DIVISION OF ENTOMOLOGY
BOARD OF AGRICULTURE AND FORESTRY
HONOLULU, HAWAII

COMMERCIAL *Guava Processing* IN HAWAII

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UNIVERSITY 50 OF HAWAII
FIFTIETH ANNIVERSARY

Hawaii Agricultural Experiment Station

University of Hawaii

June 1957 Bulletin 111

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ACKNOWLEDGMENTS

The funds and facilities which made possible this report on the commercial processing of guavas were supplied through a grant to the University of Hawaii by the Industrial Research Advisory Council (now known as the Hawaii Economic Planning and Coordination Authority).

Additional funds for some of the processing phases were supplied under a contract with the U. S. Department of Agriculture and authorized by the Research and Marketing Act of 1946. The contract was supervised by the Western Utilization Research Branch of the Agricultural Research Service.

The authors are grateful for the assistance of Francis A. I. Bowers, Junior Horticulturist at the Hawaii Agricultural Experiment Station, for supplying most of the fruits which were used in this project, and to Thomas N. Shaw, Assistant Food Technologist at the Food Processing Laboratory at the University of Hawaii, 1950–55, now President of Hawaiian Juice Industries, Ltd., for aid and advice in this project.

COMMERCIAL GUAVA PROCESSING IN HAWAII

Frank P. Boyle, Henry Seagrave-Smith, Seiji Sakata, and G. Donald Sherman

INTRODUCTION

The guava is the most important pomiferous fruit of the Myrtle family. Hedrick (*1*) lists 15 species of the genus *Psidium*, all of which are native to tropical America. Only one species, *Psidium guajava* L., is grown commercially to any great extent and this species has been introduced into the West Indies, Florida, India, West and South Africa, and several of the Pacific island groups. This is the species which grows wild in the wet valleys and on the mountain slopes throughout the Territory of Hawaii.

History in Hawaiian Islands

Don Marin, horticulturist in charge of the Royal Gardens, is credited with having brought the common guava to Hawaii prior to 1800. Undoubtedly, it was planted by traveling Hawaiians in many of the valleys on the other islands soon after this, because by the middle of the nineteenth century the tree was growing wild. Birds and other animals which eat the fruit probably aided in distributing the seeds widely. In many locations in the Territory it has become a pest, taking over large areas of land.

The ripe fruit can be eaten fresh and has been popular for jams and jellies for a long time. Commercial manufacture of jams and jellies started in the early 1920's and continues to grow steadily, especially as the sale on the Mainland augments the local consumption. Other products, mainly canned nectar drinks, have been manufactured for a number of years and have been introduced to the mainland market to a limited extent. These products will be discussed in more detail in subsequent sections of the bulletin.

Description of Fruit

The fruit of the common guava tree has a rough-textured yellow skin and varies in shape from round to pear-shaped. In the wild, individual fruits from 1 to 3 inches in diameter are found, but under cultivation the size can be increased to 5 inches and the weight to 1½ pounds. 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 puree per unit weight than the thin-fleshed types. The distinctive musky flavor is more intense in some selections than in others and the acidity varies, too, from those with a pH of 3.0 to a few which have a pH of 4.0. The majority of the common guavas in Hawaii fall into the sour or sub-acid category (pH 3.0–3.5).

From a nutritional standpoint, even the wild guavas are superior to oranges in vitamin C content. One of the wild selections from the island of Maui contains 600–700 milligrams of vitamin C per 100 grams of fruit, 10 times the amount found in oranges. Many reports in the literature single out guava as an excellent source of this important vitamin (*2, 3, 4, 5, 6, 7*). It is a fair source of vitamin A, calcium, and phosphorus and also contains some iron, thiamine, and niacin.

Wild Versus Cultivated Fruit

The statement has been made that only 10 percent of the wild guava fruits are being utilized in the homes and food processing plants of the Territory. Therefore, why should anyone be concerned about planting the trees in orchards? First of all, the majority of the fruits which are not harvested are located in inaccessible areas or in places where it would not be economically feasible to pick them. The wild fruits vary extensively in all of the quality factors which processors would like to control in the raw product, such as color, flavor, yield of puree, acidity, soluble solids, and vitamin content. In order to manufacture a finished product of uniform high quality, it would be necessary for the processor to analyze each separate lot brought to him by pickers and to blend skillfully the different lots. This is impracticable unless the processor is willing to grade out or discard those fruits which are below minimum standards of raw product quality. Furthermore, the trees growing in the wild are apt to be crowded, lacking in essential mineral element balance, and liable to insect and disease damage.

From the standpoint of the processor, selected guava seedlings or varieties grown in orchards would assure him of uniform quality fruit. Since guava trees grow well on land which is considered marginal for other crops, there are many areas in the Territory of Hawaii where it would be feasible and profitable to grow this fruit as a cultivated orchard crop. Growers could propagate vegetatively one or more of the desirable types of fruits by any of the methods described in Extension Bulletin 63, University of Hawaii (*8*). High yields of excellent-quality fruit could be expected where good orchard management is practiced, such as fertilizing, irrigating, pruning, and control of weeds, insects, and diseases. Harvesting would be more economical and might be mechanized to some extent. Another advantage of orchard culture, both for the grower and the processor, would be the production of fruit from selections which mature in the off-season. The grower should get a premium price for this fruit and the processor would have fresh fruit available during some of the months when wild fruit is scarce.

For the past several years a cooperative program of analysis and propagation of selected wild fruit and varieties from other countries has been carried out by the Food Processing Laboratory at the University of Hawaii and the Department of Horticulture. Table 1 gives the results of analyses of some of the more promising seedlings which have been evaluated. Many more fruit types were tested than are reported in the table but were discarded due to lack of one or more quality factors which were considered essential for a good processing guava. After considerable experience with the variations in the fruits and with the products to be made from them, a list of desirable characteristics was compiled to aid in screening guavas being tested for processing. These goals are enumerated in table 2. Large fruits with thick outer flesh and small seed cavities yield more puree. Guavas with few seeds and small quantities of stone cells are desirable, provided they have the other essential qualities. The more acid fruits, pH 3.3 to 3.5, are better for processing than the sweeter fruits. Without a doubt, good color and flavor and high vitamin C content are the most important factors in selecting fruit types for processing. For the very near future, processors will not have much control over most of these quality factors; uniform high quality will be attainable only when the best selections are cultivated commercially.

