice, by centrifugal separators - which exist in most industrial fruit juice plants. The same enzymatic treatment and method of concentration - as mentioned above for mango - was applied, in order to obtain partially clarified (cloudy) papaya liquiform free-flowing products with a typical papaya flavor.

3A.III. Guava

Guava is one of the most important pomiferous fruits of the Myrtle family. The species, *Psidium guajava* ., is grown comercially in subtropical and tropical countries in Africa, Asia and America. The ripe fruit can be eaten fresh and has been popular for making nectars, jams, etc., but is still underutilized to a great extent, because most of the above products are consumed locally. Guava puree and concentrated purees (mainly by sugar addition) are produced for consumption in the producing countries, while no guava clarified juices and concentrates are marketed, to the best of our knowledge.

The fruit has a rough-textured yellow skin and varies in shape from round to pear-shaped, and in size, depending on the variety. Fruits - *ca*. 13 cm in diameter and 680 g in weight are common in cultivated varieties (Luh, 1980). The color of the inner flesh varies from white - to deep pink - to salmon red. Desirable fruits for processing are those with a thick outer flesh and a small seed cavity, since they

yield more (Luh, 1980). The distinctive musky flavor is more intense in some selections than in others and the acidity varies too, from pH 3.0 to a few with pH 4.0. The fruit acidity is due to both citric and malic acids, present in almost equal amounts. Guava is a rich source of vitamin "C" (AA) and a fair source of vitamins A and B.

The total pectin content of the guava increases up to the edible maturation stage, followed by an abrupt (but not large) decrease with an advance in maturity. At the edible maturity stage guava contains less pectin than citrus fruit. Guava pectins have a high methoxyl index and produce stable gels (Luh, 1980; Dhingra et al., 1983).

Nakasone et al. (1976) reported the following characteristics of guava puree from different pink varieties: extraction yield - 68 to 79%; acidity (as citric acid) - 1.05 to 2.0%; carotenoids (including lycopen) - 4.78 to 6.9 mg/100 g. The TSS in certain commercial guava seedlings in Hawaii were between 8 and 11.5%, pH - 3.26 and 4.0, ascorbic acid - 144 to 492 mg/100 g (Boyle et al., 1958). Guava puree contained about 6% total sugars, mostly reducing, and 130 mg/100 g ascorbic acid (Chan and Kwok, 1975). Padula et al., (1983) reported the following quality characteristics of guava juices (not clarified) in Brazil: total carotenoid content - 6.8 to 27.4 µg/100 g; TSS - 6.1 to 7.4^{o} Brix; pH - 3.5 to 3.8; acidity (as citric acid) - 0.50 to 0.56%; AA - 7to 44 mg/100 g, etc.

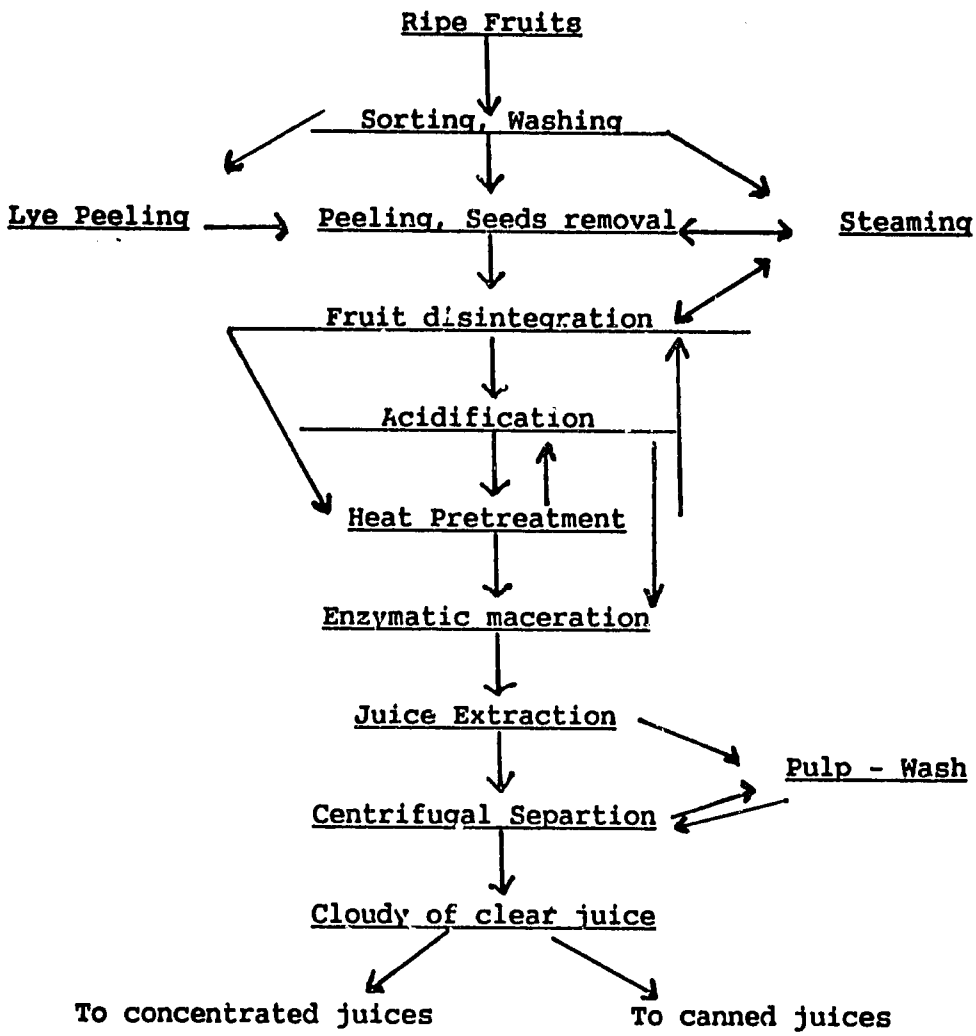
Brekke and Tanaki (1970) prepared 2.5-fold guava concentrated puree, using pectolytic enzymes (Pectinol 10M, Rohm and Haas) in order to reduce the viscosity prior to vacuum concentration. According to Luh (1980), guava juice could be obtained by direct squeezing to guava puree in a mechanical press with a suitable pressing cloth (but the yield was low). Sreekantiah et al. (1968) obtained a relatively high yield of completely clarified guava juice with commercial enzyme (0.5% concentration) In order to obtain this yield the enzymic treatment took 18 h. The juice was filtered by filter press, allowed to stand another 48-72 h under refrigeration, and then filtered again. We do

not think that such a process would be economically feasible. Imungi et al. (1980) also prepared clear banana concentrate using a pectolytic enzyme, but the guava drink prepared, possessed only mild guava flavor (in his opinion). According to Hugo (1981), use of maceration enzyme did not show clear cut advantages for production of guava pulp and nectar. Sreekantiah et al. (1980) found in clarified guava juice relatively high tannin content which, as he suggested, can be removed by precipitation with gelatin.

Our opinion (see also mango and papaya) was that carefully designed preprocessing and processing methods, applying recently developed specific pectolytic (and other) enzyme preparations, would lead to high production yields and typical high quality characteristics of cloudy guava straight and concentrated juices.

Enzymatic maceration of Papaya, Mango and Guava was tested both on lab and pilot plant scale, appling basically the process steps - given in the following Flow Diagramme.

Basic Flow Diagramme of the Process for Tropical Fruit Maceration



3B. EXPERIMENTAL

A. Raw Material

"Eating-ripe" papaya, mango or guava were obtained directly from commercial or experimental plantations in Israel and Costa Rica. Selection of ripe, sound fruits, (with additional natural ripening - if needed - at ambient conditions - were applied) (see also Results and Discussion).

B. Pretreatments

a) Peeling - Specific peeling methods were studied for each fruit. Whole papaya, for example, was lye-peeled in 10% boiling NaOH for 5-7 min or steamed, or treated in boiling water for 2-4 min and the results compared with mechanical removal of the peel (by pulper), after removal of the central cavity liquid and seeds. The same procedure removing manualy the seeds was applied for Mango. Guava was treated only by pulper, to remove the seeds and peel. After selection of the best peeling methods (as to yield and quality), they were applied for future peel removal. (See also results and discussion).

b) Steaming or Blanching - of whole, or peeled and "cut-in pieces" fruits were aplied for inactivation of the naturally occurring undesirable enzymes. The results were compared with those of non heat-treated fruits (see also results and discussion).

c) Fruits disintegration and peel removal - All fruits were manualy disintegrated (or by a Ritz disintegrator) - to relatively large-size particles, in order to prevent excessive undesirable enzymes' activity and oxidation effect, before the natural enzymic inactivation (if applied). Peel particles attached to the pulp were removed by "pulper straining", before or after the enzyme treatment, which was determined for each fruit after preliminary experiments (as to yield and quality).

d) Heat pretreatments of the pulp - The pulp was subjected (or not) to aditional heat treatment (steam-jacketed kettles) - for several minutes at 88-95°C (enzymic inactivation checked by PE inactivation) and immediately cooled to the optimum temperature for the enzyme treatment (ca. 40 to 50°C). Subsequent evaluation of the macerated pulp, etc., supplied the necessary information on the necessity of this operation (as to yield and quality) for each of the fruits (see results and discussion).

3. Acidification and enzymatic maceration

The pulp was acidified with citric acid (if necessary) to the optimum pH (=<4.5) needed for the enzyme treatment. Papaya pulp was acidified as soon as possible, in order to avoid gellification and development of off-flavors (Brekke et al., 1975). Several commercial pectolytic enzymes, such as Pectinol, Pectinex, Ultrazyme etc., alone or in combination with Celluclast (celluloitic enzyme) were first evaluated with a relatively small pulp sample (500-1000 g.), at different concentration, pH, temperature, etc. Respective treatment times were studied. The working conditions and the best possible combination of enzymes were selected for the process, after assessment of the yields and quality characteristics (flavor, viscosity, cloud stability, etc.,) of the respective separated juices (see results), Temperature-controlled conditions were maintained in a steam-jacketed kettle, with continual stirring of the pulp.

4. Juice extraction and clarification

The enzymatically macerated pulp was strained by a finisher (screen - 0.5 mm) and then the juice was separated in Israel with a centrifuge, in order to remove fibrous particles, etc. The resulting clarified (to cloudy or transparent) juice represents the obtained yield and quality characteristics of the non-preserved products. The separated pulps were washed and the pulp-wash was added back to the

concentrated juices, in order to increase the respective yields. In Costa Rica the pulp was subjected to hydraulic press (cloth), at 2000-2500 PSI and the so separated juice - centrifuged in order to obtain - "cloud stable" juices.

5. Juice pasteurization, hot-filling and canning

Part of the clarified juices was flash-pasteurized (plate heat exchanger) and hot-filled in suitable cans (enamel lining). The containers were immediately cooled to 35°C (or less) with tap water. The cans were stored at ambient condition and their integrity (corrosion effects) as well as the juice quality characteristics were evaluated (including taste panels) after 3 to 6 months of storage.

6. Juice concentration

Another part of the juice was flash-pasteurized (as above) and subjected to vacuum concentration in "Luwa", or "Votator" - scraped surface - vacuum evaporators up to 60° or more Bx (depending on viscosity). The resulting concentrate was evaluated, as of the effect of concentration - on flavor, cloud stability, color (non-enzymatic browning), consistency, etc., of the concentrated and reconstituted juices.

The concentrates were blast-frozen (Frigoscandia blast freezer) in polyethylene bags and freeze stored, or canned (see above) after hot-filling (>82°C for 1-2 min) and than stored - for up to 6 months - at ambient temperature or refrigeration (<4°C), for subsequent quality evaluation.

B. Analytical Methods

1. The TSS, acidity, pH, ascorbic acid, etc. contents were assessed by standard methods (Levi et al., 1983,1985) in the raw fruit pulps and the final juices and concentrates. The color was evaluated with a "Gardner Color Difference Meter" (Levi et al., 1980).
2. The preliminary efficiency of the enzymatic maceration as to juice yield, pectin breakdown, etc., was pre-evaluated by standard methods as described by the producers of commercial macerating and clarifying enzymes (Assessment of enzyme activity in crushed fruits: Ultrazim, Ciba-Geigy, Switzerland; The application of pectolytic enzymes in the citrus industry: SFAG, Swiss Ferment Co. Ltd., Basel).

