COMMERCIAL PASSION FRUIT PROCESSING IN HAWAII

PETER E. SEALE and
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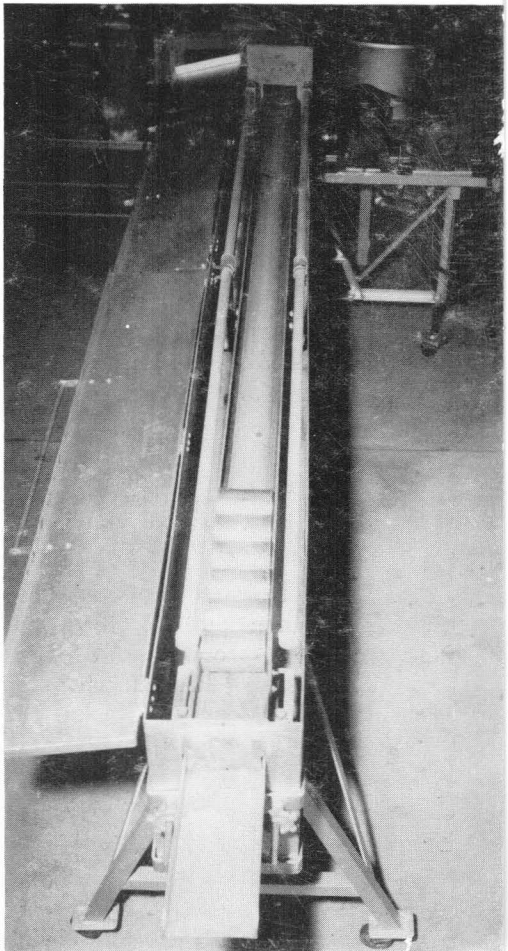

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INTRODUCTION

The passion fruit, *Passiflora edulis,* commonly known in Hawaii as lilikoi, is believed to have originated in Brazil. The seeds of the purple variety were introduced from Australia about 1880 by Eugene Delemar and were first planted at Lilikoi on East Maui (*1*). Wild plants soon began to appear in the district, and later spread to all the Islands where they now occur in the lower forest regions at elevations of 400 to 3,000 feet.

The yellow passion fruit, *Passiflora edulis* forma *flavicarpa Degener,* which is cultivated as a commercial crop in Hawaii, originated in either Australia or South America as a sport from the purple variety. The first plantings were made from seed collected in Australia by Mr. E. N. Reasoner, who left samples with the Hawaii Agricultural Experiment Station. Subsequent unrecorded introductions have been made, and these probably account for several type variations that have been observed in cultivation.

The first recorded commercial production in the Islands was a planting in the late 1930's at Pupukea, Oahu. This venture included an attempt to can passion fruit nectar, but was discontinued during World War II. The planting, however, was important as it provided planting material for the University selections, and spurred the development of a crude centrifuge that has been modified into the efficient unit used today in the Hawaiian passion fruit industry.

DESCRIPTION OF FRUIT

P. edulis f *flavicarpa* is a vigorous-growing, woody, perennial vine which under most conditions is more robust than the purple variety. The leaves are three-lobed, with finely-toothed edges and a cordate or heart-shaped base. The fruit is round or oval in shape and varies from 1½ to 2½ inches in diameter, and from 2½ to 4 inches in length. The fruit has a tough rind, canary yellow in color, with a smooth, glossy surface and an inner white layer similar to the albedo of citrus fruits. Within this hard, brittle rind are numerous small blackish seeds, each enclosed in a sac containing a yellowish, aromatic juice with a pleasant but rather acid flavor.

PASSION FRUIT VARIETIES

There are no true horticultural or clonal varieties of passion fruit in Hawaii, or in other countries where the fruits are grown commercially. The fruits appear to be self-sterile, so that cross-pollination is essential for a heavy fruit set and high juice yield from the crop. Selection has produced strains with fairly homogeneous fruit characteristics without incurring sterility due to varietal purity. The following selected types have been used in evaluating and developing the industry in Hawaii.

Australian Purple Selection

Commonly known as Nelly Kelly; this is the strain recommended for planting in Australia. It is a medium-sized, purple-skinned, round fruit about 1½ inches in diameter, which bears heavily over a short fruiting season. The flavor is mild, but penetrating, and its high sugar and relatively low acidity complete a pleasant flavor pattern.

Common Purple

This fruit grows wild in the tropical rain forest areas and originated from the strain introduced by Eugene Delemar. The fruit has a thick skin and small seed cavity, but has the best flavor and lowest acidity of all strains.

Waimanalo Selection

This is a combination of four strains selected from seedlings originating in the first commercial venture at Pupukea. The four strains, C-39, C-54, C-77, and C-80, have similar characteristics for size, shape, color, and juice composition. The inclusion of strain C-39, which is a universal pollinator, is necessary to ensure a heavy fruit set.