PROCESSING

In the foregoing sections the qualities of the fresh fruits have been emphasized. In this section, each unit operation for preparing and processing the fruit into a puree will be described briefly. Depending on the size of the processing plant, modifications of each operation may be made by individual plants. Smaller plants undoubtedly will use more manual operations, whereas larger plants will need to mechanize as much as possible. There is no "best" way for any unit operation. Methods for each have been adapted from practices of other fruit processors and have been tried out and modified in the pilot plant of the Food Processing Laboratory at the University of Hawaii. A generalized flow sheet for guava processing is shown in figure 1. Tressler and Joslyn present a thorough discussion of juice processing in their recent book, *The Chemistry and Technology of Fruit and Vegetable Juice Production (9).*

TABLE 1. Quality Measurements of Fruit from Selected Hawaiian Guava Seedlings

SEEDLING NO.	NO. FRUITS TESTED	AVERAGE DIAMETER OF FRUIT	AVERAGE WEIGHT OF FRUIT	PERCENT SEEDS	COLOR OF PUREE	FLAVOR	SOLUBLE SOLIDS	pH	VITAMIN C MG./100 G. FRESH WEIGHT	COMMENTS
		in.	*oz.*	%			%		*mg.*	
B-30	11	2½–3	8.3	1.6	strong pink	normal, mildly sour	8.0	3.52	143.8	Good flavor and color, soluble solids low, vitamin C satisfactory.
D-31	13	2½–3	6.0	3.7	light pink	normal, sour	11.5	3.26	158.2	Good flavor, color weak, soluble solids and vitamin C satisfactory.
P-1	3	2–2½	3.5	4.1	strong pink	normal, slightly sweet	10.6	4.0	207.9	Small in size, color fine, too sweet.
Lupi-1	6	2¾	6.3	4.4	medium pink	mild, slightly sour	9.8	3.7	492.0	Flavor and color weak, vitamin C outstanding.

TABLE 2. Quality Goals for Selecting Guavas for Processing

DIAMETER OF FRUIT	WEIGHT OF FRUIT	pH	SOLUBLE SOLIDS	VITAMIN C	COLOR	FLAVOR	YIELD OF PUREE
3.3–3.5	8–24 oz.	3.3–3.5	9–12%	300 mg./100 g. or more	strong pink	typical guava, no off-flavors	90%

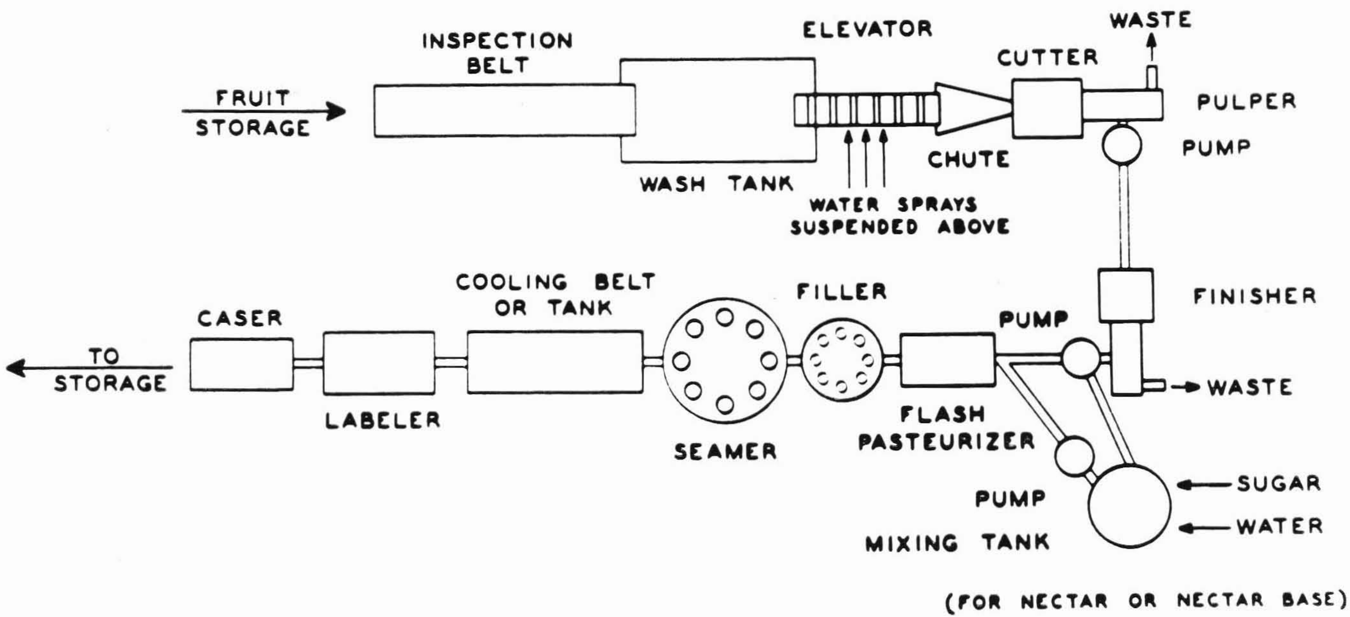

FIGURE 1. **Flow Sheet for Guava Processing Line** (for frozen products by-pass pasteurizer and cooling belt).