   After selection of the optimum enzyme concentrations and maceration conditions - pH, temperature, time - batches of 10-50 kg of raw fruit pulp, were enzymatically macerated and subjected to the full process. The quality characteristics (viscosity, color, flavor, etc.), were assessed with 0.5 to 1.0 kg samples. The cloud stability by juice-pulp separation at 370xG for 20 min and cloud intensity defined by spectrophotometric (absorbance) determination of the supernatant at 660 nm.
4. The acceptability of the final liquiform products were assessed by taste panels in both Israel and Costa Rica.
5. Alcohol-insoluble solids (AIS) were prepared from the untreated and the blanched tissue by repeated extractions with 70% and 96% alcohol. Soluble pectin was prepared by sequential extraction of the AIS with water at room temperature until no glacaturonic acid appeared in the extract. Calcium pectate was extracted from the washed pellet of the soluble pectin with 0.2% EDTA and Tris-HCL (0.02 M, pH 6.2), dialyzed against water, and freeze-dried.

The pellet which we received was extracted with 50mM NaOH in order to get the NaOH soluble pectin. The residual insoluble cell wall was

freeze-dried. The four fractions or the combined fractions of the pectins and the residual insoluble fractions were analyzed for galacturonic acids by the m-hydroxyphenol (Blumenkrantz and Asboe-Hansen, 1973).

The composition and the amount of individual neutral sugars were obtained by hydrolysis in trifluoroacetic acid. The respective alditol acetates were analyzed by gas chromatography as described by Albersheim et al. (1967).

3C. RESULTS AND DISCUSSION

3C.I. ISRAEL

3C.I.1. Mango

The most extensive experiments to study the enzymatic maceration of the fruit pulp were made with Mango. Eating-ripe Mango fruits of the Maya var. were obtained from the experimental plantation of the Agricultural Research Organization (ARO) in Bet Dagan. After several experiments the following premaceration steps were used to prepare the mango pulp (see also Experimental) for maceration:

...Cutting and removal of seeds-manual (sharp knives);

...Peel removal and disintegration (to coarse particles) - by Ritz (knives) disintegrator ("diameter) - followed by finisher (6 mm diameter).

...The so obtained coarse pulp was (or not) subjected to heat pretreatment (blanching, pasteurization), before the enzymatic maceration.

The influence of different commercial enzymes on the juice yields of mango pulp is given in Table 1.

The juice yields are also calculated by the following formula:

$$\text{Yield Index} = \frac{\%\ \text{Juice} \times {}^{o}\text{Bx (of juice)}}{\%\text{Juice (of control-no enzyme)} \times {}^{o}\text{Bx(control)}} \times 100 = \text{YI}(\%)$$

From the results represented in table 1 various indications, as to the influence of the enzyme concentration and the treatment-temperature and time were reached.

Table No. 1. Yields of Mango Juice Maceration by different Enzymes (YI**-Yield index-%)

Time (min)	Enzymes used			
	Pextinex 3XL	Rohapect TF	Ultrazyme	Biopectinase
		45°Cx500ppm		
60	168	140	140	135
60(150ppm)	(143)	(138)	(156)	-
120	158	142	177	151
180	163	162	182	158
240	163	162	-	-
		40°Cx150ppm		
60	160	-	162	-
		40°Cx500ppm		
60	146	-	157	120
120	-	-	174	144
180	-	-	191	152
240	-	-	168	158
		50°Cx150ppm		
60	160	-	191	152
120	158	-	172	151

*Juice separated by centrifugation at 7000g for 30 min.

**YI of Control (no enzyme) = 100% (45°Cx60min) - Highly viscous liquid)

The best enzyme and conditions for non-heat pretreated Mango pulp maceration - giving the higher yield are:

a) Ultrazyme (UZ) - 150ppm - for 60 min at 50°C;

b) Higher enzyme concentration , or lower temperature, or longer treatment reduced the yield of the UZ treated juice;

c) Hypothetically, higher enzyme concentrations, or longer time, or higher temperature treatments - or combinations between them, result in further degradation of the polysaccharides in general and the pectic substances (more specific) in this case. It is possible that the more degraded pectins, possess higher liquid absorption ability, than the less degraded ones (down to a certain degree of degradation). This could explain - for example - why UZ treatment for 120 min, resulted in lower yield, than that for 60min (150ppm, 50°C) and similar.

d) The effect of the temperature, seems to be more complicated than only increase in yield (as given in the instructions of the "commercial pectin companies") - up to 50°C, probably also because of the "degradation effect". For example - compare yields with 500 ppm ultrazyme for 180 min at 40°C (191) and 45°C (182).

Repeating some of the experiments, with 1-2kg pulp gave similar results as those given for table 1.

The influence of the heat pretreatment, which could be blanching (of fruits) or pasteurization (of coarse pulp), was studied mainly with pectinex 3XL, parallelly with the study of the effect of a celluloitic enzyme - Celluclast - tables 2 and 3. The given results represent experiments, with 2-3kg mango pulp for each experimental condition.

From these results, it is highly probable that pectinex is less efficient in celluloitic activity, than Ultrazyme. Celluclast alone was not enough to liberate the juice. It seems that even reducing significantly the viscosity, without considerable pectin degradatioon, is not enough for juice liberation. The remaining undegraded, or

partially degraded imbibing pectin, is probably responsible for the observed low yield. Again - Ultrazyme was the best enzyme, yielding higher and affecting positively the AA content, as well as the cloud (lower T) and the fluidity of the juice. Heat pretreatment inactivated the natural enzymes, but apparently increased the juice absorption (probably by changing the polysaccharide molecular configuration), therefore lower juice separation yield was observed.

Table No. 2. Yields of mango juice by enzymatic maceration (1hr at 45°C; Separated at 7000g for 1/2 hr)

Enzyme-treatment	Yield %	TSS-°Bx	YI-%	Flavor
Control-no enzyme	34.4(24.1)*	19.0	100.	Typical(viscous)
Pasteurized** "	18.5(13.0)	20.4	58.5	- -
Celluclast (CLC)-				
1000ppm	33.0(23.1)	19.4	98.5	- -
Pectinex(PX)-				
150ppm	53.5(37.5)	19.3	158.0	Juicy-typical
PX-Pasteur.-CLC	60.0(42.0)	20.5	189.0	- -
CLC- " -PX	58.2(41.0)	21.6	194.0	- -

*Within brackets - yield on whole fruit basis;
*Coarse pulp treated for 1 min at 90°C.

Table No. 3. Yield and Quality Characteristics of Mango Juice by Enzymatic Maceration (45°Cx60min) of pasteurized pulp.

Enzyme-treatment	YI (%)	AA+ (mg/100g)	Acidity (%)	pH	T-% (660nm)	Viscosity** (sec)
Control(no enzyme)	100.0	46.0	0.35	4.07	-	Very high
Pasteurized-as above	58.0	35.0	0.45	4.04	14.8*	108
Celluclast 1000ppm	98.0	27.0	0.40	4.10	9.4*	10.0
Pectinex-150ppm	158.0	32.0	0.38	4.00	33.1	3.9
CLC+PX	194.0	30.0	0.45	4.00	97.6	4.0
Ultrazyme 150ppm	197.0	41.0	0.36	3.98	33.5	4.0

*After a dilution 1:5 with distilled water;

**Measured as the time of flow with standard pipette;

+ AA-Ascorbic Acid

Repeating the above experiments with the same raw pulp, but with batches of 3-5kg pulp and changing some of the conditions - resulted in similar yields and characteristics of the Mango juices - table 4.

Even working with lower enzyme concentration for the celluclast, or shorter-time treatment, resulted in very similar yields. Again the probable deficiency of Pectinese in celluloitic acitivity is confirmed, while Ultrazyme, even at lower concentration (than in table 3), resulted in higher yield. Adding celluclast to the ultrazyme did not give higher yields or different quality characteristics of the resultant juice (results not presented here). The advantage of the ultrazyme is obvious, specifically if evaluating the much lower transmitance, even at higher maceration yields. The color characteristics of the juices are similar and no advantage is observed

(in general) of a certain enzyme; taking into account also the yield and the fluidity (viscosity).

There is no doubt that the color (as measured by the absorbance and even by the reflectance (higher - "a") of the (too) pulpy juices is more intensive, but due to the very low fluidity (high viscosity), they cannot be considered as juices, but more as a macerated mango pulp.

The results and recommendations of the studies in Israel were transferred to Costa Rica, where the experimental design was based also on the Israeli experience.

Table No. 4. Yields and quality characteristics of Mango juice by Enzymatic Maceration (45°Cx60min). Pasteurized Pulp;

Treatment-enzyme	YI (%)	L	+a	+b	T (%)	A+ 440nn	Viscosity (sec.)	Flavor
Natural Pulp-45°Cx60min	100.0	55.1	5.1	34.1	-	-	High	Typical
Pasteurized Pulp-45°Cx60min	60.0	57.7	5.1	38.9	0.88*	33.1*	112.0	"
(CLC)Celluclast--750ppm	95.0	57.5	6.4	36.5	9.4*	27.3*	10.0	"
(P3x)Pectinex 3LX-150ppm	160.0	56.6	4.3	36.5	84.0	0.92	4.0	Juicy of Mango
(CLC+P3X (750+150ppm)	195.0	56.0	3.8	39.6	88.0	0.85	4.0	" "
Ultrazyme-100pppm	198.0	56.0	4.0	39.8	33.5	0.90	4.0	" "

*Calculated-after dilution 1:5 with distilled water;
+Absorbance=A.

3C.I.2. Papaya

No study of the influence of varieties was performed in Israel, because the main goal was to develop the overall process of enzymatic maceration with emphasis on the technology to be transferred to Costa Rica (and for the benefit of other developing countries). The variety used in Israel was Solo from Kfar-Haim. The fruits were physiologically mature and were left to ripen at ambient conditions - up to >80% yellow-orange coloration of the peel, at which stage they possess maximum Total Soluble Solids (TSS) - Bx value. At this stage the papaya pulp was of a typical orange color (Levi et al., 1985).

The ripe-firm papaya fruits were lye- (Levi et al., 1983), or steam (2 min at atmospheric pressure) - treated and peeled under high-pressure tap water showers, cooling down the fruit. Trials to peel papaya pieces directly by "Ritz" or "Finisher" were efficient for peel removal, but the pulp was bitter. The peeled papayas were halved by sharp knives and the seeds and "central cavity" liquid manually removed, to prevent bitterness and off-flavors (Khedkar et al., 1980; Levi et al., 1983, 1985). The halves were cut in smaller pieces and coarsely pulped by finisher (10-15mm openings). The coarse pulp was also subjected to preheat treatment (1min-90°C), if not previously blanched (2-3 min-steaming) - in order to inactivate undesirable enzymes. Before the enzymatic maceration the papaya pulp was acidified with citric acid down to pH<4.5, in order to prevent gellification , off-flavors, etc. and to permit pasteurization (instead of sterilization) of the juice.

After preliminary experiments (0.5kg-1.0kg pulp) with several enzymes (see also Mango) - Pectinex "3XL", Pectinex Ultra SP (PSP), Rohapect, Rohament etc. we found that P3x, PSP and Ultrazyme, gave the best yields, significantly higher than the other enzymes. Therefore we studied in more detail and with larger (2-3kg pulp batches), the enzymatic maceration of these enzymes and combinations with celluclast (CLC) - Table 5.

Ultrazyme seems to be the best enzyme as to the yield, resulting in significantly higher yields, than other enzymes, including combination between P3x or UZ with celluclast. In this case, quite high juice yield was obtained, only by holding the pulp at 45°C for 60 min., or by use of celluclast only. The advantage of limited specific degradation by the cellulase (our hypothesis), is confirmed again. The yield index with 750 ppm celluclast was higher than with 1000ppm, which was similar (even a little bit lower) to this with 500ppm celluclast. The relatively lower pH observed with PSP, could be, because of more degraded pectin (to galacturonic acid monomers and oligomers), which may be responsible for a limited decrease in pH. That conclusion is supported by the lack of correlation between the acidity (expressed as citric acid content) and the pH observed in the macerated as above, juices - table 6.

Table No. 5. Effect of some enzymes on the maceration* yields of Papaya pulp (not pasteurized; acidified to pH 4.4).