Sevcik Selection

A beautiful golden yellow passion fruit that is a prolific bearer. However, due to an off-flavor in the juice and its susceptibility to brown rot, this variety has not been recommended.

Kapoho Selection

This selection was developed from the seed of crosses between unknown yellow strains and the Sevcik variety. It produces large fruit, is a prolific bearer, and yields a high juice recovery.

The juice of some of the fruit has a woody, off-flavor, characteristic of its Sevcik parentage; and this flavor is accentuated by thermal processing. In addition, the fruit is susceptible to brown rot and has a high incidence of hollow fruits which contain little or no pulp.

Yee Selection

A very attractive round variety with an almost unblemished yellow skin. This selection has a high disease resistance, but bears fruit with a thick rind and therefore low juice yield.

University Round Selection

Several individual vines selected from crosses between the "Waimanalo Selection" and the "Yee Selection." The fruit is rather similar to the Yee

variety, but yields 10 percent more juice. Flavor is an improvement over the mild Yee selection, but the fruit does not have the same attractive appearance.

Pratt Hybrid

This strain is believed to be a natural cross between the wild purple and an unknown yellow variety. The juice has good color, excellent flavor, and the low acidity characteristic of its purple parent, but also inherits its susceptibility to rot.

University Selection No. B-74

The crossing of the Pratt Hybrid and strain C-77 has produced a fruit with a good juice yield and characteristics similar to the Waimanalo selection. The skin color is generally yellow, with occasional red tints.

The yellow strains of passion fruit have been developed commercially because of their high yield of 25,000 to 50,000 pounds per acre as against 5,000 to 10,000 pounds per acre for the purple. The cost of growing passion fruit in Hawaii requires a yield of 30,000 pounds per acre to be an economic venture. The heavy application of complete fertilizer (10-5-20) is essential to maintenance of production level yielding a desirable economic return. Other cultural practices are covered in the publication by Akamine, *et al.* (*1*).

FUTURE DEVELOPMENTS

A limited number of natural and induced crosses between the yellow and purple varieties have been evaluated. The ideal passion fruit would have the flavor characteristics of the purple fruit, and the high yield per acre, good juice yield, disease resistance, and vigor of the *flavicarpa* strain. Further plant breeding is proceeding with these objectives as a goal. Greater use of vegetative propagation will be essential to provide for maximum yield of good quality fruit. This can only be obtained by selection of vines which are prolific and possess quality, coupled with vines which will serve to insure adequate pollination. Akamine and Girolami (*2*) have found that passion fruit is self-sterile and a high degree of incompatibility for pollination exists between individual vines. Certain selections such as C-39 are universal pollinators.

GENERAL COMPOSITION

Passion fruit juice is golden yellow in color, with a cloudy appearance caused by the maceration of cellular material during the extraction process. It is sharply acid in taste and has a penetrating flavor and exotic aroma. Color is principally due to carotinoid pigments.

The characteristic flavor resides in a deep yellow-colored, volatile oil, which has been extracted in the laboratory scale distillation unit described by Walker and Patterson (*10*) at a concentration of 23–43 ppm. Hiu (*4*) has separated 18 components and identified the 4 major compounds as n-hexyl caproate, n-hexyl butyrate, ethyl caproate, and ethyl butyrate.

TABLE 1. Average composition of passion fruit juice per 100 grams (7)

	Selected Value
Water	82 gm.
Reducing sugar	7 gm.
Total sugar	10 gm.
Crude fiber	0.2 gm.
Protein	0.8 gm.
Fat	0.6 gm.
Calcium	5 mg.
Phosphorus	18 mg.
Iron	0.3 mg.
Vitamin C	12 mg.
Vitamin A	570 I.U.
Calories	78
Soluble solids (by refractometer)	15
pH	3.0
Titratable acidity (as citric acid)	4.0

The approximate composition of the juice has been determined by Miller, *et al.* (7), and is given in table 1. Passion fruit juice is a fair source of vitamins A and C and also contains small quantities of calcium, phosphorus, and iron. The juice contains significant quantities of starch, estimated at 2 to 5 percent for the purple varieties, with smaller quantities in the yellow species. This starch content has an important influence on processing procedures. The enzyme systems and the role of metallic ions and other nonenzymic oxidative compounds have been investigated by Ross and Chang (9), who found catalase present in the juice and peroxidase in the skin and cellular material. The presence of pectin esterase in the rind has also been demonstrated. The juice has an unusually high acidity, averaging 4 percent as citric acid, with variations from 3 to 5 percent, depending on variety, locality, and seasonal conditions.

SEASONAL VARIATIONS IN COMPOSITION

In Hawaii, flowering commences in April and the fruit is continually harvested from June through January, with two distinct periods of heavy supply. The major portion of the crop is picked in the summer season (July and August) with another period of increased supply in October and November, the so-called winter season.

