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COMMERCIAL FRUIT PROCESSING

Second Edition

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Canning of Fruits

B. S. Luh, C. E. Kean, and J. G. Woodroof

Commercial canning of fruits and fruit juices is an important industry, particularly on the Pacific Coast of the United States. The total pack varies from year to year but has been about 163,000,000 standard cases since about 1972.

The top 10 canned fruit and fruit juice packs in 1980 were as follows: clingstone peaches—26,765,000; orange juice—19,146,000; grapefruit juice—19,303,000; applesauce—18,613,000; pineapples—17,057,000; fruit cocktail mix—14,426,000; pineapple juice—13,628,000; pears—10,926,000; cranberry sauce—7,023,000; and apples—1,791,000.

THE CANNERY

Plant Location

The factors that determine the suitability of any location for a cannery are availability of raw products; adequate supply of water of suitable quality; availability of labor during the canning season; transportation at reasonable rates between the cannery and markets; and adequate facilities for disposal of plant waste. Locating a factory near the raw material will permit the fruits to mature properly and will decrease injury from handling and deterioration from changes after harvesting.

The site should be easily accessible for the receipt of raw fruit and the

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shipment of finished materials. It should have ample space and be in a clean locality.

Water

The water supply for a cannery must be adequate. If there is not reliable water source from city mains, then filtration and treatments are needed to remove impurities from the water.

It is advisable to install a continuous water-softening plant. Water for boilers should be softened to prevent the formation of scale. The water used for washing the plant and floors requires no treatment for hardness but must be clean.

When cooling of cans is done with circulated water, the water should be chlorinated. The chlorine content must, however, be controlled to avoid overdosing, as this will cause corrosion of cans. Automatic chlorine solution injectors are widely used. The amount of active chlorine in the water at the entrance will be determined by the quantity of organic matter present. It is not uncommon to have 1–2 ppm of active chlorine at the entrance end. If the cooling water is recirculated and used again it is extremely important to check the residual chlorine level at both the entrance and discharge end of the cooler. The continuous addition of chlorine solution to recirculated processing and can-cooling waters has made possible considerable reduction in water consumption without undesirable effects on the quality of products.

The remarkable germicidal efficiency of chlorine in water is attributed to its ability to attack and inactivate sulfhydryl enzymes essential for life of the microbial cell. Hypochlorous acid (HOCl) formed by chlorine compounds in solution is the germicidal agent. With a given chlorine solution, the germicidal efficiency increases as the pH becomes more acid. However, corrosion of cans also becomes more severe as the pH is lowered.

Off-flavor may result from excessive use of chlorine in the processing of certain sensitive fruits. Canning syrups must be free of chlorine.

Lighting

In a fruit-canning plant, proper lighting is very important, particularly for sorting of prepared fruits, inspection, filling of cans, and the operation of automatic can-filling machines and can sealers. Proper lighting means adequate light of good quality, directed where it is needed, and with good diffusion.

The lighting system in a cannery requires careful planning by a specialist who will make sure that wiring is properly designed and of suitable current-carrying capacity. The switches, control panels, and outlets must be properly selected and installed so that they are safe for the workers in the plant.

The lighting should permit comfortable vision so as to avoid fatigue. It should be sufficiently intense to promote clean and sanitary conditions, efficiency, and pleasant working conditions. Low surface brightness is desirable in lamps used for general lighting. Fluorescent lamps usually have lower surface brightness and provide better diffusion of light than other light sources.

The Cannery Illuminating Committee recommends the following intensities of light illumination: 10 fc for receiving and dispatching, retort and exhaust-box areas, can unscramblers, dining room, stairways, and rest rooms; 20 fc for preliminary sorting, washing raw materials, cutting and pitting, canning, syruping, seaming, and labeling; 30 fc for the machine shop; and 30–50 fc for the laboratory.

Sorting and canning operations for peaches and apricots require critical inspection, and 85–125 fc of illumination are recommended. For color evaluation of foods the level of light illumination should be 200 fc. The MacBeth light is widely used for determination of USDA color score by visual grading.

Cannery Organization

Because cannery operations are always under pressure during the peak of the season, the work flow must be well organized. The plant operation should be studied carefully and the work planned well in advance of the season.

The Fieldman. Quality in canned fruits is at all times dependent on the raw material. The canner must employ a fieldman who understands fruit physiology and can deal with growers tactfully to ensure that only material of good quality is delivered to the cannery.