(45°Cxlh)

Treatment-enzyme	Yield (%)	TSS °Bx)	Yield Index (%)	pH	
Control (no enzyme)	61.0	11.6	100.0	4.20	Viscous
P3x-100 ppm	76.0	11.3	122.6	4.33	Typical flavor
PSP- " "	67.6	12.6	121.7	4.13	" "
UZ- " "	75.0	12.8	137.0	4.20	" "
CLC-1000ppm	66.8	11.8	112.6	4.27	Viscous "
CLC-750 "	69.6	11.7	116.3	4.20	"
CLC-500 "	68.8	11.6	114.0	4.27	"
(100)P3x+CLC(750ppm)	71.6	11.4	115.7	4.30	Juicy-typical
(100)PSP+CLC(" ")	72.0	11.4	117.3	4.22	" "
(100)UZ+CLC (" ")	71.8	11.4	117.0	4.30	" "

*Juice obtained by centrifugation at 7000g for 30 min, on pulp basis

The quality characteristics of the juice obtained by the UZ maceration are reasonably good. The juice contained a relatively high amount of ascorbic acid, was more cloudy (lower T) and colored (A), than other juices, yielded significantly better and was fluid, as the other juices obtained by other pectolytic, or a combination between pectolytic enzymes with celluclast (see also table 1). On the other hand all the pasteurized juices obtained from non-pasteurized pulp, became bitter after storage at ambient temperature for 3-4 weeks. Therefore, we studied the effect of a preheat treatment (blanching or prepasteurization of the pulp), on the yield and quality of the respective papaya juices (tables 7 and 8).

The yields of the non-heat pretreated (NH) juices were higher. The reasons for the difference are probably both, the activity of the natural polysaccharides' degrading enzymes, as well as the heat-induced modification of the complex "cellulose-hemicellulose" and mainly the pectic substances. Unfortunately the much higher yields of the NH juices are parallel to the effects of non-desirable enzymatic activity, resulting in off-flavors (in this case - mainly the bitter taste), as well as in the lower cloudiness observed (higher transmittance value). Therefore - at least in Israel (see further), only blanching or prepasteurization (prior to the enzymatic treatment) were practically considered. The case in Costa Rica was different, as we will see in their results (see further).

Table No. 6. Quality characteristics of macerated* papaya (non-heat pretreated) juice by different enzymes (see also table 5).

Treatment Enzyme	Acidity (%Citr.Ac.)	pH	Ascorbic Acid (mg/100g)	Transm-T** (%-660nm)	Absorbance-A** (440nm)
Pulp-not treated	0.10	5.0	73-78	-	-
Control-acidified	0.32	4.40	71-76	88.3	0.11
P3x-100ppm	0.24	4.30	67.0	90.5	0.10
CLC-750 "	0.26	4.30	70.0	72.8	0.23
UZ-100 "	0.32	4.20	75.0	87.5	0.12
PSP-100 "	0.32	4.15	77.0	88.4	0.11
P3x(100)+CLC(750)	0.27	4.30	71.0	91.3	0.09
UZ(100)+CLC(750)	0.27	4.20	71.0	91.0	0.08
PSP(100)+CLC(750)	0.28	4.30	64.0	81.0	0.18

*Macerated at 45°Cx1h;

**Transmittance-T at 600nm represents turbidity;

Absorbance-A at 440 " " yellow color.

Table No. 7. Effect of heat pretreatment (blanching) on juice yield of enzymatically macerated papaya (45°Cx1h - after acidification of the pulp to pH 4.4).

Enzyme	Yield (% Juice)		TSS-(°Bx)		Yield Index-(%)	
	H*	NH*	H*	NH*	H*	NH*
Control-no enzyme	52.0	61.0	11.8	11.3	100	117
Ultrazyme (UZ)-100ppm	76.0	85.0	12.8	11.8	147	163
Pectinex 3xL(P3x) "	68.0	76.0	11.8	11.3	131	146
Pectinex SP(PSP) "	65.0	67.6	11.8	12.6	125	130
Cellulast (CLC)-750ppm	69.6	74.0	11.8	11.7	134	144
UZ(100ppm)+CLC(750ppm)	78.0	71.8	11.8	11.4	151	116

*H-Heat pretreated; NH-no "heat pretreated" (became bitter on storage)

Table No. 8. Quality characteristics of the Juices - in table 7

Enzyme	pH		Acidity (%)		Ascorbic Acid (mg/100g)		Transm. (%)	
	H*	NH*	H	NH	H	NH	H	NH
Control	4.35	4.20	0.28	0.32	44.5	71.0	82.0	88.3
UZ-100ppm	4.35	4.10	0.29	0.32	53.0	75.0	68.0	87.5
P3x-" "	4.35	4.30	0.18	0.19	51.0	67.0	85.3	90.5
PSP-" "	4.10	4.00	0.27	0.32	44.0	77.0	82.4	88.4
CLC-.750ppm.	4.20	4.20	0.17	0.16	50.0	70.0	43.4	72.8
UZ+CLC	4.35	4.10	0.28	0.27	51.0	71.0	82.4	91.0

*H-heat pretreated; NH- no "heat pretreated" (became bitter on storage)

The effect of the blanching is probably the reason of the observed lower acid content in these juices (compared with the non-heat treated samples).

The blanching was applied in non-acidified fruit (pH-5.4), therefore the protecting effect of the acidity (lower pH) was also lower. Natural enzymic activity reduced in some cases the pH of the acidified juice. The ascorbic acid content of the non-blanched juice was much higher.

Ultrazyme treatment was the best and resulted in the best yield and cloud (except the CLC), for these high fluidity juices (the CLC was of higher viscosity). Combination between CLC and ultrazyme did not cause a significant increase in the yield of the blanched sample, but a significant decrease in the non-blanched one (see also table 5). In addition significantly higher "T" (clarification) was observed, specifically in the non-blanched (NH) juice. These results again justify our hypothesis of higher degree of degradation of the

polysaccharides - resulting in more degraded cellulose and further degradation of the liberated (by the CLC) pectic substances - probably down to soluble compounds and not suspended particles. These observations justify further studies for better understanding of the maceration process by commercial (and natural) enzymes.

Pilot plant experiments with the optimum conditions and enzymes found, gave similar results, but higher observed yields - reaching up to 80% and more juice (on pulp basis) - derived from heat-pretreated pulp. Our methdos and conclusions were transferred to Costa-Rica, for further evaluation, with the local papaya varieties (see further).

Comparing the enzymes maceration efficiency, at equal concentrations (except the CLC), resulted in an advantage of the P3x over the UZ. The increase from 40°C to 45°C (Px-60min), caused significant increase in yield, while higher temperature maceration, resulted in lower yield (60min-45°C and 50°C). That could be because of further degradation of the pectins to pectic compounds with higher "water-holding" capacity. The same reasons could be supposed, as to the lower yield found after increase in UZ concentration from 150ppm to 200ppm (45°C). Combinations of P3x and CLC increased the yield further.

3C.I.3. Guava

Guavas are grown in Israel mainly for fresh consumption. The white and yellowish varieties, are more abundant, while lately some pink varieties were also introduced. We worked with the Ben-Dov (yellow) var. because our goal was to evaluate methods and enzymes for enzymatic maceration , to be applied in Costa Rica (and other developing countries).

In preliminary experiments was found that the fibrous guava peel and its seeds can be removed by direct straining of the fruit with finisher (1-2mm cpenings) after disintegration to a coarse pulp by a

Ritz disintegrator (strain of 10mm diameter). The peel and seeds could be removed also with basket centrifuge.

Three to five kgs guavas - for each experimental condition, were washed, disintegrated and the coarse peel and seeds removed by finisher or basket centrifuge. The resultant pulp was subjected to maceration by different enzymes - table 9.

Table No. 9. Effect of enzymatic maceration+ of guava - at different conditions - on juice yields (centrifugation-7000g for 30min).

Enzyme	Conc. ppm	Time min	Temp. °C	Yield* %	TSS °Bx	YI* %	Fluidity
Control (no enzyme)	0.0	60	50	34.0	13.0	100	Viscous
Celluclast(CLC)	750.0	60	45	50.1	13.7	134	"
Pectinex 3xL (Px)	150.0	60	40	65.6	13.1	170	Juicy
" " "	150.0	60	45	71.1	13.2	182	"
" " "	150.0	120	45	71.1	13.5	188	"
" " "	150.0	60	50	67.7	13.4	178	"
Ultrazyme-UZ	150.0	60	45	65.2	14.0	178	"
"	200	60	45	65.0	13.2	169	"
Px(100)+CLC(750)**	100+750	60	45	70.0	13.8	190	"
" " "	100+750	120	45	79.0	14.0	218	"
***CLC(60min)+ P3x(60min)	100+750	60+60	45	89.0	14.7	225	"

*On fresh fruit basis; **Simultaneously applied for 60 or 120min. ;
***Treatment by CLC for 60 min. followed by P3x fop 60min.;
+Non heat-pretreated fruits or pulp .

The increase in yield even by CLC (16% more), already indicates that polysaccharide degrading enzymes are necessary for guava maceration to "liquiform" products. Pectinex 3x caused a significant increase in yield, when applied for 60min (150ppm) at 40°C. Macerating at higher temperature (45°C), also caused an increase in the yield (YI), which increased again, if applied for a longer time, probably because of polysaccharide degradation-down to soluble; or with less "water (juice) holding capacity"-polysaccharides (or olygasaccharides). Liberating the pectins from the "cellulose-hemi-cellulose" matrix by CLC, followed by pectiolytic enzyme (P3x) maceration, resulted in further increase in the guava juice yield (YI), supporting the above mentioned hypothesis, as to the poly-saccharide (further) degradation.

Because of the higher maceration' efficiency of the UZ, as observed with Mango and Papaya, we compared again P3x (alone and with CLC) and the UZ, assessing also some quality characteristics of the juics, as well as the centrifugal separation conditions (table 10).

The results given in Table 10 indicate clearly that a combined treatment of CLC+P3X gives much higher yield than UZ alone or UZ with CLC (see also table 1). Increasing the UZ concentration indeed caused an increase in the yield, and more suspended insoluble solids were present in the juice (lower T), but in any way the combination P3x+CLC is by far more efficient for guava maceration. The juice still possesses high cloud value and ascorbic acid content. The increase in yield by longer centrifugal separation is obvious and it has to be further studied, if technically found economically feasible.

Table No. 10. Yield and Quality of Guava pasteurized juice by Enzymatic Maceration.

(Enzymatic treatment -1hx45°C)

Enzyme ppm	Time min.*	Yield %	TSS (°Bx)	YI (%)	Acid. (%)	pH	Transm. (%)	Asc. Acid (mg/100g)
Fresh pulp (no enzyme)		-	14.6	-	0.77	3.65	-	366
UZ-100ppm	15	56.0	12.8	100	0.73	3.84	46.6	393
UZ-" "	30	61.0	12.8	113	0.73	3.84	46.6	393
UZ- "	60	70.0	13.0	126	0.70	3.80	50.0	380
UZ-200ppm	30	64.0	14.0	130	0.58	3.80	49.1	390
P3x(100)+ CLC(750)	30	78.0	14.7	166	0.68	3.74	55.2	388

* Of centrifugal separation at 7000g

The conclusion is that P3x possesses better maceration ability - for guava, which may be further improved by a combination with celluoitic enzyme (at least for the variety studied in Israel).

In order to verify further the above and compare the maceration again - with other enzymes, we repeated the experiments (with 3-5kg pulp for each experimental condition), including also Rohapect (RP) and Biopectinase (BP) – table 11. Again, the best enzymes for the enzymatic maceration are the combination of P3x and CLC, but longer maceration was needed. The above conclusion is valid. The longer time needed was probably because of the higher content of cellulose in the guava and the slower degradation of the "cellulose-hemicellulose-pectin" complex, of the cell walls. The influence of the complex "cellulose-hemicellulose-pectin" matrix complex of the cell walls and

its degradation, on the efficiency of the enzymatic maceration, liberating the juice, is obvious. Prolonging the enzymatic treatment, or increasing the temperature, did not result in higher yields (see table 10), with the pectinex only. Even increase in concentration of the UZ, did not result in a yield increase and a small decrease in yield was observed (table 10).

In addition, the "P3X+CLC" (120min) macerated juice, possessed relatively high ascorbic acid content and the best "cloud" value (lower "T" observed). The higher "cloudiness" is caused by more stable "insoluble solids suspension " (after 7000g centrifugation) - see also table 10 - of the cloud particles liberated after 120 min maceration.

The resultant juices possessed also typical guava flavor and were not astringent at all (see further for guava in Costa-Rica). Another very important conclusion is that no preheat-treatment was needed for better maceration of the guava.