The variations in the seasonal composition of the different strains of passion fruit are presented in table 2. In general the winter crop is slightly lower in soluble solids and has possibly a slightly higher acid content. The soluble solids content in the different strains range from 12.5 to 17.7 percent with most of the fruit of strains varying from 15 to 17 percent. The total juice yields are higher in the yellow strains, ranging from 31 to 39 percent, than either the purple or the hybrid strains which have juice yields ranging from 26 to 31 percent. The purple and hybrid strains have a higher ascorbic acid content than the yellow strains. The range of content of ascorbic acid in the fruit of purple and hybrid strains ranged from 17 to 31 milligrams per 100 grams and for the fruit of yellow strains, 10 to 13 milligrams per 100 grams.

TABLE 2. The analysis of passion fruit juice from different varieties. Fruit was collected during summer (July–September) and winter (October–January)

VARIETY	TIME OF HARVEST	JUICE YIELD %	pH	TOTAL ACIDITY % CITRIC ACID	ASCORBIC ACID MGM/100 GM	SOLUBLE SOLIDS %	DESCRIPTION OF FLAVOR
Australian Purple Selection	Summer	28	3.3	3.01	21.6	15.9	Excellent
	Winter	26	2.9	3.05	22.0	15.4	Excellent
Common Purple (Hawaii)	Summer	31	3.2	2.59	22.6	16.7	Excellent
	Winter	31	3.0	3.75	31.0	15.1	Excellent
Waimanalo Selection	Summer	39	3.0	3.81	12.2	16.8	Very good
	Winter	37	2.8	4.13	12.9	16.3	Very good
Sevcik Selection	Summer	35	3.0	3.05	11.0	12.5	Woody, musty
	Winter	33	3.0	3.10	11.8	13.0	Woody, musty
Kapoho Selection	Summer	34	2.8	3.98	11.0	16.9	Faintly woody
	Winter	32	2.8	3.90	11.6	15.0	Faintly woody
Yee Selection	Summer	32	3.1	3.91	15.8	14.4	Very good
	Winter	34	3.0	3.88	15.0	15.9	Very good
University Round Selection	Summer	33	2.9	3.98	11.6	17.6	Very good
	Winter	31	2.8	3.80	10.6	17.2	Very good
Pratt Hybrid	Summer	30	2.9	3.94	18.9	15.6	Good
	Winter	29	2.8	4.39	17.3	16.4	Good
University Selection B-74	Summer	28	3.1	3.24	22.2	17.7	Very good
	Winter	28	3.3	2.84	20.0	15.5	Very good

Flavor intensity is also strongest in the purple species and has been noted as weakest in the presently available hybrid types. As characteristic flavor differs noticeably between varieties and represents one of the major quality factors, it has been used as one of the primary considerations in selecting recommended planting material. Experienced taste testers were used to evaluate flavor characteristics, at 1 percent and 5 percent juice concentrations, during the main fruit seasons. Seasonal variations showed no effect on the characteristic flavor of each variety, but two strains had distinctly discernible "woody" type of flavors.

COMMERCIAL EXTRACTION OF PASSION FRUIT JUICE

The process used in extracting the passion fruit juice was developed from the earlier extractor used by Mr. Haley in his plant prior to World War II—Kinch and Shaw (*6*). A number of modifications were developed and the basic centrifugal extractor was greatly modified (*5, 6*). The flow sheet for the process is given in figure 1. The details of process from harvest to packing are as follows:

Harvesting and Storage

On reaching maturity, the fruit falls from the vine and is harvested from the ground at least once a week and preferably more frequently in wet weather. The recommended procedure calls for packing in open crates, with provision for adequate ventilation. However for short storage and ease of transportation, sacks are frequently employed. The fruit can be stored for about one week at 36° to 45° F., but for best results should be inspected to remove cull fruit and packed in boxes, with provision for air circulation.

Inspection and Washing

The fruit is fed to an inspection belt (fig. 1), where culls and immature fruit are removed. It is desirable to trim off any adhering stalk ends if centrifugal extraction of the juice is to follow. This may be done by running fruit over rollers running in opposite directions as in a strawberry destemmer. The fruit is then thoroughly washed under powerful sprays with the addition of detergent in the first stage, followed by clean water as a final rinse. For volume production and economy of space for the washing operation, dumping into a tank containing detergent solution, followed by elevation to a corrugated cylindrical spray washer, is an ideal arrangement.

Juice Extraction

The recovery of passion fruit juice presented an interesting and challenging problem in extraction techniques. The basic problems which had to be considered were:

1. The fruit has a tough rind.
2. There should be a minimum of contact between the juice and cut surfaces of the rind to prevent undue enzyme contamination.
3. The small, black seeds must be separated from the pulp.