The cannery should have sufficient raw fruit to operate at full capacity. A contract that specifies the quality of fruit to be delivered should first be drawn up and inspection of each load made where possible.

The fieldman must keep in close touch with the cannery and report what raw material is due in advance. This gives the cannery the opportunity to adjust the labor supply in the case of shortage of raw material.

Receiving. The foreman of the receiving department should be thoroughly familiar with all varieties of fruits. He is the factory link with the fieldman and should keep him advised at all times as to the amount required and the condition of material as received. The foreman of the receiving department must be fair in his dealings with growers.

Preparation. One supervisor should be appointed for each 30 workers, and when piecework is employed an assistant may be required for checking the work done by this number. The work of the supervisors in each department should be coordinated by a foreman.

Details for washing, peeling, and preparation of fruit for processing are presented in Chapter 3.

Syrup and Brine. The preparation of syrup for fruit requires great care, and experienced personnel should be employed for this work. Automation of syrup mixing and delivery is now common practice in many canning plants. Since liquid sugar is becoming more popular, the plant should have facilities for holding liquid sugar.

Sterilization. Heat sterilization of the canned product is the most important part of the canning operation. The time and temperature required for heat processing will vary with the maturity of the fruit and other conditions. These operations must be done by experienced employees who understand the principles involved in heat sterilization of canned foods.

The cannery should employ competent technologists, and the heat sterilization foreman should be guided by the information received from the laboratory where testing of the product at various stages is carried out.

Labeling. The labeling and casing of the canned product should be directed by a person who is concerned with neatness and appearance. The appearance of an article is one of the main sale factors, and the labeling department must be made wholly responsible for this. The duties of the foreman are to supply the machine with labels, paste, resin, etc., and to see that all cans going into cases are correctly labeled and that the cases are fastened straightly and securely, with the proper markings outside.

Warehouse. The foreman of the warehouse controls all products from the cannery and arranges shipments as required. He should have expert knowledge of rail and road transport and should be capable of arranging loads from orders as received from the order department. Today, computers are being used by large canneries in order to have an accurate record of their inventory at all times.

Cans

Cans are made from tinplates, which are very thin sheets of steel lightly coated with tin. This tin coating serves two purposes: it covers the face of the steel sheet, preserving it from rust; and it acts as a medium by which parts of a sheet may be made to adhere to one another by soldering.

Sanitary cans can be cleaned readily. One end of the body is left completely open and is flanged at the mouth. The lid is made with a flange which hooks over the flange of the body and is finally rolled on without difficulty by means of two rollers, the first of which forms the seam and the second of which tightens it.

Cans are usually referred to by numbers that correspond to the size of the can. Table 6.1 lists the cans used principally in the United States. The first number of the symbol denotes the diameter, and the second, the height of the can. The first digit of either number represents the number of inches, and the last two digits, the number of sixteenths. Thus, a can that is 3 7/16 in. in diameter and 4½ in. high would be designated as 307 × 408. The corresponding dimensions in millimeters are also presented in Table 6.1.

Aluminum Cans. Although aluminum cans have captured a sizable portion of the beer and beverage market, they have not been popular for canned food uses except for the small-size drawn can. Aluminum cans become less attractive as can size increases because of the need for heavy gauges to prevent paneling. Even the higher strength aluminum alloys employed today still require an increase of about 35% in the gauge of aluminum to provide equivalent buckling resistance to conventional tinplate in 303 diameter cans.

Experimental and practical experience in food canning has shown that most canned fruits and vegetables packed in uncoated aluminum cans attack aluminum quite readily.

Lacquered Cans. The tin container by itself is perfectly satisfactory for preserving most foods. For foods that deteriorate in appearance when packed in a plain can (e.g., boysenberries, plums, olives), it is necessary to coat the insides of cans with a lacquer. Two kinds of lacquered cans are available: an acid-resisting lacquer, which is used for acid foods, mostly fruits; and a sulfur-resisting lacquer, which is used for products of the nonacid group, including vegetables, beans, and meats.

Fruits like apricots, grapefruit, peaches, pears, and pineapples are packed in plain tin containers. Cans for highly colored fruits such as boysenberries, raspberries, strawberries, and red plums must be coated inside with acid-resistant lacquer. Cans for jams made from fruits high in anthocyanin pigments should also be lacquered.