Table No. 11. Effect of various enzymes on maceration yield and quality characteristics of guava juice (pasteurized)

(Maceration at 45°Cx1h; Centrifugation-7000g for 30 min)

Enzyme	TSS °Bx	YI (%)	Acid (%)	pH	Asc.Ac. (%)	Transm.-660nm (mg/100g)
Fresh pulp	13.0	-	0.64	3.7	316	-
CLC-1000ppm	13.7	100	0.54	3.8	288	5.6*
RP**-150ppm	13.2	127	0.52	3.7	288	50.0
BP**-150ppm	13.8	123	0.62	3.8	266	51.6
UZ**-150 "	14.9	145	0.52	3.7	288	50.0
P3x-150 "	14.3	146	0.63	3.7	300	54.0
P3x*100+CLC (1000)-60min.	13.8	146	0.70	3.7	300	58.5
P3x(100)+CLC (1000)-120min.	14.7	180	0.72	3.7	288	43.0

*Very viscouse -T-calculated after dilution 1:10

**Adding CLC to these enzymes did not increase the yield significantly.

3C.II. COSTA RICA (CR)

3C.II.1. Papaya

Papaya is one of the more economically important tropical fruits cultivated in C.R. Papayas are grown in about 800 hectars, mainly in the regions of Alajuela and Puntarenas (Cerdas", 1987). The export of papaya increased 4-folds - from 1982 to 1986. In 1989 the export income was more than 1.5 million IS $. The advantage of the papaya for export is, that it is harvested all around the year and possesses typical desirable aroma characteristics - for the national and international markets.

On the other hand the post-harvest excess of the local (Criolla) var., reached about 40%, compared with 2-30% of the Sunrise Solo (export var.). This excess cannot be exported because of size, antrachinosis, etc., while the local industry does not process the most part of the papaya surplus (Cerdas, 1987).

The "Criolla" var., are not subdivided and characterized as such, except by their "pulp-color", fruits of yellow or red pulp (Calderon and Aguilar, 1987).

Calderon, R. and Agrular, F. (1987) Some production aspects of papaya, mango and guava cultivated in Costa-Rica. Rep. of "Centro de Investigacines en Tecnologia de Alimentos (CITA); Costa Rica (Spanish).

Cerdas, M. 1987) Study of agroindustrial market for Papaya; Ministerio de Agricultura y Ganaderia (MAG; San Jose, Costa Rica, 20pp (Spanish)

The juice obtained by preliminary studies (as proposed by the Israelies), with Sunrise-Solo var. (SS), was significantly better than that obtained with Criolla cv., specifically the flavor.

In Table 12, some of the fruit characteristics are given.

Table No. 12. Characteristics of Papaya-"Sunrise-Solo" cv.

	Range	Average
Longitude-cm	12.5- 15.2	13.85
Diameter-cm	7.2- 9.2	8.17
Weight -g	354.0-543.0	440.4
Peel -%	47.5- 63.0	58..6
Seeds -%	13.1- 22.5	16.14

The pulp represents only between 47.5 and 63.0%, while more than 35.0% and up to a bout 55.0% are peels and seeds. Because of the variations in pulp-seed-peel percentage, it is better to evaluate the results of the enzymatic maceration on pulp-basis. The difference in quality characterisitcs of the local and the Solo cv is obvious, as presented in table 13. In general, Solo varieties contain more sugar and about double ascorbic acid (Vit C), than the local (Criolla) cultivated varieties (in Costa Rica). More detailed studies as to the suitability of the Papaya var. grown in Costa Rica (as well as in other developing countries - "DC"), are needed in order to select the varieties feasible - for agroindustrialization. In our case the "Sunrise Solo", was selected for further experiments to assess the preparation and maceration influence.

Table No. 13. Composition of "Solo" and Criolla" varieties on 100g edible portion)

	Criolla*	Solo**
Moisture-g	-	86.8
Calories-	32.0	46.0
Protein -g	0.5	0.36
Fat-g	0.1	0.06
Total Sugar-g	8.3	12.18
Vit. "C" -mg	46.0	84.0
Calcium -mg	20.0	30.0

*Instituto de Investigaciones de Salud-Costa Rica (INISA, 1985) Tables of composition of foods in Costa Rica (Spanish)

**Chang, M.H., Tang, C.S. (1979); The chemistry and biochemistry of Papaya; in "Tropical Foods; Chemistry and Nutrition, ed. by Inglett G. and Charalamons, G., Academic press, New York.

Table No. 14. Evaluation of methods for removal of Papaya peel (% removed peel)

Treatments	Na ON-10%*	Water*	Steam**
Time-min			
2	21.0	20.5	20.0
3	32.0	25.3	-
4	-	31.3	-
5	43.0	43.6	35.0

*Boiling; ** At atmospheric pressure

The efficiency of some peeling methods, based on the experience of the Israeli team in general and A. Levi et al. (1983) in particular, was evaluated - table 14. The facility of the peel removal by water-sprays after the different treatments was similar, but the yields were different. More than 4 min. treatment was excessive - removing also part of the pulp. At 2 min. steaming or "water-dip" gave similar results as compared with the NaOH immersion, but without the necessity to wash the NaOH completely out, they decided in Costa Rica, to peel the fruit by boiling "water-dip" for 2 min.

The above given conditions may vary - depending on variety, peel thickness, degree of maturity, etc. - but at least they indicate the optimum time, concentration (NaOH) and temperature-for efficient peel removal.

As reported before, we found (in Israel), that heat pretreatment (blanch or pre-pasteurization) of the papaya pulp was necessary to prevent the development of bitter off-flavor-on storage- of pasteurized papaya juices. Therefore and considering also the publications of Brekke et al. (1973), Levi et al. (1985) and Diaz* et al. in Columbia, that "the thermal treatment minimizes the microbial count and the oxidation deterioration of papya pulp", the thermal pretreatment was also studied in Costa Rica. In preliminary experiments was observed that "blanching" caused a high loss of papaya flavor in the macerated juice. The bitterness, which appeared and was intensified during storage of pasteurized (non-heat-pre- treated juice), in Israel did not appear at all in Costa Rica. Although bitterness was not a problem with "Solo-Sunrise-CR", this

---

* Diaz, D. et al. (1985) Manual for processing and preservation of some tropical fruits pulps by chemical methods. Rep. Instituto de Investigaciones Technologicas. Bogota, 40pp.

contradiction (between Israel and CR) must be further investigated with different varieties in more countries. Probably "blanching" or "preheating" is not always necessary, specifically if taking into consideration that maceration of "non-blanched" papaya resulted also in significantly higher juice yields, in Israel.

Maceration of "prepasteurized" (2minx90^{o}C) vs non "heat-treated" papaya, resulted in the following yields - on a lab.scale Table 15.

Table No. 15. Juice yield after maceration of papaya (Lab. scale*)

(% Juice)

Enzyme	Pasteurized	Non-pasteurized
Control-no enzyme	48.0	44.0
Pectinese 3X-150ppm	55.2	55.2
P3XLx150+Celluclast-1000ppm	56.0	56.4

* Batches of 0.5-1.0kg for each condition.

No difference in yields was observed between the macerated with enzymes-pasteurized (2min) and non-pasteurized pulp at 45°Cx1h.

Trials on a PP scale (5-10 kgs batches) indicated the "really expected" yields. The results of these experiments including sensory evaluation of the juices, are given in Table 16.

It is clear, that the "prepasteurized" juice was inferior both in yield and flavor, although its flavor was found acceptable by the "test-panel".

As to the pH - the pH of the raw-papaya pulp was around 5.3, therefore the pulp was acidified with citric acid, down to pH 4.5, while pasteurization and/or maceration, decreased the pH further.

Table No.16. Pilot Plant Evaluation of the Heat-pretreatment of Papaya Enzymatic Maceration (Pectinex SP-150ppmx60min, at 45°C) of acidified (to pH 4.5) pulp

Pulp	Yield-%	TSS-°B	YI-%	pH
Control-non-treated	-	-	100.0	4.50
A. Pasteurized*	64.0	11.5	127.0	4.34
B. Non-pasteurized	81.6	12.0	171.0	4.20
		Sensory evaluation		
	Juice A	Juice B	Significance	
Taste	54.13	88.39	2.95**	
Quality-general	50.74	73.17	2.59***	

*A - prepasteurized at 87°C for 40 sec.; ** 1% Significance; ***5% Significance

More experiments to evaluate different pectolytic enzymes, as well as combinations between pectolytic enzymes and celluclast (CLC) showed that there is no need for CLC. Pectinex Ultra-SP gives optimum yield and quality. The optimum conditions for pretreatment and enzymatic maceration seem to be the following:

a) Coarse fruit pulp - without heat pretreatment;
b) Peeling - boiling water (or steam - Israel) - 2 min.
c) Enzyme - Pectinex Ultra-SP or Pectinex 3xL), -150ppm, at 40°-45°C 30min.

The above conditions are based also on yields and quality evaluation, studying the influence of the following maceration conditions, see table 17.

Table No. 17. Experimental Conditions for Enzymatic Maceration (non-preheat treated pulp, acidified to pH 4.5)

Concentration-ppm	150	200	250
Time -min	30	45	60
Temperature -°C	40	45	50

Enzymes - Ultrazyme, Pectinex 3XL, Pectinex Ultra-SP.

The maceration was performed in a steam-jacketed kettle, with occasional agitation of the pulp - in order to keep homogeneous ature and enzyme concentration, as well as to obtain stable cloud, which depends on the size at the cloud particles and the colloidal properties of the insoluble solids and the surrounding liquid (Shomer*, 1988).

A high precipitation of the cloud particles was observed after storage of the pasteurized juice prepared as described above and extracted with the help of a mechanical press, using "press-cloth"-pressing up to 2500 psi. Experiments to increase the cloud stability by any of the following methods: variations in maceration conditions (temperature x time x enzyme concentration); in strainer conditions

Shomer, I. (1988) Protein self-encapsulation: a mechanism involved with colloidal flocculation in citrus fruit extracts. J. Sc. Food Agric. 42: 55 .

(smaller diameter) etc., did not improve the stability of the final fully pasteurized juice. The only condition, which stabilized significantly the cloud was to heat the macerated pulp to 70°C - for 10min. - prior to pasteurization. Yields of between 30 and 38% were obtained with pectinex 3xL on a pilot plant scale, with batches of above 40kgs papayas - on a fresh fruit basis (about 50 to 70% on a pulp basis) - see Table 12).

The process stages recommended, considering the results of the pilot-plant evaluation, are given in fig. 2.

Papaya juice was prepared by the process steps given in Fig. 2 (Press-2500 psi), on a pilot plant scale with 50kg fruit. The average juice yield was of 80% on pulp basis (or 34%-on fresh fruit basis). The juice stored for up to 6 months showed good storage stability, including the cloudiness and good flavor acceptability. Its quality characteristics are given in Table 18.

It is clear that the enzymatic maceration, as proposed, will result in a "new" papaya product - juice. this juice can be concentrated (see further) and the papaya liquiform products (juice, concentrate, etc.), possess typical papaya characteristics and can be later marketed as "new" products, with good "technical-feasibility" and commercial possibilities. (The economical feasibility has to be evaluated in each developing country, based on our studies.

Figure No. 2

Flow Diagram of the Enzymatic Maceration Process - to Papaya Juice

Papaya

Selection and Washing

Peeling - water immersion - 90°Cx2min

Removal of seeds and fiber

Pulping (1/4" diam.)

Preheating-to 40°C

Acidification - to pH 4.5

Enzymatic Maceration - 150ppm P3XLx30minx40°C

Heating - to 708o8Cx10min

Juice Separation (Desludger or Hydraulic Press)

Juice

Pasteurization	Pasteurization
Canning	Concentration
Canned Juice	Concentrate

Table No. 18. Quality characteristics of (macerated) pasteurized Papaya Juice (Fig. 2).

	(Heat-pretreated)
Total Soluble Solids-^{o}Bx	14.20
pH	4.36
Acidity - % citric acid	0.20
Ascorbic Acid - mg/100g	81.0
Total Solids - %	16.3
Total Sugars - %	12.05
Reducing Sugars - %	8.98
Protein-total - %	0.39
Viscosity (compared with water)	1.31
Flavor	good
Cloud	stable
Total Pectin (before maceration)-mg/100g	379
" " (juice) - mg/100g	91.8

3C.II.2. Mango

The Mango export from Costa Rica started in 1980 (Calderon, Sandra - personal information) - mainly to some European countries. A clear tendency of the CR consumers to prefer the so-called "red" varieties was observed, since 1988 . This situation resulted in considerable surplus of the yellow-Haden cv. It was selected for the enzymatic maceration studies, because of the existing surplus and the preference shown by a test-panel of preliminary prepared Mango juice (Table 19.)

Table 19. Sensorial evaluation of the Acceptability* of Enzymatically Macerated Mango Juice (ranking test).

Variety	Acceptance%
Haden	68.0
Irving	44.0
Smith	55.0
Singapur	31.0

*Test panel instructed to assess color, flavor and consistency.

Preliminary experiments to define the process steps and conditions were performed and the following was observed:

Ripening of physiologically mature Mango, by dipping for 2 min. in 1500ppm Ethrel solution, followed by storage of up to 9-10 days at ambient temperature (18°C-24°C), was needed to ripen to mature Mango.