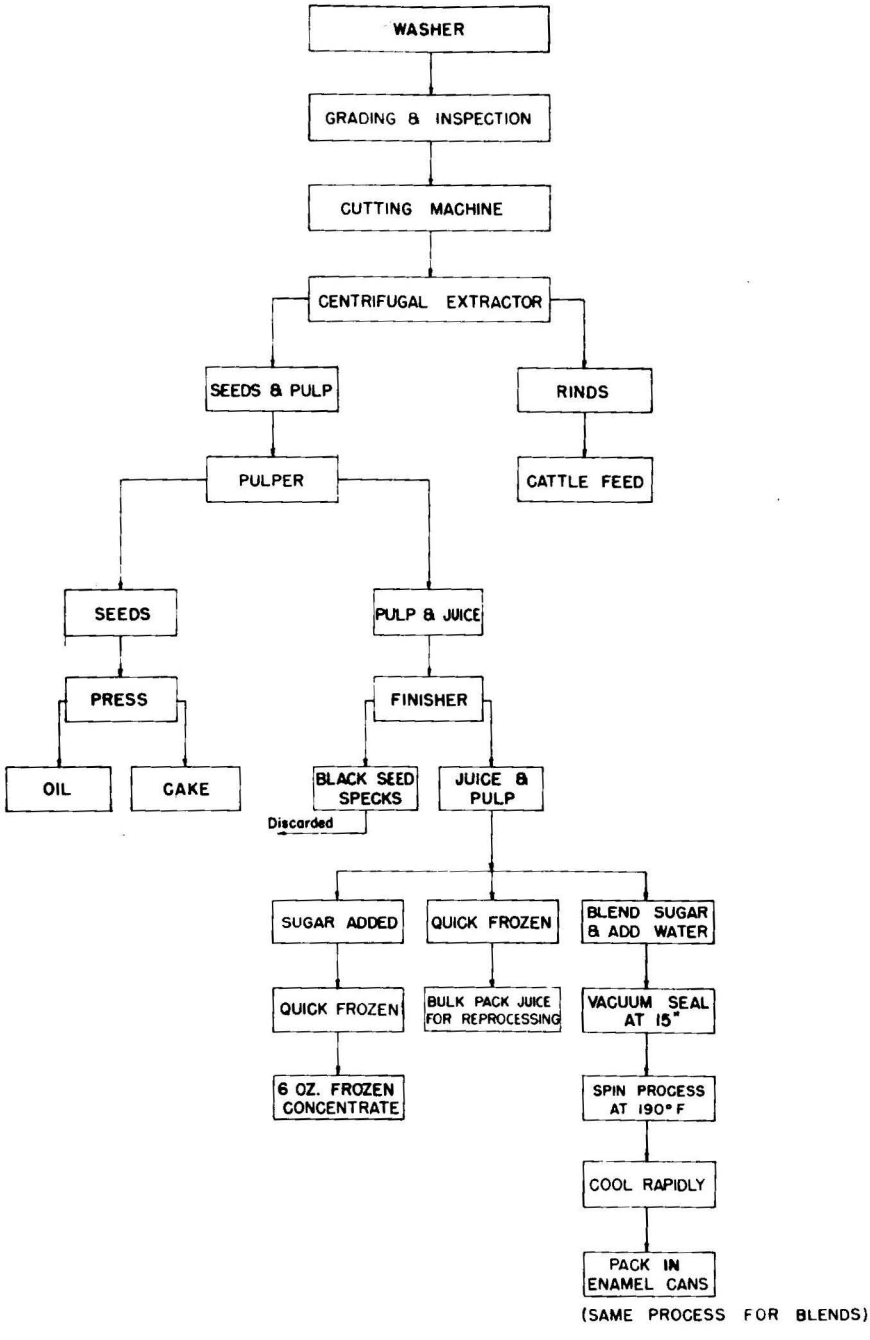

FIG. 1. Flow sheet for the processing of passion fruit products.

Several ingenious extraction procedures have been developed in the various major producing countries. Each of these methods has inherent advantages and disadvantages. The University of Hawaii process is outlined in the flow sheet presented in figure 1.

The most efficient method for volume production and high extraction yields has been developed as a cooperative venture between the Agricultural Engineering Department and the Food Processing Laboratory of the Hawaii Agricultural Experiment Station (*5, 6*). This is a centrifugal extraction, which necessitates a preliminary slicing of the fruit into ⅝-inch-thick slices. This operation is performed by a gang of serrated-edge blades, mounted on a common shaft with ⅝-inch spacers. The fruit is fed down a tubular inlet, and the serrated edges of the blades assist in pulling the fruit through the slicing operation. Some commercial companies utilize a mechanical feed, using fingers mounted on a shaft parallel to the cutter blade shaft, and meshing between the slicer blades, to force the fruit through the cutting operation. This innovation gives a considerable increase in cutting capacity, with no risk of fruit jamming between the blades.