Harvesting

For several years to come the bulk of guavas brought to plants will be those collected by pickers of wild fruit. Firm, yellow, and mature fruit with no signs of insect or fungus damage should be sought. A bonus for fruit of this type, as well as with good flavor, color, and vitamin content might pay off for the quality-conscious processor. Half-ripe fruit can be stored at 36°–40° F. and allowed to ripen but there is bound to be some loss. Green fruit should not be processed since it does not have full flavor nor will it yield as much puree as the fully mature fruit. The best wild fruit obtainable probably can be furnished by the pickers if the buyer insists on quality and is willing to pay for it.

Cost of harvesting will be reduced when sufficient quantities of cultivated guavas become available. Partial mechanization of harvesting as well as greater yield and size of fruits will help to reduce this cost.

Transportation to Processing Plant

Speed and careful handling are necessary for this phase of the operation. Guavas picked at peak maturity will not keep well, so there should be no delay in getting them to the plant where they can be processed immediately or held in refrigerated storage. Small wooden boxes are preferable to orange crates for carrying the fruit because of the ease with which the ripe fruits are crushed or bruised. Damaged fruit deteriorates very rapidly, starts to ferment, and must be discarded at the plant, especially if it is held for any length of time before processing.

Large quantities of guavas are shipped from one island to another in Hawaii, which poses special problems in transportation. Again the fruit should be packed in small boxes to prevent damage, and if shipped ripe, should be refrigerated. Transporting by barge at night is preferable to daytime shipping, but if transported during the day some protection from the sun should be provided. Perhaps the best practice under present conditions would be to ship by water only those fruits which are firm and slightly underripe, and to finish off the ripening under controlled conditions at the processing plant.

Storage of Fresh Fruit

Mention has been made several times about refrigerated storage of fresh fruit at the processing plant. Fully ripe guavas should be processed without delay, but if necessary they can be held for about a week at 36°–45° F. Using vitamin C retention as a measure for quality in stored fruits, the data in table 3 indicate that there appears to be only a small loss after seven days at the two storage temperatures used. To prolong the storage life by another week or so, the guavas may be kept at

TABLE 3. Retention of Vitamin C by Whole Guavas Stored at 36° and 45° F. and 90% Relative Humidity

NO. OF DAYS IN STORAGE	TREE 1 (PINK FLESH)		TREE 2 (PINK FLESH)		TREE 3 (PINK FLESH)		TREE 4 (PINK FLESH)		TREE 5 (WHITE FLESH)		TREE 6 (PINK-ORANGE FLESH)	
	36°F.	45°F.	36°F.	45°F.	36°F.	45°F.	36°F.	45°F.	36°F.	45°F.	36°F.	45°F.
	mg.*	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.
0	96	96	102	102	95	95	114	114	187	187	90	90
1	99	101	91	98	102	101	119	102	145	177	94	76
2	98	101	97	101	97	98	116	108	170	166	64	81
3	93	99	93	102	90	114	112	98	172	178	80	85
4	----	----	74	105	96	86	110	106	160	188		
6	100	92		----					96	182		
7	88	106		108					92	157		

*Milligrams of vitamin C per 100 grams of fruit remaining after storage for stated number of days.

TABLE 4. Retention of Vitamin C by Whole Guavas Stored at 0° F.

NO. OF DAYS IN STORAGE	POAMOHO TREE NO. 1	POAMOHO TREE NO. 2
	mg.*	mg.
0	93	103
1	97	----
2	106	----
3	108	101
6	109	----
7	118	120
8	115	----
9	105	----
10	99	----
11	----	113
13	110	106

*Milligrams of vitamin C per 100 grams of fruit remaining after storage for stated number of days.

0° F., which is a storage temperature used commercially in Hawaii. Table 4 shows the effects of storage at this temperature on the retention of vitamin C.

Green fruits can be held at room temperature in boxes or bins until they have ripened, but they should be protected from the weather and from insects and rodents. Good ventilation will help to prevent losses due to spoilage.

Inspecting and Washing

When guavas are ready for processing they should be dumped out on an inspection belt. Here the badly spoiled fruit should be removed and the green fruit set aside for ripening. Those fruits which have only small areas damaged due to insects, diseases, or overmaturity may be trimmed to make them acceptable for processing.

From the inspection belt the sound fruits drop into a washing tank or onto a washing belt. Mechanical or manual agitation and the addition of a detergent help to remove dirt, debris, and dried-on flower parts. An elevator belt onto which clear water is sprayed removes the fruits from the washing bath and rinses off the detergent from the skins.

One type of inspecting and washing set-up is shown in figure 2.

FIGURE 2. **Inspecting and washing of whole guavas before processing. (Courtesy Hawaiian Juice Industries, Ltd.)**

Pulping

Guava is one of the easiest fruits to process since the whole fruit is fed into a paddle pulper for macerating into a puree. If the fruits are rather firm, it may be necessary to attach a chopper or slicer to the hopper which feeds into the machine. Several food machinery companies manufacture pulpers and chopping attachments in enough sizes to fit the needs of different-sized plant operations. To remove seeds and fibrous pieces of skin tissue, the pulper should be fitted with 0.033- or 0.045-inch perforated screens. Chopping of all fruit, whether firm or soft, before feeding into the pulper may be desirable since it allows for a more uniform rate of feed. This is important because the rate of feed, as well as the speed and adjustment of the paddles, controls the amount of waste being discharged from the machine. Non-uniform movement of the material through the pulper may cause discoloration of the puree.

Removal of Stone Cells

Throughout the outer flesh of nearly all guava types found in Hawaii there is a considerable number of hard stone or grit cells. These are exactly the same kind of cells that one finds in pears. Removing the majority of the stone cells not only improves the texture of the final product but also enhances the color. Being yellowish or tan in color, the stone cells "dilute" the bright pink that is sought for finished guava puree.

One good method for getting rid of these unwanted cells is to pass the puree through a paddle finisher equipped with 0.020-inch screens. This machine is exactly like the pulper except that the steel paddles are replaced by neoprene rubber strips held in place by stainless steel or hardwood cleats. The rubber paddles can be adjusted so that they almost touch the screen and the angle should be decreased from that at which the paddles are set for the pulping operation. For this operation, the speed of the machine is reduced to 600–800 rpm. and the puree is fed into the hopper at a uniform rate. Adjustment of paddles, pitch, speed, and waste gate should be continued until the waste is slightly moist.