Corn, red kidney beans, and lima beans contain very little acid, but they evolve an appreciable quantity of sulfides when heat-processed. This, while quite harmless, causes an unsightly blackening of the inside surface of the can. To prevent this blackening a special sulfur-resisting lacquer has been developed. Its use is almost universal in the packing of vegetables where quality packs are desired. The lacquer contains zinc oxide, which reacts with the sulfide to form colorless ZnS, preventing the

Table 6.1. Common Consumer Can Sizes for Fruit Canning

Recommended product standards		
Can name	Dimensions[1]	Diam. × Hgt. (mm)
For applesauce, apricots, cherries, berries including blueberries, figs, fruit cocktail, grapes, peaches, pears, plums, prunes, cranberries, citrus salad, fruits for salad		
—	211 × 212[2]	68.3 × 70.0
8Z Tall	211 × 304	68.3 × 82.6
No. 300	300 × 407[2]	76.2 × 112.7
No. 303	303 × 406	81.0 × 111.1
No. 2 ½	401 × 411	103.2 × 119.1
For pineapple (sliced, crushed, tidbits, and chunks)		
—	307 × 201.25	87.3 × 52.8
No. 1 ¼	401 × 207.5	103.2 × 62.7
—	307 × 309	87.3 × 90.5
No. 2	307 × 409	87.3 × 115.9
For ripe olives		
—	211 × 200	68.3 × 50.8
8Z Tall	211 × 304	68.3 × 82.6
—	300 × 314	76.2 × 98.4
No. 300	300 × 407	76.2 × 112.7
Pt. Olive	211 × 600	68.3 × 152.4
For juices, drinks, or nectars (citrus juice, juice drinks, nectars, other fruit juices, pineapple juice, tomato and vegetable juices)		
—	202 × 214[3]	54.0 × 73.0
—	202 × 314	54.0 × 98.4
211 Cyl.	211 × 414	68.3 × 123.8
No. 2	307 × 409	87.3 × 115.9
No. 2	307 × 512	87.3 × 146.1
Cyl.	404 × 700	108.0 × 177.8
No. 3		
Cyl.		
For pie fruits and fillings: apples, cherries (RTP), pumpkin, squash, and prepared fillings		
No. 303	303 × 406	81.0 × 111.1
No. 2	307 × 409	87.3 × 115.9
No. 2 ½	401 × 411	103.2 × 119.1

Source: Canning Trade Almanac.
[1]Diameter × height. First figure in each series is inches, the two remaining figures are 1/16 in.
[2]Cranberries only.
[3]Baby food only.

formation of dark-colored iron or copper sulfide. Sulfur-resisting lacquered cans should not be used for acid foods because the lacquer may peel away from the tinplate. It is also unwise to use lacquered fruit cans for products where the processing temperature exceeds 100°C, as this will cause peeling.

Lacquer is usually applied to the tinplate before fabrication of the can. Sheets are fed through a machine with cleaning rollers, passing from there under a rubber roller coated with lacquer and adjusted to give the desired thickness of film to the sheet. The sheets are then carried through long ovens where the lacquer is baked on. The lacquered sheets are usually passed through the lacquering operation twice in order that any small defect in the first coat will be covered by the second.

The best lacquered cans are produced by a method know as "flush lacquering." After the can is made from plain tinplate, it passes through a machine where it is filled with lacquer or the lacquer is efficiently sprayed on the inside. The can is then inverted and drained, after which it is again filled or sprayed with lacquer. The can is again inverted and drained, after which it is baked in special ovens at a low temperature so as to prevent any softening of the solder in the side seam. Tinplate covered with lacquer may be fractured to some extent during fabrication of the can. The application of the lacquer on the finished open-top can is the safest guarantee of a complete film which will protect the fruit from any contact with tinplate or base metal. The ends or covers are also sprayed on a special machine and are baked at a low temperature.

Lithographed Cans. Lithographed cans are now widely used. If the canner packs individual lines in large quantities, it is advisable to use decorated cans, as they save labor and present a good appearance on the shelf. The best plan is to order 50–75% of the estimated requirements in lithographed cans, leaving the balance for plain cans with labels.

APPLES

Apples are canned primarily in the Pacific Northwest, New York, and Pennsylvania. Canned sliced apples are used for the preparation of pies in restaurants and hotels. Canning of apples is considered a by-product industry in most apple-growing areas and is a means of utilizing the best quality of culls. The fruit for canning purposes should be of fair size and reasonably free of blemishes. Apples unfit for canning may often be used for cider, vinegar, or applesauce.