The cut fruit then drops into a centrifugal extractor described by Kinch and Shaw (*6*) and Kinch (*5*). It consists essentially of a 19¾-inch-diameter basket having 16° inclined perforated walls punched with ¼-inch holes at ⅝-inch spacings. Four ¾-inch-high radial vanes are welded within the walls to form four compartments, to ensure that the sliced fruit rotates at the same speed as the basket (175 rpm). The basket is balanced on a slotted ball-and-socket joint, with a slender vertical drive shaft to permit considerable angular movement of the basket.

Under the influence of centrifugal force, the slices move up the inclined walls, and seeds, juice, and pulp are ejected radially through the perforations, while the rinds move upwards to leave the basket above the juice-retaining cover. This unit has a capacity of up to 3,800 pounds of fruit per hour and an extraction efficiency of 94 percent. Its main disadvantages are (1) that a number of seeds are cut in the slicing operation, which necessitates the use of a very fine screen in the final finishing operation, and (2) there is some extraction of skin juice and presumably enzymes under the influence of the gravity produced in the centrifuge.

In Australia two different extraction methods are employed. One factory in Queensland utilizes a modified apricot depitting machine in which the fruit falls into rows of hemispherical pockets, where they are held and then pierced from underneath to give a cross-shaped cut in the skin. A plunger then descends on the fruit and ejects the juice, seeds, and pulp through a hole in the bottom of the pocket. In completing this operation, the plunger virtually turns the fruit inside out. This procedure provides a minimum contact with the cut surface of the skin and therefore very little contamination with enzymes or skin pigment, a most important consideration when handling the purple fruit.

A large processor in Sydney utilizes a somewhat similar method in which the fruit is squeezed between rotating rollers, which compress the fruit, burst the skin, and eject the pulp and seeds.

The New Zealand industry uses a suction method, in which the fruit halves pass over a steel plate and the pulp and seeds are removed by suction. Juice recovery and a limited handling capacity are limitations with this method.

Each of these extraction methods serves only to remove the seeds and pulp from the rind. Separation of the juice from the seeds and pulp is accomplished in a two-stage operation in a paddle finisher, equipped with rubber blades. The first stage uses a screen with .033-inch perforations, followed by a finishing screen of 60-mesh stainless steel to remove any broken seed fragments.

Commercial processors in Hawaii obtain an average juice yield of 33 percent. Recovery experiments conducted at this laboratory, using fruit grown at the Waimanalo Experimental Farm, have shown yields of up to 41 percent on batch runs of 500 to 1,000 pounds of fruit.

PROCESSED PASSION FRUIT PRODUCTS

Processed passion fruit products fall into two main categories: those preserved by heat processing techniques and those that are frozen and held in frozen storage until consumed. Typical examples are frozen passion fruit nectar base, passion fruit sherbet, canned passion fruit nectar, and nectar combinations with citrus, pineapple, and other juices. These items, and several new products with considerable promise, will be described in more detail.

Two characteristics of passion fruit juice exert an important influence on methods of processing. The first consideration is the influence of heat on the extremely sensitive flavor constituents with the result that pasteurization inevitably leads to some loss of fresh fruit flavor. Secondly, the high starch content causes accumulations of gelatinous deposits on the heating surfaces of tubular and plate type heat exchangers and results in localized scorching, with a resultant drop in heat exchange efficiency and deterioration in juice flavor.

The heat sensitivity of passion fruit makes it difficult to heat process passion fruit juice without markedly changing the flavor of the juice. Many attempts have been made to process a satisfactory pasteurized product. The use of tubular and plate type heat exchangers results in a darkened product with poor flavor. The most successful method has been the use of a spin cooker designed by L. J. Lynch of the Canning Section Division of Food Preservation, C.S.I.R.O., Australia, shown in figure 2. This is a cheap and easily constructed unit that utilizes optimum can rotation speed to provide rapid heat transfer with mild effects on the product. The can is spun on an inclined belt at approximately 140 rpm in an enclosed chamber, with steam sprays impinging on the can surface. Pasteurization is achieved in about 1¾ minutes with a 190° F. temperature in the center of the can, after which the can is immediately and rapidly cooled with a cold water spray in a similarly constructed water spray system in another closet so