Another method of finishing is to run the puree through a mustard mill so that the stone cells are pulverized. This does reduce the grittiness but does not improve the color. Both methods described above are in use by guava processors.

Mixing, Heating, Deaerating, Filling, Seaming, Cooling, Labeling, Casing

These unit operations in the processing of guava are described in more detail in the sections on guava puree and guava nectar which follow. Some of the steps may be carried out manually or they may be mechanized, depending on the size of the plant. The use of lithographed cans eliminates the labeling operation, and the casing operation, again, may be performed by hand or by machine.

Packaging

At present a suitable metal container for heat processed guava products is not available in Hawaii. Of the two types of cans, plain and single-coat citrus enamel, which are supplied to processors, the enameled container is more satisfactory. The enameled can is the same one which is called "citrus" or "T" enamel by the can companies. After prolonged storage even the enameled can imparts a tinny or metallic flavor to the guava products. In a one-year storage test the metallic aftertaste imparted to guava nectar was much stronger when the plain tin was used than when the enameled can was used. The color was bleached from the nectar stored in plain tin while that packed in enameled cans was better in color. Heavy feathering was observed in the plain versus numerous lines and spots on the inside of the enameled cans. This storage test indicated that the enameled can is somewhat superior to the plain can but better containers are needed for canned guava nectar.

TABLE 5. Effect of Container on the Quality and Iron Content of Canned Guava Nectar (Nectar canned at 175° F. for 60 seconds)

TYPE OF CONTAINER	COLOR	FLAVOR	IRON CONTENT IN NECTAR MG./100 G.
T single coat citrus enamel	yellowish tinge	poor, metallic after-taste	50.0
N two coats of enamel (citrus enamel & vinyl)	salmon, less yellow	fair	0.5
N+ above and double side seam stripe	salmon, less yellow	fair	0.6
H two coats enamel (fruit enamels & vinyl)	salmon, less yellow	fair	0.6
H+ above and double side seam stripe	salmon, less yellow	fair	0.6

Several other enameled containers, "N", with two coats of enamel (citrus enamel and vinyl), and "H", with two coats enamel (fruit enamel and vinyl), by one manufacturer, were tested for corrosion-resistance along with the "T" enamel previously mentioned. Guava puree was heated to 175° F., filled into the various containers, air cooled, and then stored at room temperature (±75° F.). The results of various tests made on the stored samples are shown in table 5, indicating that the "N" and "H" enamels are superior to the "T". In addition to differences in color and flavor, these data show a much higher iron content in the "T" enameled cans.

For frozen puree or nectar base the "T" enameled cans are satisfactory. Thirty-pound tins lined with plastic bags are good for bulk handling of frozen puree or nectar base.

Wooden barrels have been used to some extent for shipping both heated and chilled guava products. Neither method is recommended since it takes too long for the heated puree to cool off and it also takes too long for barrels being chilled to reach low temperatures in the center. The use of a slush freezer might improve the quality of the chilled product since it would be put into the barrels at a low temperature and be kept at or below the freezing point during shipping and storage. There is a definite need for devising good methods for shipping bulk quantities of guava puree to mainland plants to be reprocessed.

Storage

Depending on whether one is dealing with frozen or canned products, it is obvious that the storage conditions will be quite different. Products to be kept and sold in the frozen state should be handled with the greatest expediency during processing, since no treatment is included to kill the microorganisms and to inactivate enzymes. Freezing preservation relies on slowing down the activities of enzymes and contaminating organisms so that the frozen foods reach the consumer in about the same state as when they were processed. In order to promote rapid freezing, it may be necessary to stack individual containers with plenty of air space around each one so that the circulating cold air in the freezing room or tunnel can come in contact with as much surface as possible. Once frozen, the containers should be cased and sealed and maintained at 0° F. or lower. Any time that the temperature rises in the storage warehouse the rate of deterioration increases and shortens the storage life of the frozen products.

Canned guava may be stored at ordinary warehouse temperatures, but, again, the higher the temperature and the longer it is stored, the more the product deteriorates in flavor, color, and nutritional value.

CANNED GUAVA PRODUCTS

Many food products can be manufactured from guavas. These products will be discussed under two main categories, those prepared by ordinary heat canning technique and those made by freezing and holding in frozen storage until consumed. A number of these products are already on the market, such as guava jam and jelly, canned guava nectar, frozen guava nectar base, and guava ice cream. The methods and formulae for making these products will be described in this section of the bulletin.

Canned Guava Puree

The methods for making puree have already been discussed, but several variations in procedure may be worth mentioning here. After pulping and finishing to remove the seeds and stone cells, it would be advisable to pump the puree through a deaerator to remove entrapped air. Several advantages of deaerating are apparent. First, the removal of oxygen lessens the deterioration caused by this gas during prolonged storage. Oxidation is one of the chief causes for loss in color, breakdown of vitamins, loss of flavor, and production of off-flavors. Second, the removal of air makes for a more uniform and smoother-looking product with improved color. Third, the prevention of foaming, as caused by mixture with air, allows correct and uniform fill of containers. This last advantage of deaeration is important, especially if a mechanical filler is used in the processing line.

There are two main methods adaptable for heat preservation of canned guava puree. One, the so-called batch process, involves heating the puree in a steam-jacketed kettle until it reaches 185° F. The second method, using a flash pasteurizer or heat exchanger, consists of heating to a high temperature for a much shorter period of time. For guava puree the recommended time-temperature relationship would be 60 seconds at 195° F. Other time-temperatures can be used. Although flash pasteurization does less damage to the flavor of guava puree, it still imparts a heated or "canned" odor and flavor to the product.