The optimum temperatures of the fruits (for maceration) ripened as above were: 18°C-22°C. The basic process steps selected for pretreatment of the ripe Mango after preliminary experiments (see also Papaya) were:

a) Selection and washing - ripe-firm sound fruits were washed by immersion and tap water-spray at ambient temperature;

b) Slicing - manual, with sharp knives - removing the flesh from the seeds and cutting it in pieces, to facilitate the pulping.

c) Pulping - by fruit pulper (600 kg/h) (Strain diameter 1/4") - to coarse pulp - removing the peel and the coarse fiber.
Significantly different average pulp yields were observed within the same variety (Haden), but from two different seasons (Table 20).

Table no. 20 Yields by pulping of Mango (Haden cv.) Fruits (%)

	1989	1990
Pulp	65.0	52.0
Seeds	21.0	33.0
Peel	14.0	15.0

Even if the yields are not representative (statistically), the observed difference in pulp yields is highly indicative, as to the differences between fruits of the same cv. The main difference observed was that of the seeds, a difference of 50% between 1989 and 1990. Therefore, the ideal would be to select Mangoes with small seed size, so greatly increasing the industrial yield, at least of the single strength juices.

Basing on the Israeli results as well as the papaya evaluation in CR the effect of preheating of the pulp (pasteurization) was studied (Table 21).

Table No. 21 Yield and characteristics of Mango juice by enzymatic Maceration

(1hx50°C) ;

Pulp	Enzyme*	Yield (%)	TSS (°Bx)	pH	Acidity (%)	T (%)	Flavor
Pasteurized	CLC**(1000) +UZ(150)**	71.3(100)+	19.5	4.2	0.35	44.4	Typical
"	BAN***(100) +CLC(1000) +UZ(150)	68.7(96.4)+	19.5	4.1	0.19	65.3	Off-flavor
Non-Pasteur	UZ (150)	55.7(60.4)+	19.0	4.2	0.15	70.9	Typical
" "	CLC-(1000)+						
" "	UZ(150)	52.7(55.2)+	19.0	4.2	0.06	86.9	"

* Simultaneously;

** CLC-Celluclast; UZ-Ultrazyme;

***Ban-Amylolytic Enzyme-commercial;

+ In Brackets, relative yields in percent of "total" pulp (100%).

The natural pH of the mango pulp was about 5.0; therefore the pulp was acidified with citric acid to about pH 4.5, before the enzymatic maceration (the pH of the Israeli Mango - (see there) was lower than 4.5 and no acidification was needed). According to the literature, starch is also present in mature (even ripe) Mango; therefore an amylolitic enzyme (BAN) was also added. The results indicate, that the amylolytic treatment, decreased the yield, causing also a distinct negative off-flavor in the Mango juice. In CR, celluclast increased the yield and improved the cloudiness (lower transmittance) of the juice, probably because of degradation of the "cellulose-hemi-

cellulose" and higher fiber content in the C.R's Haden. Higher yields were observed in the pretreated (pasteurized) samples.

A combination between UZ and CLC, resulted in the best yield and quality juice, extracted after maceration of pasteurized Mango pulp.

The experiments presented in table 21 were performed on a lab scale (about 1 kg sample for each treatment). Repeating the experiments on a larger scale gave similar results, after macerating with UZ or P3XL (150-200ppm), combined with CLC (1000ppm) and pulp acidification to pH 4.5 (prior to maceration).

The juice was separated from the macerated pulp by pressing it at 2500 psi with press-cloth. The restant (after juice extraction) pulp was dry and very fibrous, probably because of the remaining non-degraded coarse fiber. The juice itself contained some non-stable cloud (more than the desirable fine- pulp content of about 10%-maximum), therefore desludging by centrifugation was needed. The undesirable unsoluble pulp particles, were separated with "Super-Minor Westfalia Centrifuge" (desludger) at 9000 RPM, with a flow of about 500 ml/min.

The final-cloudy juice was canned (90°Cxlmin), hot filled in 200z cans (coated with laquer "C"), and the seamed cans cooled to about 35°C. The cans were stored at ambient temperature (18°C-22°C). No significant flavor, color and cloud changes were observed on storage up to 6 months, even when compared with freshly prepared canned Mango juice.

The quality characteristics of mango juice and pulp during its maceration are presented in table 22.

Table No. 22 Effect of Maceration on quality c haracteristics of Mango juice

Item	Acidity-%	TSS-^{o}Bx	pH	Viscosity*
Non-treated pulp	0.18	18.0	5.11	36.5
Macerated "	0.40(acidified)	18.2	4.13	1.91
Juice (from press)	0.28	17.1	4.17	1.84
" (centrifuged)	0.36	17.0	4.14	1.54
" (pasteurized)	0.36	17.1	4.27	1.54

* Relative to water at 21°C

As expected, the maceration effect on the viscosity (parallel to the polysaccharides degradation), is one of the main reasons of the increase in yield and in fluidity of the juice. The reason for the lower pH values observed after maceration is probably the degradation of the pectic substances to polygalcturonic acid polymers, oligomers and even monomers (galacturonic acid). The decrease in TSS after the juice extraction is not clear and has to be further studied, because it was about 10% lower than the TSS content of the pulp.

As mentioned before, a difference was found between the average yields of juice maceration from Mango fruits of two different seasons. On the other hand the seasonal difference, between two years on a pilot plant scale (Table 23) was not as on lab scale.

The results show mainly the difference and yields of two different batches of the same variety (not a season's avarage). Twenty one percent difference in yield on a pulp basis is very significant. This difference is probably mainly because of the natural difference between the pulps, as a raw material for juice maceration, specifically the polysaccharides as a substrate - for the pectolytic and celluloytic enzymes. This hypothetical opinion is also supported by the higher cloudiness, but lower viscosity and lower yield of

maceration of the 1989 juice. The significant difference in the pH (and the parallelly observed acidity) after equal acidification (to pH 4.5), also indicate difference in "aceration-degradation", at equal concentration and conditions of the enzymatic treatment. Therefore an obvious conclusion is that more profound studies on differences between varieties and within the same variety are necessary, in order to understand better the enzymatic maceration, both from scientific and economical feasibility points of views.

Table No. 23 Yield and quality characteristics of Mango (cv. Haden) Juice, after enzymatic Maceration on a Pilot plant scale (200 ppm P3x + 1000ppm CLC, for 45min. at 45°C).

Parameter	Season Evaluated	
	1989	1990
Yield (fresh fruit basis) -%	38.0 (100%)	43.0 (113%)
Yield (pulp basis) - %	60.0 (100%)	81.0 (135%)
Total Soluble Solids - °Bx	17.1(Yl=100%)	13.5(Yl=106.6%)
Total Sugars - %	10.82	11.1
Reducing " %	5.27	6.1
Ascorbic ascid - mg/100g	-	21.5
pH (preadjusted to ≤4.5)	4.3	3.8
Acidity - % (citric acid)	0.30	0.48
Color (Absorbance at 440nm)	0.646	0.195
Cloud (Transmittance at 660 nm)-%	94.7	65.5
Total Solids (dry matter) - %	18.2	-
Relative Viscosity (to water at 22°C)	1.54	1.95

Figure No. 3

Flow Diagram for Mango Pulp Maceration to Pasteurized Juice

Mango (Haden cv.)

Selection and Washing

Removal of seeds

Desintegration and Pulping

Adjustment of pH (to<4.5)

Enzymatic Maceration (P3XL+CLC;45°Cx45min.)

Pressing or Centrifugal Separation

Juice

Desludging

Hot filling (Pasteurization of Concentration -90°Cxlmin.0)

Canned Pasteurized Mango Juice

The results of the pilot plant studies in CR, as presented in Table 23, lead to the Fig. 3 - Flow Diagramm - as proposed by the Costa Rica team. On one hand the results in Costa Rica and in Israel lead to the conclusion that preheating of Mango is not needed and even in Israel was found that it reduced the maceration yield by about 50%. On the other hand, clear advantage of the prepasteurization is shown in table 21 (although on a lab. scale). Using the same enzymatic combination (CLC+UZ), the preheated pulp yielded about 40% more than the non-preheated. Probably both "direct" and "after preheat" maceration could be feasible, but the contradiction observed is probably due to the natural difference of the polysaccharides in the fresh fruit, used for maceration. Again, the need of this or other preprocessing and processing treatments, must be determined in each specific case, because of the high variability of the Mango (and not only Mango) fruits - varieties, season, growing conditions, climate, etc. etc. The same contradictions were found also for the papaya (see Papaya).

FINAL CONCLUSION

The proposed process-steps can be applied on industrial scale, but the exact details need modification, after enough industrial experience in each processing plant. Further modification would probably be needed, with the introduction of other varieties, etc.

As to the availability of Mango, as a raw material for the juice industry in Costa Rica, it will specifically increase the surplus. From about 22.000 tons available in 1988 in CR, the projected quantity in 1999 is of around 55.000 tons (MAG*, 1988). The surplusses could be better used for Mango products, also because of the relatively short seasonal availability of Mango, mainly from March to June, with only one variety - Tommy Atkins, available fresh up to September (Manzur,** 1987).

---

*MAG (Ministerio de Agricultura y Ganaderia (1988), Boletin Informativo No. 2., Direccion General de Meracdec Agropecnario. San Jose, Costa Rica

**Manzur, E. (1987) "Descriptive Study of the Conditions of the export potential of selected products in Costa Rica (Spanish). Centro de la Promocion de las Exportaciones y de las Inversiones. San Jose, Costa Rica: 20 pp.

3C.II.3. Guava

Guava is one of the most industrially processed fruits in Costa Rica. Nevertheless, very few studies on quality characteristics of guavas exist in the country, probably because of the fact, that guavas are sparcely found in natural form, growing in cattle farms around CR (and are not cultivated).

Because of the above, the following information is by personal collection of data (Calderon Sandra), obtained from national agroindustries, processing guava's in cottage, semi-industrial and industiral form, as well as some preliminary studies in CITA.

The harvest season is between May and November, considering different production sites around the country. In general the harvest is about 3 months per year. No variety classification exists and the guavas are identified by 3 types, red, white and yellow. No information exists on the area, but in general, it is dispersely grown mainly in low, hot dry (seasonally) lands - in the "North-Pacific" part of the country.

The estimated annual production used by 15 agroindustries for various products, derived of Guava-gelly, marmalade, pulp, nectar, etc. is of around 1500 tons. All of the national supply of guava in Costa Rica is for national consumption, mainly for Guava products.

Some Latino-American countries export fresh guavas, mainly of the so-called Brasilian varieties. No statistical data are avaiable but guavas are exported to Canada, USA and the European Community.

Because Brasilian varieties do not exist in Costa Rica** and their introduction is limited, there is no possibility to assess in advance commercial production before 1992. Some similar (to the Brasilian) varieties, (for example from Hawaii), were introduced commercially in 1987, but they could be evaluated only starting in 1992.

Unfortunately and probably because of the inferior quality of the national guava fruits in CR - all the experiments (see further) to obtain enzymatically macerated juice - resulted in highly astringent

taste of the product. The astringency was observed already during preliminary experiments, with or without heat pretreatments.

The seeds and the coarse fibers of the unpeeled fruits were removed with the same pulper, straining the fruit, first through a larger diameter, followed by a smaller diameter.

Enzymatic Maceration

The lab yields of Guava (highly viscous pulpy juice), without enzymatic treatment, were around 47%. The experiemnts were based on the experience in Israel and transferred to Costa Rica.

Pilot-plant experiments in CR, marcerating with 150 ppm of Ultrazyme or Pectinex, at 50°C for 1h at the natural pH (around 3.6), resulted in the best yields. Yields of about 72% to 75% (on fresh fruit basis), were observed. The juice was cloudy with typical color and flavor, but very astringent. Use of gellatine - to remove the astringency (A. Levi,) as proposed in the literature by Sreekantiah et al. (1980), did not help at all and the juice remained astringent.

Results of yields and some quality characterisitsc of Guava Juices by enzymatic maceration (as above) are presentged in Table 24.

---

*Villalobos, O.E. and Boyer, V.G. (1966): Exports of Fruits from the "Central Pacific" to North America and Europe. CITA Rep. (Spanish).

**Calderon, C.R. and Aguilar, V.F. (1987). Some aspects of production of Papaya, Mango and Guava-cultivated in Costa Rica. CITA Rep. (Spanish).

Table no. 24 Yield and quality characteristics of Guava Juice* by Enzymatic Maceration (UZ or P3X-150ppm; at 45°C for 45 min.)