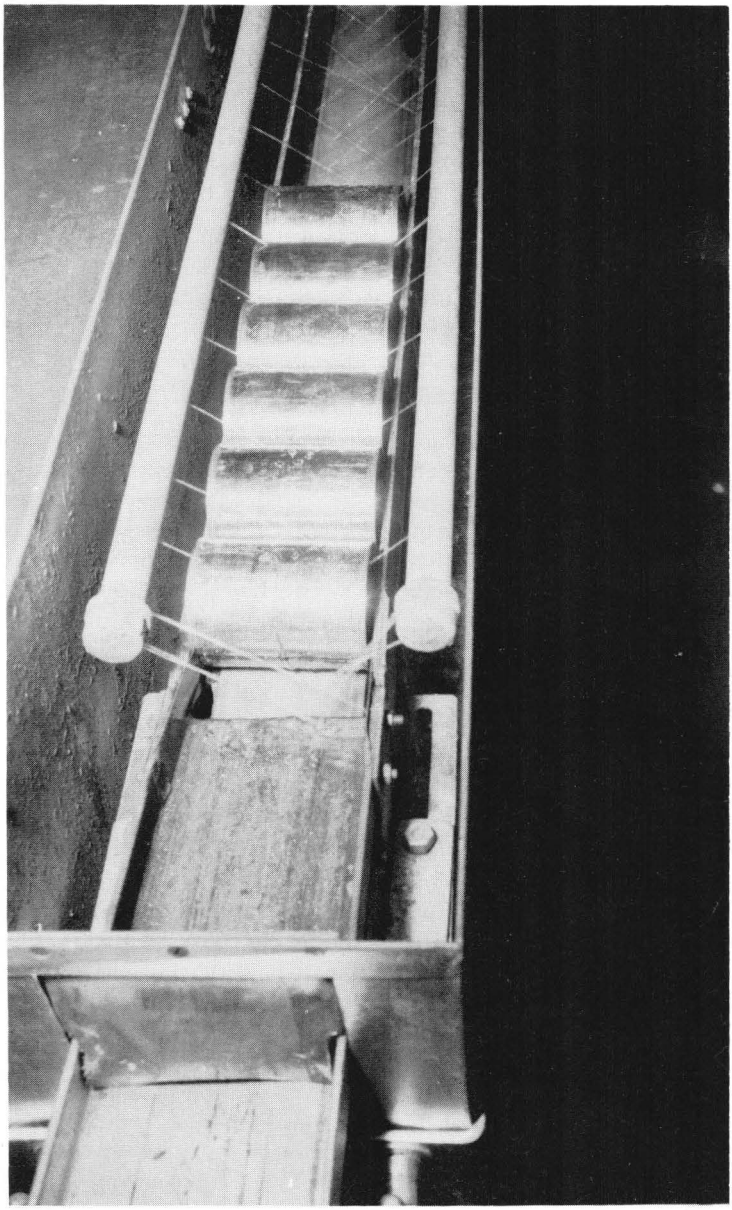

FIG. 2. The Australian spin cooker showing the cooling of No. 2 cans of processed passion fruit juice by sprays of cold water. The heating cycle was done in the same chamber by spinning in hot steam.

that cans can pass to cooking chamber to cooling chamber. In the model spin cooker at the Food Processing Laboratory, cooling was accomplished in the same chamber in which pasteurization took place. The steam inlet was closed and a cold water inlet opened, thereby spraying cans in cold water. An essential prerequisite for a spin process is a vacuum or steam flow closing machine to give a high can vacuum.

Experimental batches processed at the Food Processing Laboratory have been packed in No. 2 enamelled cans, using 5/16-inch headspace and 15-inch vacuum on the vacuum sealing machine. Loss of some of the more delicate flavors was apparent in the processed product, but color retention was very good and the general result was far superior to any alternative method of heat preservation. Storage of this product at 36° F. showed no noticeable flavor loss in 6 months. Room storage samples showed a slight but detectable change in flavor. These flavor changes could be considered as approximately comparable to the degree of change noticeable in a good quality canned orange juice stored under the same conditions. The effect of heat is minimized when passion fruit is diluted or mixed with other juices as in juice blends or diluted nectars or ades.

Passion Fruit Nectar and Nectar Blends

Passion fruit nectar base is a combination of passion fruit juice and sugar in suitable proportions for dilution with water to produce a palatable drink. The recommended ratio of ingredients is as follows:

Passion fruit juice	100 parts
Sugar	55 to 65 parts

One part of this mixture is diluted with 4 to 4½ parts of water to give a pleasant and refreshing nectar.

These find ready acceptance as canned products and for distribution through dairy outlets as pasteurized chilled products packed in waxed cartons. To achieve attractive flavor combinations, passion fruit is frequently blended with orange and pineapple juices. A suitable balance of flavor is achieved by the addition of citric acid, sodium citrate, and essential oils with algin derivatives added to control viscosity and appearance. These blends are frequently fortified with vitamin C.

The canned products are mixed in blending tanks and normally pasteurized to 190° F., filled hot into enamelled cans, sealed, and then cooled in rotary coolers. A better flavored product can be prepared using the spin cooker process. The juice is filled into enamelled cans at room temperature, sealed in a vacuum closer, and then spin processed to a can center temperature of 190° F. The cans are then rapidly cooled before storage.

Nectar intended for packing in waxed-paper cartons is normally processed in a tubular or plate type pasteurizer and then run through a refrigerated milk cooler to drop the temperature below the melting point of the wax coating used in the carton manufacture.