After heating, the puree should be filled immediately into the containers and then cooled by water sprays or some other method for lowering the temperature of the cans rapidly to 100°–120° F. From this temperature on, the cans should be stacked and air-cooled until they reach room temperature. Prolonged water cooling may result in external rusting of the cans. Casing and stacking in the warehouse while the cans are still hot may result in spoilage by thermophilic bacteria and also lower the quality of the puree due to heat damage (sometimes called stack burn).

Canned guava puree is the starting material for a number of other guava products. Sugar and water may be added to make a nectar drink. The puree can be used directly with commercial mixes for making ice cream, sherbet, and ice. As a flavoring for pastries, the straight guava puree or a sweetened puree may be used. Several fruit punch bases are already on the market which use guava puree as an ingredient. This outlet certainly will expand as more of the product becomes available and methods for shipping the puree in bulk are devised. Another use for guava puree, either sweetened or unsweetened, which has not been exploited to any great extent, but which appears to have a potentiality is manufacture as a baby food. From the standpoint of nutrition and flavor, the product should be popular.

Canned Guava Nectar

Several local processors have been marketing canned guava nectar for a number of years. The puree mentioned above is the basic ingredient for this palatable and nutritious fruit drink. Depending on the soluble solids of the puree, proportioned amounts of sugar and water are added to make the nectar drink. In general, winter fruit contains from 6 to 8 percent soluble solids and summer fruit from 8 to 10 percent. If possible, a measurement of the soluble solids of each batch of fruit should be made with a refractometer in order to control the final soluble solids of the nectar.

The following formula, having 20 percent puree by weight, is calculated so that the soluble solids of the finished product will be approximately 11 percent, and the acidity (depending on that of the original fruit pulp) will be between pH 3.3 and 3.5:

Guava puree (average soluble solids 7%)	100 pounds
Cane sugar	48 pounds
Water	352 pounds
Yield of nectar	500 pounds

Pour the water into a stainless steel mixing kettle or tank and add the sugar with mixing until it is dissolved. Then, add the puree at a steady rate while mixing thoroughly again. Next pump the mixture through a heat exchanger (60 seconds at 180°–190° F.), fill into containers, seam, and cool to room temperature. After labeling and casing, the cans are ready for shipping or warehousing.

Some processors and some consumers believe that the addition of a small amount of acid, such as citric acid, enhances the natural flavor of guava. Small-scale taste tests conducted at the Food Processing Laboratory at the University of Hawaii were inconclusive as to whether the tasters could detect those samples to which citric acid had been added or whether the samples with added acid had any better flavor.

Sodium benzoate may be added as a preservative up to the limit prescribed by law, provided that such an addition is stated on the label. The use of this or any other preservative, however, does not assure the processor that his product will not spoil. Careful checks for cleanliness in each step of processing and strict adherence to processing times and temperatures give much better assurance that the product will not spoil.

Clarified Guava Juice

There are undoubtedly some uses for guava where it is desirable to remove the color and insoluble solids. One possibility is the blending of guava juice with other fruit juices or extracts in which the processor wishes to retain the guava flavor but wants the color removed because the resulting mixture is lacking in color appeal or develops a "muddy" off-color. Other uses for the clarified product would be in the making of jelly or of clarified guava nectar.

Two methods for making clarified guava juice have been developed at the Food Processing Laboratory at the University of Hawaii. In the first method, whole guavas are frozen to help break down their internal structure and are kept in frozen storage until one is ready to use them. In the second method, the starting material is frozen guava puree. From here on, both processes are essentially the same, except that when whole guavas are used the yield of juice is less due to interference of the seeds in the pressing out of juice. After thawing, the fruits or puree are placed in a press cloth and the clear juice squeezed out by applying mechanical pressure. When puree is used, it is advisable to warm it to about 100° F., and to add a filtering aid before pressing. "Celite," a diatomaceous earth, at the rate of 1 percent by weight, thoroughly mixed with the puree, was found to be a good filtering aid.

The clarified juice may be blended then with other juices, made into jelly or clarified nectar, or heated and stored for future use. Since the flavor and odor of this juice are weaker than that of the guava puree, more of it must be used in juice products.

Clarified Guava Nectar

Starting with the clarified juice mentioned in the previous section, a palatable but mild-flavored guava nectar can be manufactured. For a finished nectar of 11 percent soluble solids, one must use 30 percent by weight of clarified juice as compared to 20 percent by weight of guava puree for making ordinary guava nectar. Here are the ingredients:

Clarified juice (average soluble solids 7%)	100 pounds
Cane sugar	29.5 pounds
Water	203.5 pounds
Yield of nectar	333 pounds

Mix all the ingredients thoroughly and pump through a flash pasteurizer at 190° F. at a rate which holds the nectar at this temperature for 60 seconds. In lieu of a pasteurizer, the nectar may be heated to 195° F. in a stainless steel steam-jacketed kettle. Filling, seaming, subsequent cooling, labeling, and casing are carried out exactly as for ordinary guava nectar.

Guava Jam and Jelly

Both jam and jelly made from guavas are included in the Federal Food, Drug, and Cosmetic Act standards of identity. The main points of the law as far as these two products are concerned are as follows:

1) The jams and jellies are made of mixtures composed of not less than 45 parts by weight of the fruit ingredient to each 55 parts by weight of one of the optional saccharine ingredients (for our purposes, sugar).

2) Such mixtures are concentrated by heat to such point that the soluble-solids content of the finished jelly is not less than 65 percent, as determined by means of a refractometer (for preserves or jam this reads, "Such mixture, with or without added water, is concentrated by, etc. . . .")

3) The fruit ingredient for jams means the weight of fruit separated from its pits, seeds, skins, cores, etc., and undiluted in any way by water, sugar, or other substances added for processing or packing.