Variety (type)	Yield (%)	T.S.S. (%)	Color (A-440nm)	Cloud(660nm) (T-%)	Viscosity (sp)
White	73.0	9.5	0.62	55.2	15.0
Yellow	75.0	8.0	0.44	65.0	16.5
Red (Pink)	72.0	9.5	0.43	66.3	15.5

* Unacceptable, because of high astringency, although with typical Guava flavor.

Relatively high yields, as well as a good cloud stability, but a relatively low TSS content were observed in all the types. Introduction of new varieties - in Costa Rica, would probably improve the quality characteristics without astringency, because pasteurized guava pulps, from other South American countries, are used for nectars, baby foods etc. and astringency was not a problem (A. Levi, Personal Information). In any way the results of the Guava enzymatic maceration could be a reliable information for other developing countries, taking also in consideration the experiments in Israel. No astringent off-flavor was observed at all in the guave-juice in Israel.

Because no treatment (or pretreatment) would remove the astringency, it was decided to discontinue the development of guava juice (for the time being) in CR and to rely on the results shown by the research in Israel.

3C.III. CONCENTRATION OF TROPICAL FRUIT JUICES

The concentration of fruit juices is an operation of evaporation (or removal otherwise) of the natural water from the juice, applying energy (heat for evaporation), usually under vacuum, obtaining a storage-stable fluid product. Some aroma compounds, to lesser or greater extent, are also removed during vacuum-heat concentration, but the costs of storage, packaging, transportation, etc. are reduced significantly, as well as the storage stability. .

Single strength fruit juices are water solutions of soluble solids and suspension of insoluble solids - derived from the fruit cells- with typical aroma, taste and color, responsible for the organoleptic characteristics and the consistency. The water removal by different concentration methods - evaporation, freeze-concntration ,reverse osmosis, etc., affect to some extent the quality characteristics. Therefore, water must be removed by such methods, as to affect as little as possible the desirable characteristics. On the other hand, concentration must be also economically feasible. The most practiced, technically- and commercially-feasible methods for concentration of fruit juices, are by "heat-vacuum" evaporation, during which some aroma compounds are also removed. If the typical flavor is too affected and the concentration is designed and used for "large-enough" quantities, -aroma-recovery units recover partly or fully the aroma compounds, which can be added back, or even used for other products.

The pasteurization of the juice (before the evaporation) and of the concentrate also affect significantly the flavor of the finished product. In order to prevent non-desirable enzymes activity and microbial spoilage (starting even during the concentration), one has to pasteurize the juice.

One of the objectives of development of tropical fruit juices is to produce commercial highly concentrated ones, because even

enzymatically treated pulps can be only partially concentrated. We tried to concentrate (in Israel) the juices obtained by enzymatic maceration and found that although some aroma compounds were removed, the concentrates possessed typical flavor, more or less intensive. The flavor was improved by "cut-back - adding back single-strength juice, or pulp wash" to the concentrated juices.

The effect of the concentration was studied also on a pilot-plant scale in Costa Rica. Juices obtained by enzymatic maceration, of papaya, mango, banana and guanabana, were subjected to vacuum evaporation with a "Votator"-type Turbo-Film "04-012" evaporator. The process conditions and the degree of concentration are presented in table 25.

Table No. 25 Results of pilot plant concentration of tropical fruit juices (concentrated in 3 stages).

Fruit juice	TSS(^{o}BX) Juice	TSS(^{o}BX) Conc.	Temp. (^{o}C)	Time (min)	Velocity (ml/sec)	Characteristics (all were fluid)
Papaya	12.5	72.5	42.0	20.4	8.9	Aroma-loss signif.
Mango	19.5	67.5	38.0	19.3	52.2	Some "aroma-loss"
Banana	23.0	68.0	44.0	11.3	6.8	No "aroma-loss" but slight darkening
Guanabana	14.0	61.0	45.5	14.6	5.3	High aroma loss, significant darkening.

As expected, most of the concentrated juices (except banana), lost more or less their single-strength juice aroma, but most of the reconstributed juices had similar color and flavor (even weaker),

except the guanabana - which was much darker. There is no doubt that because of the practical fluidity of the concentrates and the possibility to concentrate various tropical fruit juices (even if possessing stable cloud - and not completely clarified), the enzymatic maceration of tropical fruits could be commercially feasible. As to

the aroma-losses, the aroma can be recovered, or at least better flavor can be obtained by "cut-back", with "single-strength" juice (or pulp-wash), as practiced commercially in the industrial production of citrus (and other fruits' concentrates). In any way the cloud, flavor and color stability of various tropical fruit concentrates - specifically on storage - must be further studied. These extensive studies could not be performed within our budget limitations. At least indicative positive results, as to the probability to commercialize our results, were shown and can be introduced in the developing countries.

4. CHANGES IN PECTIN AND NEUTRAL SUGARS DURING FRUIT PROCESSING

RESULTS AND DISCUSSION

Commercial pectinases were tested in order to evaluate their relative ability to degrade pectins the tissue. The activity of pectinesterase (PE), polygalacturonase (PG) and pectin lyase (PL) were tested on purified substrates, as the rate of a decrease in viscosity which an indication for the combination of all their activities. From the four commercial enzymes (Table 26) ultrazyme 100 seems to be the most active followed by C-80 and pectines 3x. Ultrazyme is an enzyme which is based on high activity of PG and PL and low activity of PE. In contrast C-80 hydrolysed the pectin by a mechanism which was based on higher activity of PE and lower activity of PL. In Pectinex we found low activity of PE, but sufficient activity of PG and PL. Elimination of PE activity seems to be important in order to prevent gelation of the final product and for this reason C-80 is not a suitable enzyme.

The mechanism of hydrolyzed pectin seems to be much more complex especially if we compared Pectinex-3x with C-600. Both have high PG and PL and low PE but C-600 almost did not decrease the viscosity of the pectin. It seems that we are not dealing with one type of PG or PL but with a large spectrum of activities. For our experiments we choose to work mainly with Pectinex 3x from Novo.

MANGO

Conten of the alcohol insoluble solids (AIS) from the various steps of the processed mango fruit showed (Table 27) that during preparation the pulp, the amount of the AIS decreased by about 10%, the probably by natural pectolytic enzymes activity, or by the heat treatments. Macerating the pulp by commercial pectolytic enzymes

decreased the amount of the AIS by more than 20%. Separating the macerated product by centrifugation resulted in 85% juice which has 0.42% insoluble solids. Analyzing the galacturonic acids (GA) and the neutral sugars contents of the AIS (Table 28) showed that they decreased during the juice processing. The main changes were found in the GA, but still more than 25% of it were found in the insoluble particles which were not extracted into the juice (are into the cake). In contrary to the GA, the pectins containing neutral sugars (NS) were not much hydrolyzed by the pectolytic enzymes and only a small part of the neutral sugars was released into the juice.

The changes in the composition of different fractions of pectin in the processed fruit is shown in (Table 29).

Ripe mango is rich in soluble pectin which composed almost 50% of its total pectin content. A significant part of the pectin was bound to the insoluble part of the cell wall which was not solubilized by 50mM NaOH. Preparation the pulp from the fruit caused degradation to the soluble pectin, the EDTA and the NaOH pectic fractions, but not the residual cell wall. Only by using commercial pectolytic enzymes we degraded this fraction and resulted with juice which contained more than 80% of the soluble pectin in the fruit.

The composition of the neutral sugars in the mango cell wall is shown in Fig. 4. The main neutral sugars in the cell wall appeared to be glucose, xylose, galactose and arabinose. Beside xylose, all the other sugars did not changed much during preparing the pulp or during maceration. Only small amounts of NS was released into the juice. In order to follow more specific changes in the NS, the cell wall was fractionated to two main fractions:EDTA - NaOH and the insoluble residue. As shown in Fig. 5 a lot of changes occurred during processing which changed the content and the ratio of the NS in these fractions, but not during the release of the NS to the juice. Rhamnose for example increased by more than two times after the enzymatic maceration in the EDTA-NaOH fraction. It was partially solubilized,

but not enough to be part of the juice, (Fig. 5, column 5). Arabinose content did not change after the pulp preparation, but increased after the enzymatic process. Xylose, contrary to arabinose decreased during the process. Galactose increased during pulp preparations and did not change after addition of commercial enzymes, as glucose decreased in the pulp, but increased after enzyme treatment.

Following the changes of the NS in the EDTA-NaOH fraction (Fig. 5), we can see that rhamnose, arabinose and glucose increased after the enzymatic treatment as xylose and galactose decreased after this treatment. In the insoluble residue (Fig. 6) all the NS were changed during the various steps of the process. The main changes were after the maceration without much changes after the enzymatic treatment. The only exception was in the glucose content. After pulping its amount increased, probably through maceration of the cellulose (which was not included in the insoluble residue analysis.) After addition of the commercial enzymes it degraded and its content decreased.

The hydrolysis of GA and NS polymers in the tissue during processing could explain the decrease in holding capacity of the water in the tissue and as a result of it the increas the yield of the juice production.

GUAVA

Preparation of AIS from guava fruit showed (Table 30) that the amount of the insoluble solids in this fruit is much higher than mango. The amount of the AIS decreased during the processing from 4.25% in the fruit to 3.92% after enzymatic treatment and resulted with 80% guava juice which contained 0.38% AIS.

The content of GA and NS in the fruit (Table 31) showed that guava has much higher amounts of GA than NS. The content of GA is about 32% of the AIS compared with 20% of the NS. Not much hydrolysis of the GA and the NS was observed during maceration of the fruit by enzymes. A small part of the GA (8%) appeared in the juice, but the main part

(92%) remained as a bound material in the cake. The same phenomenon was observed with the NS which may have changed during the process, but not completely degraded to small oligomers and were found to be mainly part of the cake (91.7%).

The composition of the NS in the guava after hydrolysis with TFA showed (Fig. 7) that the tissue contains mainly xylose (70%), following by arabinose and galactose. Total NS was about twice as much compared with the mango fruit. Not many changes were noticed in the composition of the NS during maceration of the tissue. The main changes were after the enzymatic treatment. In this case glucose decreased almost 45%, galactose about 20% and xylose about 10%.

PAPAYA

Preparation of AIS from papaya showed that its content is much lower (Table 32) compared to guava and mango, which means that the carbohydrate polymers in this tissue are on a lower level, compared to the other fruits. More than 80% juice was received by using pectolytic enzymes for maceration the tissue. About 420mg/100gFW (grain frsh weight) of GA and 100mg gFW of NS were found in ripe fruit of papaya (Table 33). After maceration the tissue the amount of the GA drastically decreased to about 140 mg/100 gFW. The amount of the NS decreased during the pulp preparation but did not change much after the enzymatic treatment.

The changes in the composition of the NS during papaya juice preparation is shown in Fig. 8. The main NS in papaya are galactose and xylose followed by rhamnose and arabinose. It is unique that the amount of rhamnose in the tissue is higher than arabinose and glucose. During maceration the amount of all the NS decreased significantly, especially with higher rates than others, are galactose and arabinose. Enzymatic maceration of the tissue occurred mainly in rhamnose, galactose and arabinose. Glucose content increased more than in the untreated tissue, maybe because of cellulose degradation.

CONCLUSIONS

Preparation of the tropical juices by enzymatic maceration of mango, guava and papaya was accompanied by a decrease in the AIS content, especially in carbohydrates. In all the fruits we observed many changes during the processing. In general galacturonic acids decreased much more than the neutral sugars. Although the NS did not much decrease, their composition changed during the processing steps.

Table No. 26 Comparison of the activities of commercial pectinases

Source of the enzyme	Pectin esterase (PE) µmole COOH/mg min enzyme a	Polygalacturonase (PG) 50% decreasing in viscosity values b	Pectin Lyase (PL) O.D. 235 nm c	PE + PG + PL 50% decreasing in viscosity values (min/mg enzymes d
C-80	0.320	13.66	2.1	0.46
Pectinex 3x	0.084	29.05	2.5	0.50
Ultrazyme 100	0.064	45.00	5.0	0.3
C-600	0.100	22.50	2.6	12.5

a. Pectinesterase was tested at pH 5.5 with 0.5% pectin including 0.1M NaCl and 1 mg enzyme.

b. Polygalacturonase was tested with 1% polygalacturonic acid in buffer sodium acetate pH 4.5 including 0.1mg enzyme. The time for 50% decreasing in viscosity values of the substrate was chosen as a standard assay.

c. Pectin (0.5%) was dissolved in 0.1M Na-acetate pH 4.5 and incubated at 40° for various length of time till one hour and the absorbance at 235 nm was learned.

d. 0.5% pectin (P.E. 72% M.W. 84.000) was chosen for learning the total decreasing in viscosity of the three of the pectinases (PE, PG, PL) together. The time for 50% decreasing in viscosity values of the substrate was chosen as a standard assay.