Frozen Punch Blends

Passion fruit juice may be quick frozen directly from the finisher. It is usually packed in 30-pound containers and quick frozen. This product is sold to manufacturers of juice blends and foods using passion fruit as an ingredient or as a major flavor constituent. The bulk of the Hawaiian passion fruit is packed for this trade. A passion fruit concentrate is made by adding 55–65 parts of sugar to 100 parts of passion fruit juice. The concentrate is packed in 6-ounce cans and quick frozen. The concentrate can be diluted to make a nectar or an ade. Passion fruit juice frozen without heat will retain a fresh flavor but with time this flavor slowly deteriorates. Passion fruit juice which has had a partial heat treatment of 165° F. before freezing will lose considerably in flavor but will have a longer storage life at a lower flavor level.

One of the most promising fields for future expansion in the passion fruit industry is the rapidly increasing frozen juice blend market. There are several blends already marketed with relatively minor additions of passion fruit juice, and there would appear to be excellent prospects for a blend in which passion fruit provides the major flavor note, with suitable modification by a combination of other juices. Two such blends have been developed at the Food Processing Laboratory.

POLYNESIAN PUNCH

Passion fruit juice	18 parts
Pineapple concentrate	5 parts
Acerola puree	4 parts
Apple juice	3 parts
Orange concentrate	4 parts
Lemon juice	2 parts
Water	8 parts
Sugar	56 parts
Add citric acid to give an acidity of 1.7 percent	

The ingredients are mixed in a blending tank, and then citric acid is added to adjust to the standard acidity. The product is then filled into enamelled cans and quick frozen. For use, this blend is diluted with 4½ parts of water.

A second punch blend featuring passion fruit juice and acerola puree has been developed, with the aim of producing a high natural vitamin blend with an emphasis on the passion fruit flavor.

Passion fruit juice	24 parts
Acerola puree	12 parts
Pineapple juice	10 parts
Orange concentrate	4 parts
Sugar	50 parts

Citric acid is added to give 1.4 to 1.5 percent acidity. The vitamin C content of this blend approximates 220 mgm/100 gm, which is about 50

percent greater than frozen orange concentrate. For consumption, the base is diluted with 4 parts of water.

TROPICAL FRUIT COCKTAIL

Tropical fruit cocktail and tropical fruit salad, which are experimental variations of the popular canned fruit cocktail, represent a major potential outlet for passion fruit juice. Ingredients for a typical pack are:

Pineapple cubes or tidbits	9 parts
Papaya cubes	6 parts
Banana slices	2 parts
Passion fruit juice	1 part
Syrup	9 parts

The passion fruit juice content is minor in quantity but powerful in effect and makes a major contribution to the exotic flavor of this product. As all these ingredients are heat sensitive, spin processing or some alternative rapid process is very desirable.

PASSION FRUIT SHERBET

Passion fruit juice has proved to be too acidic for the manufacture of ice cream, but this characteristic is an advantage in the preparation of sherbet. The addition of passion fruit juice at 10 to 15 percent to the basic sherbet mix is considered to be the optimum for a full-flavored product. The use of citric acid in the sherbet mix should be discouraged except where passion fruit juice concentrations are low.

PASSION FRUIT ICE

This is another field in which passion fruit juice produces an excellent article. The powerful, distinctive flavor makes the juice requirement very reasonable.

Water	66 lb.
Sugar (cane)	27 lb.
Corn syrup, 42° Baumé	6 lb.
Gelatin	9 oz.
Passion fruit juice	10 lb.

(The juice is added to the chilled mix)

Passion Fruit Jelly and Jam Combinations

PASSION FRUIT JELLY

Because of the low pH of passion fruit juice, the use of the normal fruit to sugar ratio of 45 to 55 results in a product which is extremely prone to syneresis, resulting from the high inversion of sucrose during the boiling process. Most manufacturers, therefore, market their product under some alternative name, such as "Passion Fruit Supreme." A typical formula for this product is:

Passion fruit juice	40 lb.
Sugar	60 lb.
Pectin (150 grade, slow set)	6 oz.

The extracted juice is heated to boiling in a steam-jacketed kettle and the pectin, dispersed in 5 times its weight of sugar, is then added. After

allowing 2 minutes for dispersion of the pectin, the balance of the sugar is added in three increments, allowing a short boil between each addition. Boil to 222° F., and fill into containers. Cap, invert for 2 minutes to sterilize the closure, and then cool as rapidly as practicable. Due to the prolonged heating in the manufacture of jelly, some darkening and flavor loss are inevitable.

PINEAPPLE-PASSION FRUIT JELLY

The blending of passion fruit with other juices for jelly manufacture is a logical step to overcome the problems of high acidity and heat sensitivity. The following process has been developed from the work of Hoover, *et al.* (*3*), and gives a significant improvement in flavor and color.

Pineapple juice, or reconstituted concentrate	30 lb.
Passion fruit juice	15 lb.
Sugar	55 lb.
Water	1 gal.
Pectin (150 grade, slow set)	6 oz.
Citric acid	1½ oz.
Antifoam emulsion	4 gm.