4) For jellies, the fruit ingredient, whether concentrated, unconcentrated, or diluted, means the weight determined by the following method: Determine the percent soluble solids of the fruit juice ingredient by refractometer; multiply the percent so found by the weight of such fruit juice ingredient; divide the result by 100; subtract from the quotient the weight of any added sugar or other added solids, and multiply the remainder by the factor for such fruit ingredient (the factor for guava is 13.0). The result is the weight of the fruit juice ingredient. (This weight is the figure used for calculating the 45 parts of fruit ingredient required by the standards as mentioned in paragraph 1 above.)

5) Other optional ingredients such as spice, acids, preservatives, corn sirup, honey, and pectin are allowed within certain limits.

6) Requirements for naming and labeling products.

For a complete discussion of the standards, a jam or jelly processor should consult the FDA regulations (*9*). These regulations also are printed verbatim in the Sunkist Growers *Preservers Handbook* (*10*), which contains, besides the Federal standards, many principles, tables, and formulas useful to the preserver. The processor should keep in mind, too, that he must comply with all food laws of states where his product is sold.

Procedure for Jelly. Prepare a jelly stock by cooking graded and washed whole fruit with an equal weight of water for about an hour or until the fruit is soft. Strain the juice through a cloth or a jelly bag. The resulting stock will contain about 4 percent soluble solids and can be used to make guava jelly according to the method outlined in paragraph 4 of the above discussion of Federal standards. Since it takes 82 pounds of fruit solids and 100 pounds of sugar to make a standard 45–55 fruit jelly, for 82 pounds of this stock with 4 percent soluble solids, the calculations are as follows:

$$\frac{\text{pounds fruit juice ingredient} \times \% \text{ soluble solids}}{100} \times \text{factor for guava}$$

$$= \frac{82 \times 4 \times 13}{100} = 42.6 \text{ pounds fruit solids.}$$

This means then, that 82 pounds of the guava jelly stock are equal to only 42.6 pounds of guava juice as specified in the standards, so more than 82 pounds of stock must be added to each 100 pounds of sugar. To find how much, divide 82 by 42.6, giving a factor of 1.92 pounds of stock to equal 1 pound of fruit solids. Now, multiply 82 by 1.92, giving about 158 pounds of stock per 100 pounds of sugar.

Excessive boiling would be necessary to concentrate this mixture to 65 percent soluble solids, which would affect adversely the flavor, color, and pectin. Better quality can be obtained by cooking the first stock with a new lot of fruit, then using the pulp strained off to start a new series of extractions. It may be necessary to cook a third time with new whole fruit added to reach the optimum soluble solids of 7.7 percent. When this optimum is reached, the stock then may be mixed with sugar in the ratio 45–55 along with pectin, acid, or other optional ingredients if needed or desired.

The best sequence for concentrating to 65 percent soluble solids is to weigh the jelly stock, put it in the kettle and turn on the steam. If pectin is needed, add it to the hot juice and bring it to a boil. Now, add the sugar and continue boiling vigorously until the temperature of the batch reaches 221° F. (at sea level). At higher elevations the mixture will reach 65 percent soluble solids at a lower temperature; for example, the heating should be stopped at 220° F. for 500 ft. elevation and at 219° F. for 1000 ft.

After allowing to stand for a few minutes and removing the scum, add acid if desired and fill hot (190° F.) into clean jars, which are capped immediately and left to cool and set to a firm jelly.

Procedure for Jam. In the past, guava jam has been a by-product of the guava jelly industry, utilizing the pulp which remained after jelly stock had been made from cooked fruits. Since this material does not conform to Federal standards, an improved method for guava jam has been devised. Of course, jam still can be made from whole fruits, provided no jelly stock is taken from them.

The principal ingredient in the improved formula is guava puree, prepared as described previously in sections on processing and canned guava puree. A standard jam may be made by combining 45 parts of puree with 55 parts of sugar, but a better flavored, fancy quality jam will result if 50 parts of puree are mixed with 50 parts of sugar. After weighing the puree into a steam-jacketed kettle and turning on the steam, dry pectin or pectin solution may be added if needed and thoroughly mixed in. Next, the weighed amount of sugar is added in portions while stirring. The steam valve is not opened fully until the temperature of the mixture reaches 100°–130° F. in order to prevent scorching. Finally, open the valve to full and boil vigorously until the temperature of the entire mass reaches 221° F. At this temperature, the soluble solids of the jam will be more than 65 percent, so one may wish to stop heating at 216°–218° F. If a refractometer is available, the end point may be determined by taking representative samples and stopping the boiling when a reading of 65 percent soluble solids is reached.

Acid and other optional ingredients may be added as specified in the FDA regulations (*9*) and as described under procedures and formulas in the *Preservers Handbook* (*10*). The filling, capping, and cooling operations are the same as those described for jelly.

The advantages of using guava puree as the fruit ingredient for this improved jam are:

1. Better color, flavor, and texture.
2. Savings in time and money since the jam is heated only once.
3. Better keeping qualities.

Low Sugar Guava Spread

A jam-like fruit spread with low sugar content which retains much of the natural color, aroma, and flavor of the fresh fruit can be prepared from guavas. Since gel formation does not depend on a critical concentration of sugar and since the product does not have to meet Federal specifications, one can work with a wide range of sugar content. The use of low methoxyl pectin and calcium chloride insures gelling. Very little heating is required, but a precise procedure must be followed.

The starting material is puree, prepared as described previously, and the following formula has been proven to be satisfactory:

Guava puree	100 pounds
Sugar	67 pounds
Low methoxyl pectin	1.8 pounds
Anhydrous calcium chloride	0.1 pound

The ingredients are prepared and mixed by the following procedure:

1) Weigh out the pectin in a dry pan and mix thoroughly with ten times its weight of dry sugar (18 lbs.) .

2) Divide the puree into two parts, putting half into kettle A and half into kettle B.

3) Heat kettle A to 160° F., and stir in the pectin-sugar mixture, bring to a boil, boil for 1 minute, then turn off the heat.

4) Add the rest of the sugar (49 lbs.) to kettle A and again bring to a boil, then turn off the heat.