Pectinase C-80 and C-600 were received from Gist Brocades. Pectinex 3x and ultrazyme 100 from Novo.

Table 27. Contents of mango alcohol insoluble solids during various steps of juice maceration

Process Step	A.I.S. (%)
Fruit	2,59
Pulp	2,30
Macerated Pulp	1,98
Cake	11,65
Juice	0,42

Table 28. Changes in the content of galacturonic acids and neutral sugars during mango juice preparation

Treatments	Galacturonic acids mg/100g.F.W.	Neutral Sugars mg/100g.F.W.
Fruit	1068	423.2
Pulp	859.6	387.4
Mecerate	615.3	384.4
Cake	183.8	329.2
Juice	431.5	95.6

* g.F.W. - grain Fresh Weight.

Table 29. Changes in the pectic substances of mango fruit during the maceration.

mg/100 g.F.W.

Treatments	Water soluble pectin	EDTA soluble pectin	NaOH soluble pectin	Residual cell wall
Fruit	499	99.9	66.1	402
Pulp	310.4	55.6	33.6	400
Macerate	343.5	61.4	37.1	172
Cake	62.0	8.8	12.0	49.2
Juice	360.0	-	-	71.8

Table 30. Content of alcohol insoluble solids from guava after various steps of it's maceration.

Process step	A.I.S. (%)
Fruit	4.25
Pulp	3.85
Macerate	3.82
Cake	25.97
Juice	0.38

Table 31. The changes in the content of galacturonic acids and neutral sugars diuring guava juice preparation

Treatments	Galacturonic Acids mg/100 g.F.W.	Neutral Sugars mg/100 g.F.W.
Fruit	1347.3	850.7
Pulp	1385.6	770.3
Macerate	1387.6	757.0
Cake	1274.-	694.6
Juice	113.6	62.4

Table 32. Preparation of alcohol insoluble solids from papaya in the various steps of juice manufacture

Process Step	A.I.S. (%)
Fruit	1.55
Pulp	0.91
Macerated Pulp	1.48
Cake	12.29
Juice	0.5

Table 33. Total Amount of Galacturoic acids and neutral sugars in Papaya

Treatments	Galacturonic Acids mg/100g.F.W.	Neutral Sugars mg/100g.F.W.
Fruit	418.4	99.2
Pulp	322.2	73.5
Macerate	139	73
Cake	53.6	72.5
Juice	60.5	9.9

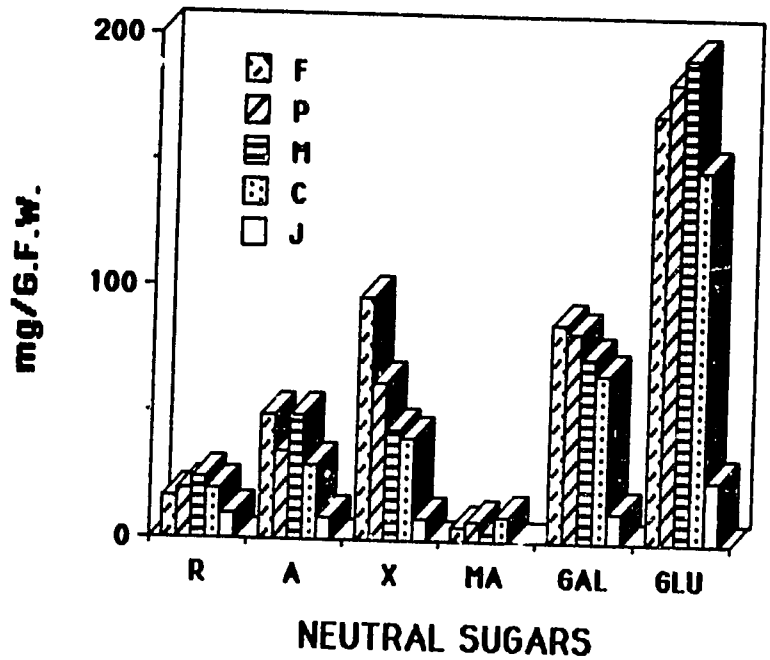


Fig. 4. The composition of the neutral sugars in mango cell wall. F-fruit, P-pulp, M-mecerate, C-cake, J-juice.

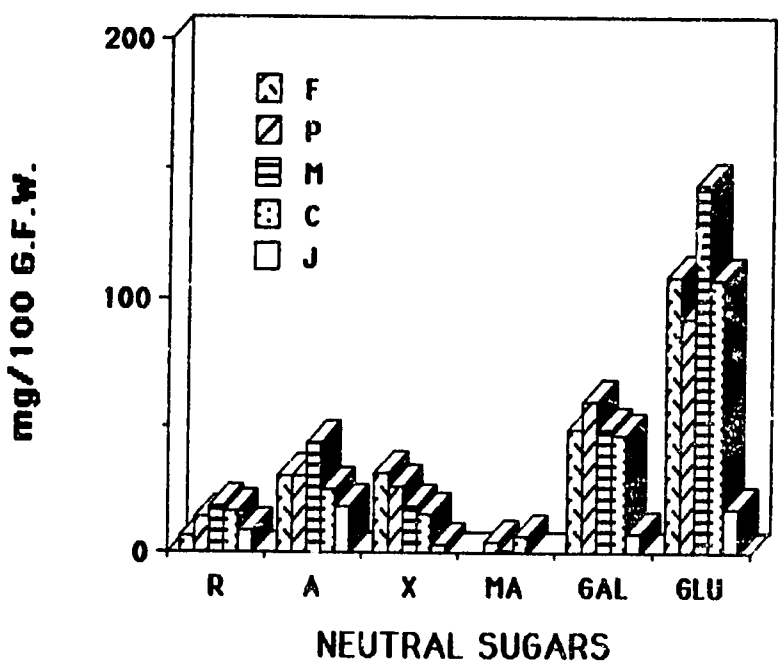


Fig. 5. The composition of the neutral sugars in the EDTA soluble pectin of the mango fruit.

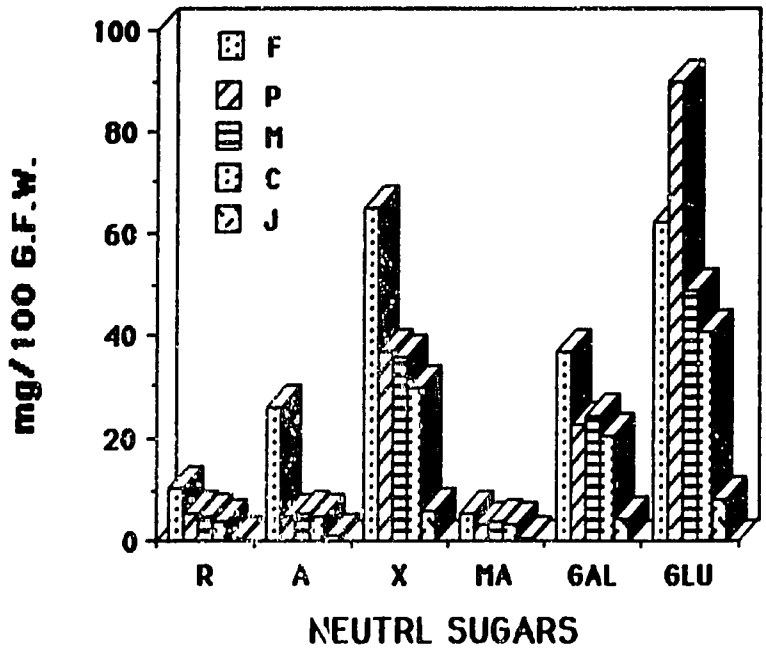


Fig. 5. The composition of the neutral sugars in the insoluble residue of the cell wall of the mango fruit.

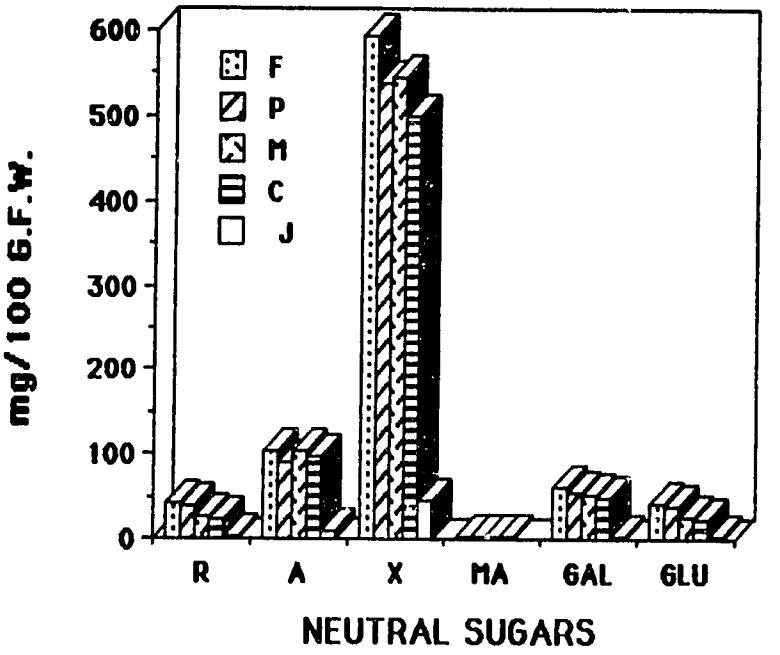


Fig. 7. The composition of the neutral sugars in the guava cell wall.

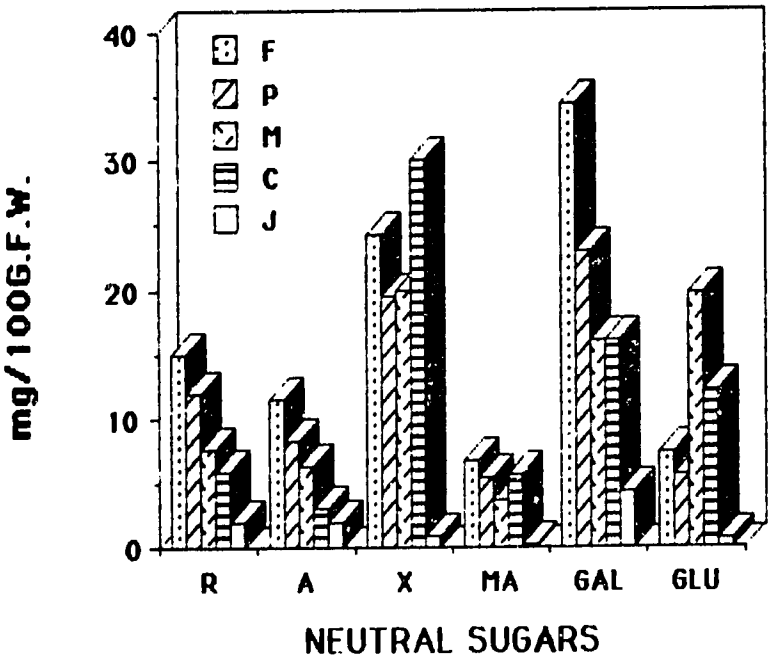


Fig. 8. The composition of the neutral sugars in the papaya cell wall
F-fruit, P-pulp, M-macerate, C-cake, J-juice.

5. SOME ECONOMICAL ASPECTS OF THE TROPICAL FRUIT JUICES MARKETING FROM DEVELOPING TO DEVELOPED COUNTRIES.

There is already an excess of production of many sub- and tropical fruits in the developing countries (DC) and even more in the least developed countries (LDC). On the other hand, there are very few tropical fruit products (TFP), specifically those, produced by more advanced "know-how" of industrial methods and more sophisticated equipment. For example, at least 25% of the world's production of bananas, were (and are) not utilized. Even in Costa Rica, 160,000 tons bananas rejected for export, were wasted (Viques et al.,*1981). Parallelly with that, about 90% and more of the banana products exported, are pulps, purees, etc. serving mainly as a semi-elaborated raw-material for more sophisticated products, in the developed countries, such as "baby foods" etc.

Parallelly with the existing huge surplusses of tropical and subtropical fruits, there is a rising demand for tropical fruits' liquidform products (TFLP), such as nectars, etc. According to Olesen, (1990) - the world export of semi-liquid and liquid fruit products, increased about four-fold between 1977 and 1988. It reached a value of about a 4.0 billion US$ in 1988. The main reason for this increase, according to Olesen (1990), is that more and more consumers prefer the tropical fruits "exotic" flavors. Even the increase in exports from 1984 to 1988 was from 2.8 to 4.0 billion US$. TFLP, except pineapple (3.5%), or citrus (82%), contributed to less than 5% (about 150 million US$) in 1988, therefore the possibilities are obvious. The Phillipines, Thailand and Brasil were the leading exporting countries of TFLP, but they mainly exported pineapple concentrates and juices. (Brasil is also the undisputed leader of the export of Orange LP). The main importing countries were the US, Germany etc. Switzerland and the Netherlands even imported some TFLP, to re-export them in more sophisticated form (Olesen, 1990). Parallelly with the increase in

TFLP, a decrease in export of other fruit juices and concentrates was observed. For example, the export of tomato juice decreased from 0.8% in 1984 to 0.4% in 1988 (of the world exports value).