Sliced Apples

Apples for canning should be firm and hold their shape in the can. They should be of good flavor, color, and texture. Acid cultivars with white flesh are preferred. On the Pacific Coast the 'Yellow Newton Pippin', 'Winesap', 'Jonathan', and 'Spitzenberg' are popular for canning. Other commonly used cultivars are 'Baldwin', 'Golden Delicious', 'Greening', 'Northern Spy', 'Rome Beauty', 'Roxbury Russet', 'Stayman', and 'York Imperial' (Jackson 1979). In Great Britain, the more suitable apples are 'Bramley Seedlings' and 'Newton Wonder'.

Ripeness of the fresh apples greatly influences the flavor, color, and texture of the finished product. In canning apple slices, underripe apples tend to produce an excessively firm green product of poor flavor; overripe apples, on the other hand, produce a soft or mushy pack having a bland flavor. Sometimes it is necessary to store the apples briefly between harvest and canning. For storage, it is preferable to use crates or 455-kg bins stacked so as to permit good air circulation. If bulk storage is necessary, small piles are more desirable, and some provision for air circulation is necessary. For prolonged storage, refrigerated storage or controlled atmosphere (CA) storage should be used.

The texture or firmness of canned apple slices can be modified by controlling pectinesterase activity and addition of calcium salts. Apples that are usually canned as slices are not covered by the FDA Standard of Identity. Use of the USDA quality grade standards is optional.

Washing and Inspection. Processors prewash the apples by fluming them in water from the receiving area to the washers. Mechanical washers equipped with paddles and high-pressure jets are used. A good water pressure must be maintained at all times to ensure that all dirt is removed. If lead arsenate sprays are used in the orchard, it is advisable to add 1–1.5% hydrochloric acid to the washing water in order to remove any spray residue. Washing with water containing a small amount of trisodium phosphate or food-grade detergent is a common practice.

After washing, apples pass over an inspection belt or conveyor, where the bruised or irregular fruits are removed. Irregularly shaped, off-size, and cull apples can be used for making applesauce.

Size Grading. The purpose of size grading is to improve the efficiency of the peeling operation and to divert small apples to the applesauce line. Divergent roller-type size graders can separate apples into two or three size groups for delivery to separate peeling lines. Through this operation, peeling loss is reduced and skips can be largely eliminated.

Peeling, Coring, Trimming, and Slicing. Mechanical peeling and coring are done on the same equipment. Use of 0.3% alkyl aryl sulfonate or 0.25% sodium octanoate as wetting agents improves both peeling rate and surface appearance of the peeled products.

Peeled apples are delivered to conveyor belts for inspection and trimming. To prevent enzymic browning, it is necessary to handle the apples rapidly after peeling, and to hold the pared, trimmed apples in fiberglass or plastic tanks containing 2% citric acid or 2% salt solution until they are sliced. Peels, cores, and trimmings may be used for vinegar production, jelly, or pectin manufacture.

The peeled, cored apples are fed to slicing machines, and the sliced apples are washed in a reel washer or shaker screen to remove small pieces.

Can Filling and Closure. In order to obtain sufficient fill weight, it is necessary to remove air from and blanch sliced apples. Vacuum treatment removes occluded air from the slices of apples and permits its replacement with water or a 2–3% salt solution either during vacuumizing or, subsequently, during blanching.

Apple slices are packed by semiautomatic or automatic fillers into plain or enameled cans. It is important to fill the cans hot, adding sufficient hot water or syrup to fill the spaces between the slices. A filling temperature of between 77° and 82°C is desirable.

Thermal exhausting may be used to obtain a proper closing temperature. An exhaust period of 3–10 min may be used, depending upon the style of pack and the can size. A vacuum in the cans is obtained by double seaming the filled cans at a temperature of 77°C employing atmospheric closure. Replacement of the headspace air with nitrogen gas is effective in reducing internal can corrosion.

Sterilization and Cooling. There should be no delay in placing the sealed cans in the cooker and starting heat sterilization. Cans should be processed in boiling water until a can center temperature of 87.8°C has been reached. The processing time is 20 min at 100°C for 307 × 409 and 401 × 411 cans (initial temperature of 71°C) and 35 min for 603 × 700 cans.

Immediately after heat processing, cans are water-cooled until the average temperature of the contents reaches 41°C. Casing canned apple slices at high temperatures may result in softening, loss of normal color, darkening, or pink discoloration of the product.