5) To the puree in kettle B add the calcium chloride, which has been dissolved in a little water, bring the mixture to a boil and turn off the heat.

6) Now transfer the contents of kettle B to kettle A with constant stirring, bring the mixture to a boil and boil for 1 minute.

7) Fill the containers hot to keep the product sterile and to prevent setting.

8) Cap and cool with water.

CHILLED AND FROZEN GUAVA PRODUCTS

In order to retain the maximum of fresh fruit flavor, aroma, and color, many products are preserved by freezing. With scrupulous care for cleanliness and sanitation, a number of frozen guava preparations may be manufactured without the application of heat.

Frozen Guava Puree

The steps in making frozen guava puree are essentially the same as in the manufacture of canned puree, omitting, of course, the operations calling for heating and subsequent cooling. After the operation of stone cell removal, a slush freezer may be installed in the processing line to chill the product before it is filled into containers. The advantage of the pre-chilling is that the puree will freeze more rapidly, maintaining higher quality and allowing labeling and casing to take place sooner. Because of the higher acidity of this product, the containers which are available in Hawaii at this time are not completely satisfactory for long storage.

Frozen Nectar Base

Guava nectar base is a combination of puree and sugar in such proportions that it may be diluted with water by the consumer in the same manner that many other fruit juice concentrates and nectars are prepared. Due to its natural color and flavor as well as high nutritional value *(2, 3, 4, 5, 6, 7)*, frozen guava nectar base should become more and more popular as a breakfast drink, both in the Territory and on the Mainland. From taste panel tests conducted at the Food Processing Laboratory at the University of Hawaii, it has been determined that the optimum dilution is 2½–3 parts of water to one part of nectar base.

The following formula is recommended for making nectar base:

Guava puree (7% soluble solids)	100 pounds
Cane sugar	48 pounds

If the soluble solids of the puree vary from 7 percent, more or less sugar should be added. It is advisable, too, to measure the pH of each lot of puree so that the finished product will be between pH 3.3 and pH 3.5. Most wild fruit is in the sour or acid category, but occasionally sweet guavas may be brought to the processor. By blending the puree from sweet guavas with that from the sour types or by adding citric acid, the pH of the final mixture may be kept in the desired range.

After blending the correct amounts of puree and sugar in a mixing kettle, the mixture should be pumped through a slush freezer before going to the filling machine. After filling and closing the containers (preferably enameled), they should be placed immediately in the freezer and kept at 0° F. or below. Labeling and casing should take place after freezing without allowing the cans to thaw.

Refrigerated Guava Nectar

Freshly prepared guava nectar can be kept in cold storage for a week or two, depending on the temperature of the refrigerated storage.

TABLE 6. Effect of Refrigerated Storage on Retention of Vitamin C in Guava Nectar*

NO. OF DAYS IN STORAGE	STORED AT 36° F.		STORED AT 45° F.	
	NOT HEATED	HEATED TO 160° F.	NOT HEATED	HEATED TO 160° F.
	%	%	%	%
0	100	100	100	100
1	95	92	88	88
2	80	84	71	83
3	70	77	60	75
4	65	----	55	----
6	----	64	----	66
7	45	56	41	69
8	40	52	32	66
9	34	48	27	63
10	28	42	25†	63†
11	24	----	20†	----
13	----	22	----	----
14	7	18	----	----

*Expressed as percentage of vitamin C remaining after 1–14 days in storage at 36° and 45° F.

†Detectable off-odor and flavor.

The unheated nectar stored at 36° F. will retain its flavor, odor, and color for about two weeks, while at 45° F. its storage life is only one week. Flash pasteurization at 160° F. for 14–18 seconds helps considerably in prolonging the storage life of refrigerated nectar under the conditions found in retail food stores. Using vitamin C retention as an index of quality, the results of storage tests at 36° and 45° F. on unheated and flash pasteurized guava nectars are shown in table 6. These data indicate that a processor or supplier must use a well-organized system of distribution and replacement of refrigerated nectar in retail outlets. A rapid turnover of product with none being retained in the store for more than a few days would be ideal for refrigerated guava nectar.

The nectar, like the canned guava nectar, may be made either from freshly processed fruits or from frozen puree. Artificial color may be added if desired. The equipment and distribution facilities of a dairy plant seem to be most useful in making and marketing this product. To avoid the formation of clots or clumps, it is suggested that first the sugar be stirred into the puree in small portions. Next, after the mixing is complete, the water can be added. This procedure results in a smooth, homogeneous nectar.

Frozen Guava Spread

A product similar to the low sugar guava spread mentioned earlier may be made without heating and preserved by freezing. The fresh aroma and flavor of the guava fruit are retained, but the spread cannot be labeled "jam" because it does not conform to the Federal standards for jam.

The starting material, again, is guava puree, the soluble solids of which have been determined by a refractometer. In order to make a spread with 56.5 percent soluble solids, the weight of sugar to be added is calculated by the following equation:

$$\text{pounds sugar} = \frac{(\text{pounds puree}) \times (0.565 - \text{soluble solids of puree})}{1.000 - 0.565}$$

Next the pH of the puree is checked by means of a pH meter and adjusted to pH 3.0 by adding citric acid. Pectin of 150 grade or better should be weighed out in such amount that it makes up 0.45–0.50 percent of the combined weight of puree and sugar.

For blending the various ingredients, separate the puree into three portions, one of 9 percent, one of 41 percent, and one of 50 percent of the total. Mix the pectin thoroughly with eight times its weight of dry sugar and stir this into the 9 percent lot of puree until the dry sugar and pectin are moist. Now, add slowly the 50 percent lot of puree to the above mixture, stirring constantly without incorporating any air. Continue stirring for at least 20 minutes. Soluble solids at this stage must be under 25 percent or the pectin will precipitate. Finally, blend the remainder of the sugar with the 41 percent lot of puree until most of the sugar is dissolved. Both blended lots may now be combined by stirring carefully to dissolve the rest of the sugar and to prevent the introduction of air.