It is quite clear that the probability to increase the consumption of TFLP worldwide and in this way to increase the export of both single-strength and concentrated tropical fruit juices are excellent. Therefore the development of such products and specifically the enzymatically macerated ones (which can be concentrated), would hopefully result in better utilization of the huge surplusses of many sub-tropical and tropical fruits, for the benefit of the developing countries in general and their agriculture and food industry in particular. This agroindustrial development would probably provide more possibilities for employment of the underemployed population of the DC and hopefully for the LDC.

6. REFERENCES

Albersheim, P., Nevins, J.D., English, P.D. & Karr, D. (1967). A method for the analysis of sugars in plant cell wall polysaccharides by gas-liquid chromatography. Carbohydr. Res., 5, 340-5.

Albersheim, P. (1974); The primary cell wall central control of elongation growth. In "Plant Carbohydrate Chemistry" (J.B. Pridham, ed). Academic Press, London.

Askar, A., El-Samahi, S.K., Abd El-Baki, M.M. and Abd-El Fadel M.G. (1981 A); Concentration of mango juice. 1. Evaluation of four methods of mango juice concentration; Chemie, Mikrobiologie, Technologie der Lebensmittel, 7(3): 70-76.

Askar, A., El-Samahi, S.K., Abd El-Baki, M.M. and Abd-El Fadel M.G. (1981 B); Concentration of mango juice II. Aroma deterioration during concentration. Chemie, Mikrobiologie, Technologie, der Lebensmittel, 7(4): 102-106.

Asfinall, G.O., Craig, J.W. and Whyte, J.L. (1986); Lemon peel pectin; Carbohydr. Res. 7: 442.

Bagar, M.R. (1980); Vitamin C content of some papaya, New Guinean fruits: J. Food Technol. 15: 459.

Barret, A.J. and Northcote, D.H. (1965); Apple fruit pectin substances; Biochem. J. 94: 617.

Bhatnagar, H.C. and Subramanyam H. (1973); Some aspects of preservation, processing and export of mango and its products. Indian Food Packer 27(4): 33-52.

Blumenkrantz, N. and Subramanyam, H. (1973); New method for quantitative determination of uronic acids. Anal. Biochem. 34: 484.

Brekke, J.E. and Tonaki K.I. (1970); Stability of guava puree concentrate during refrigerated storage. J. Food Sci. 35: 469-471.

Brekke, J.E, Chan, M.T. and Cavaletto C.G. (1973); Papaya puree and nectar Hawaii Agricult. Expt. Sta. Res. Bull. 170.

Brekke, J.E., Cavaletto, C.G., Stafford, A.E. and Chan H.T. Jr., (1975); Mango: Processed products, U.S. Dept. Agric. Res. Serv. in Coop. with Hawaii Agric. Expt. Sta. ARS-W23.

Brekke, J.E., Cavaletto, C.G., Nakayama, T.O.M. and Suehisa R.H. (1976); Effect of storage temperature and container lining on some quality attributes of papaya nectar. J. Agric. Food Chem. 24: 341-343.

Brekke, J.E. et al. (1977); Operating mannual for papaya puree processing. Hawaii Agric. Expt. Sta. Coll. Trop. Agric. Univ. of Hawaii, Dept. Ppr. 47.

Calderon, L. Ruth and Aguilar, V.F. (1987); Some production aspects of the cultivars: Papaya, Mango and Guava cultivated in Costa Rica. Centro Investig. Tecnol. Alimentos, Univ. Costa Rica pp 11-16.

Chan, H.T. Jr. et al. (1973); Development of off-odors and off-flavors in papaya puree: J. Agric. Food Chem. 21: 566-570.

Chan, H.T. Jr. Kuo, T.M., Cavaletto, C.G., Nakayama, T.O.M., and Brekke, J.E. (1975); Papaya puree and concentrate: changes in ascorbic acid, carotenoids and sensory quality during processing. J. Food Sci. 40: 701.

Chan, H.T. Jr. and Kwok, S.C.M. (1975A); Identification and determination of sugars in some tropical fruit products. J. Food Sci. 40: 419.

Chan, H.T. (1975B); Importance of enzyme inactivation prior to extraction of sugars from papaya. J. Food Sci. 40: 770.

Dekker, R.F.H. (1982); The semicellulase group of enzymes-in "Polysacharides in Food" (J.M.V. Blonshand and J.R. Mitchell, Eds.) ButterWorths, London - Boston.

Dhingra, M.K., Gupta, O.P. and Chundawat B.S. (1983); Studies on pectin yield and quality of some guava cultivars in relation to croping season and fruit maturity. J. Food Sci. Technol. India: 20(1): 10.

Doesberg, J.J. (1965); Pectic subtances in fresh and preserved fruits and vegetables. Communic. No. 25 Inst. Res. Stor. Proc. Horticult. Prod. I.B.V.T. Wageningen, The Netherland.

Fuchs, Y., Pesis, E. and Zauberman, G. (1980); Changes in amylase activity in mango fruit and pulp, Sciencia Hoertic. 13(2): 155.

Hugo, J.F., Du, T. (1981); Production of pulps for nectar from apricot, guava. Food Industr. South Africa 34(6): 34.

Hunter, G.L.K., Bucek, W.A. and Radford, T. (1974); Volatile components of canned Alphonso mango. J. Food Sci. 39: 900.

Imugi, J.K., Scheffeldt, P. and Saint-Hilair P. (1980); Physico-chemical changes during extraction and concentration of clear guava juice: Lebensmit. Wiss. Technol. 13: (5) 248.

Jarvis, M.C. (1984); Structure and properties of pectin gels in plant cell walls: Plant cell and environment 7: 153.

Jones, T.N. and Albersheim, P. (1972); A gas chromoatographic method for the determination of aldose and uronic acid of plant cell wall polysacharides. Plant Physiol. 49: 926.

Kay, D.E. (1966); The market for mango products. Trop. Prod. Inst. Rpt. G 17, London.

Khedkar, D.K., Patil, V.K. and Dabhade, R.S. (1980); Studies on preparation of tutti fruiti from raw papaya (Carica Papaya Linn.) fruit: J. Food Sci. Technol., (India): 17 197.

de Leon, S.Y. and de Lima L. (1966); Acceptability of canned mango juice from four varieties and three color stages of maturity, Philip. J. Sci. 95(4): 401.

Levi, A., Gagel, S. and Juven, B.J. (1983); Intermediate moisture tropical fruit products for developing countries. I. Technological data on Papaya, J. Food Technol. 18: 667.

Levi, A., Gagel, S. and Juven B.J. (1985); Intermediate moisture tropical fruit products for developing countries. II. Quality characteristics of papaya. J. Food Technol. 20 J. Food Technol. 20: 667.

Levi, A., Ramirez-Martinez, J.R. and Padua, H. (1980); Influence of heat and sulphur dioxide treatments on some quality characteristics of intermediate moisture banana. J. Food Technolo. 15: 557.

Luh, B.S. (1980); Tropical fruit bevereges; in "Fruit and vegetable Juice Processing Technology", ed. Nelson P.E. and Tressler D.K. Avi Publ. Co. Westport, Conn.

Mahadevia, M. et al. (1975); Studies on the internal corrosion of tin plate with mango (Mangifera Indica L.) Juice. Indian Food Packer 29(1): 5.

Nakasone, H.Y., Brekke, J.E. and Cavaletto, C.G. (1976); Fruit and yield evaluation of ten clones of guava (Psidium guajava L.) Hawaii Agric. Expt. Sta. Res. 218.

Nelson, D.B., Smith, C.B.J. and Wiles R.R. (1977); Commercially important pectic substances, in "Food Colloids" (ed. by H.O. Graham); Avi. Publ. Westport, Conn. p. 418.

Neukom, H., Amado, R. and Pfister, M. (1980); Neure Erkenntnisse auf dem gebieta der pektinstoffe, Lebensm-Wiss. Technol. 13:1.

Olesen, K.R. (1990); Rising demond for tropical fruit juices and pulps: Intern. Trade Forum. Oct-Dec, 1990; 12-17.

Orr, K.J. and Miller, C. (1955); Description and quality of some mango varieties grown in Hawaii and their suitabitly for freezing. Hawaii Agric. Expt. Sta. Tech. Bull. 26.

Padula, M., Rodriguez-Amaya D.B. and Moraes M.A.C. (1983); Comparison between the carotenoid composition and general properties of the processed juice of guava cultivar IAC-4 and commercial juices; Ciencia e Technologia de Alimentos, 3(2): 109.

Pal, D.K., Subramanyam M.D., Divakar, N.G., Iyer, C.P.A. and Selvaraj Y. (1980); Studies on the physico-chemical compostion of twelve papaya varieties, J. Food Sci. Technol. (India), 17: 254.

Paraz, P. (1990); Tropical fruits as food ingredients, Food Australia 42(5): 273.

Peleg, M. and Gomez Brito L. (1974); External color as a maturity index of papaya fruit: J. Food Sci., 39: 701.

Proctor, J.T.S. and Greasy L.L. 1969); The anthocyanin of mango fruit: Phytochem. 8: 2108.

Pilnik, W. and Voragen, A.E.T. (1970); Pectic substances and other uromides; in Biochemicstry of fruits and their products, ed. by Hulme, Academic Press, London - New-York: 53.

Ramirez-Martinez, J.R. Levi, A., Padua, H. and Bakal A. (1977); Astringency in a intermidiate moisture banana product: J. Food Sci. 42: 1209.

Rodrigues A.J. and de George L.M. (1972), Evaluation of papaya nectar from unpeeled papaya puree. J. Agricult. Univ. Puerto Rico. 56: 79.

Rees, D.A. (1977); Polysacharide shapes: Chapman, L. and Willey, H.J. and sons, New York: p. 46.

Rombouts, F.M. and Pilnik, W. (1971); Pektolytische enzyme in der Fruchtsaftindustrie. Flussiges Obst. 38: 93.

Saed, A.R., El-Tinay A.H. and Khatab A.H. (1975A); Viscosity of mango nectar as related to pectic substances. J. Food Sci. 40 203.

Saed, A.R., El-Tinay A.H. and Khatab A.H. (1975B); Characterization of pectic substances in mango. J. Food Sci. 40: 205.

Saenz, Ch.A. and Murillo, F. Adrian (1989); Bol. Tecnico No. 73. Programa Nacional Sectorial de Mango. M.A.G. San Jose, Costa Rica.

Sanchez-Nieva, F., Rodriguez, A.J. and Benero, J.R. (1959); Processing and canning mango nectars. Univ. Puerto Rico. Agric. Expt. Sat. Bull. 158.

Siddappa, G.S. and Bhatia B.S. (1955); Effect of retention of peel on the quality of canned mango slices. Food Packer (India): 9(7): 9.

Sloneker, J.H. (1972); Gas liquid chromatography of alditol asetates In: Whistler, R.C. and Bemiller, J.N. (eds.) Methods in carbohydrate chemictry. Academic Press: Mew York, London p. 20.

Sreekantiah, K.R., Jaleel, S.A. and Rao T.N.R. (1986); Preparation of fruit juice by enzymic processin. J. Food Sci. Technol. 5(3): 129.

Tandon, D.K. and Karla S.K. and Rao T.N.R. (1968); Changes in sugars, starch and amylase activity during development of mango fruit cv. Dasheari. J. Hortic. Sci. 58(3): 449.

Thomas, P. (1975). Effect of post-harvest treatment on ripening. J. Food Sci. 40: 704.

Taiz, L. (1984); Plant cell expension. Ann. Plant Physiol. 35: 585.

Van Buren, J.P. (1979); The chemistry of texture in fruits and vegetables. J. of texture study 10:1.

Viques, F., Lastreto, C. and Cook, R.D. (1981); A study of the production of clarified banana juice using pectinolytic enzymes. J. Food Technol. 16: 115-125.

Worth, H.E.T. (1967); The chemistry and biochemistry of pectic substances: Chem. Rev. 67: 465.

Yamasaki, M., Yasui, T. and Arima, K. (1967); Pectic enzyme in the calrification of apple juice. Agr. Biol. Chem. 31: 552.