Bring the water to a boil and agitate vigorously with a mechanical stirrer. Add the pectin, dispersed in 5 times its weight of sugar. Allow to stand for air bubbles to clear. Add the pineapple juice, antifoam, and 15 pounds of sugar to a steam-jacketed kettle and bring to a boil. Add the balance of the sugar and boil to about 224° F., add the pectin solution and boil to 226° F. Cool to 218° F., when trapped air bubbles will disappear, then carefully add passion fruit juice and citric acid. The batch will be cooled by this juice addition to about 190° F., which results in minimum heat effect on the sensitive passion fruit ingredient. Care must be exercised to prevent incorporation of air bubbles. Fill into containers, seal, invert for 2 minutes, and then cool as rapidly as possible.

This basic method of processing can also be applied to passion fruit jelly, but shows its best results when used in blends where the passion fruit juice can be used as the final addition ingredient.

PASSION FRUIT-PINEAPPLE JAM

Passion fruit juice	33 parts
Pineapple, crushed	12 parts
Sugar	55 parts
Pectin (150 grade, rapid set)	.5 part

Mix the crushed pineapple and passion fruit juice together in a steam-jacketed kettle and bring to a boil. Stir in the pectin, dispersed in 5 times its weight of dry sugar, and boil for 2 minutes. Add the balance of the sugar in three portions, allowing about a 2-minute interval between additions. This procedure will insure sugar penetration into the pineapple portions. Boil to 222° F., cool to 190° F., fill into containers and then apply

closure, invert for 2 minutes to sterilize the cover, and cool as rapidly as practicable.

Concentration of Passion Fruit Juice

The present volume of processed passion fruit juice makes the economics of concentration rather doubtful. However, the strong trend towards an expansion in production may make this process economical in the future to offset shipping costs to the Mainland. Successful experimental concentration to one-third volume has been achieved in a Mojonnier Low-Temperature Pilot Scale Evaporator. This is a recirculating, falling film type concentrator, which was operated at a vacuum of 28 inches and a product temperature of 75° F. Under these conditions, color retention was very good, as the reconstituted juice showed a barely discernible change from the original feed material. The reconstituted juice had lost much of its distinctive flavor and aroma, but this was almost completely restored by the reincorporation of volatile materials trapped in a dry-ice trap interposed between the condenser and the vacuum pump.

Equipment requirements would therefore be basically similar to those for pineapple concentration. Provision should be made for stripping and fractionation of volatiles, concentration of the stripped juice at as low a temperature as possible, to be followed by recombination with the volatiles. The resulting concentrate would be slush frozen, packaged, and then passed through the final freezing process.

By-products

The possibility of finding economic use for the passion fruit waste products has been explored. Passion fruit processing at the laboratory using commercial processing equipment has given the following average yield for the past 5 years: 48.6 percent pulp after finishing 35.8 percent juice and 11.0 percent seed on the basis of the original fruit yield. The juice is 10 percent higher than that obtained by commercial companies, which is probably due to superior fruit of the University passion fruit selections. Thus for every million pounds of fruit processed, 358,000 pounds of juice, 514,000 pounds of rinds, and 110,000 pounds of seeds were produced.

The skins have been proven to contain pectin, which is rapidly degraded after cutting by the action of naturally present enzymes. The pectin appears to be in short chain molecules and therefore not the most desirable type for jelly manufacture.

The major use of the skins is as cattle and pig feed, and for this purpose the pectin content is valuable as it permits the incorporation of relatively high levels of molasses into the feed. The rinds are normally chopped into ¼-inch slices and about ½ inch to ¾ inch long, and have been dried experimentally in a rotary alfalfa dehydrator (8). Small-scale ensiling studies have shown that good quality silage can be produced.

The passion fruit seeds comprise 10 percent of the fruit, and have been found to contain 20 percent of an edible oil. Feeding value and digestibility tests compared favorably with cottonseed oil, and there was no evidence of toxic or growth inhibiting substances (8).

SUMMARY

The development of the passion fruit industry in Hawaii has been encouraged and assisted by the activities of the Hawaii Agricultural Experiment Station in the fields of Horticulture, Plant Physiology, Agricultural Engineering, Economics, and Food Processing. At this stage of its development, it is a promising industry, supplying mainland and local markets. The major products are frozen passion fruit nectar base in consumer-sized cans and frozen passion fruit juice in institutional containers for incorporation into various juice blends, in most of which passion fruit is a relatively minor ingredient.

The two most promising areas for expansion are juice blends and tropical fruit cocktail or salad combinations. Juice blends, featuring passion fruit as the dominant flavor note, but suitably modified and rendered less harsh by the addition of pineapple, citrus, and perhaps acerola juices, have excellent market prospects. Tropical fruit combinations of pineapple, papaya, and banana are considerably enhanced in flavor by the addition of a small quantity of passion fruit juice. If these products can be brought into volume production at a competitive price, future prospects for this growing industry will be particularly sound.

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