After all the ingredients are well mixed, pour into containers and allow the spread to set. Standing overnight should be adequate to allow firm setting. Seal the containers and freeze at 0° F. or lower. The spread should be thawed before using.

QUALITY CONTROL

Every food processing plant, whether large or small, should have an organized procedure for checking all aspects of its operation, from raw products and ingredients used to the final finished goods sold to its customers. In a small plant this responsibility may fall upon the manager or operator; in a somewhat larger operation there may be one full-time employee charged with quality testing and control; and in a big plant a sizeable staff of technicians and professional engineers, chemists, a bacteriologist, and a food technologist may be employed. As an example of the types of inspection, testing, and control which must be thought about and put into operation if possible, it is recommended that processors read a recent article on the subject which appeared in *Food Engineering* (*12*). Probably no guava processing plant operating in the Territory at the present time will ever use such a large number of personnel in quality control work, but the organization and description of the program used at Gerber's plant should provide a goal towards which a processor may aim. A good review and additional references on the subject which may be applied to guava packing is contained in Tressler and Joslyn, chapter 28 (*9*).

For the purpose of organizing specific suggestions pertaining to quality control activities in the processing of guava products, the following brief discussion will be divided into three parts: Raw Materials, Processing, and Finished Products.

Raw Materials

As was stated earlier in the discussion of wild versus cultivated guavas, the processor will have little control over many quality factors of the fresh fruit until selected seedlings and varieties are cultivated commercially. However, there are a number of checks which a buyer may make on wild fruit brought to him for processing. Some of these are mentioned in the previous sections on harvesting and transportation and need not be repeated here. Maturity, of course, is all important both from the standpoint of yield of puree and of quality. Other qualities which should be checked on each lot of fruit are soluble solids, pH, content of vitamin C, flavor, and color.

Soluble solids can be measured with a hand refractometer. This is important in the calculation of formulations and in the blending of different lots of fruits to arrive at standardized finished products.

The acidity of different lots of guavas should be known to determine proper processing times and temperatures. This factor plays an important part, also, in the flavor of the fruit and its manufactured products. It can be measured quickly and easily on a pH meter which can be purchased from any one of several scientific instrument supply houses. A more economical but less accurate method for measuring pH is by the use of "Hydrion" papers which give different color reactions over the whole range of pH from 0 to 14.

Routine analyses of vitamin C content of fruits will become more and more important as the public learns the high value of guava products in supplying this essential food factor. Different lots of fruit may be blended to standardize the vitamin C content of processed guava products. A simple laboratory procedure and references to the original literature on the subject may be found in Tressler and Joslyn (*9*).

Color, texture, aroma, and flavor of the fresh fruit can be evaluated by visual observation and actual testing. Instruments are available for checking color objectively, but due to their high cost they probably will not be used to any great extent in smaller processing plants. The use of guavas with poor color and flavor for processing will do more harm to consumer acceptance than any other factor over which a processor has control. It is a good idea to check the raw products for these two quality factors on all lots of fruit.

Inspections and bacteriological tests for molds and bacteria in the fresh fruit can prevent the spoilage and loss of finished products. This can be done by visual examination for damage at the same time as the fruits are being inspected for other fungi and insects. Laboratory tests in which bacteria are isolated, grown in culture, and identified become more important after the fruit has been processed. It is important that the processor eliminate all sources of contamination in his plant.

Processing

During processing the byword should be sanitation. Every piece of equipment which contacts the fruit, from the crates in which it arrives to the cans in which it leaves the plant, should be absolutely clean. A schedule for regular and thorough cleaning of all machines should be set up. Chlorinated water should be used to keep down contamination on belts, elevators, and wash tanks. Precautions should be taken to keep down dust and to keep insects and vermin out of the plant.

Each unit operation during the preparation and processing of the product must be studied to learn the effect on quality. At the same time, valuable information on yield and production rate may be gathered. Careful adjustment of such machines as cutters, pulpers, finishers, pasteurizers, fillers, and closing machines will pay off in better quality as well as in more efficient and economical operation. Strict adherence to processing times and temperatures helps to assure a uniform, high quality end product. In case anything does go wrong, the use of a code mark which is changed frequently during a day's operations permits the processor to sort out only those containers which fall below standard in any respect. This device can result in substantial savings to the processor.

Finished Products

A sampling procedure which allows adequate checks on quality of all lots or batches of each product should be set up. Immediate examination then permits corrections to be made and also allows the processor to isolate any lots which should not be put on the market.

The same sort of tests which were conducted on the raw products may be run on the finished material, such as color, flavor, texture, pH, bacterial count, vitamin content, and soluble solids. Measurement of headspace and fill, as well as vacuum and oxygen content, could be made on the containers also.

Any product which is stored for considerable lengths of time in a warehouse or in frozen storage should be examined periodically. Records of storage times and temperatures should be kept, since all the care in the world during processing can be rendered useless by improper storage.

SUMMARY

The common guava has been growing wild in the Territory of Hawaii for more than 100 years. The fruit and its processed food products are very flavorful and nutritious but have been utilized only to a limited extent. In recent years a cooperative project involving members of the Department of Horticulture and the Food Processing Laboratory at the University of Hawaii has led to the selection and evaluation of desirable types of fruit for commercial processing. The results of this phase of the work are described by Hamilton and Seagrave-Smith (*8*). The cultural work is being continued and expanded at the Waimanalo and Poamoho experimental farms of the Hawaii Agricultural Experiment Station.

Steps in the processing and quality control of a number of canned and frozen guava products have been adapted and developed on a semicommercial, pilot plant scale at the Food Processing Laboratory of the University of Hawaii. Results and recommendations from this experimental work are described in detail in this bulletin.

In conclusion, one may state that the techniques for making highly acceptable guava products are available, the fruit should be in production in commercial orchards soon, and a ready market exists both in the Territory and on the Mainland. With proper development of the quality and economic factors involved, the outlook for expanding this new industry appears to be very optimistic.

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