Baked and Glazed Apples

Firmer cultivars such as 'Baldwin', 'Rhode Island Greening', 'Gravenstein', 'Northern Spy', and 'Rome Beauty' are suitable for canning as baked or glazed apples.

Choice apples about 2¾ to 3 in. in diameter should be selected for this pack. The apples are washed, cored by making a small cut across the blossom end and removing the core without cutting through the stem end, submerged in a 2–3% salt brine, and rinsed with fresh water prior to baking. The fruits are not peeled.

Baked Apples. Apples are baked at 176.7°C for about 45 min, depending somewhat on the size and cultivar of fruit. The baked apples are placed in cans of suitable size, which are then filled with hot 40°–50° Brix syrup. If a closing temperature of 71.7°C cannot be maintained, a steam exhaust should be employed to attain this temperature. After closure, the cans are processed in boiling water for 20–30 min, depending on the size of the can, and then are water-cooled.

Glazed Apples. Glazing of apples may be more practical than baking as a method of preparation for canning. Instead of baking, the cored apples are cooked in a 40°–50° Brix sugar solution for 10–14 min and placed in cans, which are then filled by the addition of syrup in which the apples were cooked. Cans are then closed and processed in the same manner as with oven-baked apples. The glazed apples tend to sink in the syrup without exhausting. This method requires much less time than baking.

Corrosion and pinholing may occur in cans of baked or glazed apples. Corrosion is caused by the malic acid of the apples in the presence of air or oxygen. Corrosion is limited or reduced to a negligible degree if the air is thoroughly expelled from the fruit by blanching and from the can and contents by exhausting.

Apples are easily sterilized on account of their high acidity. A sterilization of 8–10 min at 100°C in a continuously agitating sterilizer has been considered sufficient if the cans have been filled and sealed above 71.1°C. After processing, cans should be cooled to an average can temperature of 40.6°C.

Apples for Cake Topping. The Colby process entails placing unblanched fruit pieces in a closed vessel and subjecting the occluded fruit to a vacuum of 38.1 cm mercury. The evacuated gas cavities are then infused with an edible liquid that may contain dissolved or suspended solids to enhance the flavor or to help prevent enzymatic browning. The excess liquid is completely drained and the infused fruit pieces are then placed in cans and sealed under a vacuum in excess of 38.1 cm (15 in.) mercury and at a temperature of less than about 43.3°C. Sealed cans are heated to sterilization temperatures (about 98.9°C) for 5–20 min, and then cooled rapidly in water to less than 37.8°C. The concentration of the additives in the water solution can be 0.01–3%, and the solution should be allowed to cover the fruit for several minutes in order to provide sufficient infusion of additives throughout the fruit tissues.

Apple Juice

Apples used for juice (sweet cider) processing should be fresh and sound. Immature apples tend to produce unsatisfactory juice due to a high percentage of starch in the fruit. On the other hand, overmature apples give a low yield and cause difficulties in pressing, clarification, and filtration.

Most apple cultivars do not make a satisfactory juice when used singly but are excellent when blended with other cultivars. Factors to be considered for blending include degrees Brix, the tannin content, the total acidity, and pH. The flavor of an apple juice is based on two factors: sugar–acid balance and aroma or bouquet characteristics.

Opalescent juice, made by retaining fine pulp particles suspended in the juice, is preferred by some to the traditional clear juice.

In preparation for extraction, apples are washed thoroughly to remove all adhering dirt and sorted to remove partially or wholly decayed fruit. Then the apples are subjected to grinding. Two types of equipment are used for grinding: one type grates the apples to a pulp, the other type is a hammer mill.

Juice Extraction. The most commonly used machines for juice extraction are the hydraulic cider press, pneumatic fruit juice press, continuous screw-type press, continuous plate press, horizontal basket press, and the screening centrifuge. After apples are pressed, the juice goes through a "cider" screen, which is a cylinder of monel or stainless steel screen of approximately 100–150 mesh. This procedure reduces the suspended solids content to around 2% (Moyer and Aitken 1980).

Before filtering, the juice is treated with several materials to make filtration easier. First, pectic enzyme is added to hydrolyze pectin. Then tannin and gelatin are added to form a coagulation and then precipitate, or the juice is heated which does the same thing as the tannin–gelatin reaction. Finally, there is a bentonite treatment in which juice passes from the heat exchanger to tanks where a suspension of equal parts of bentonite and filter aid is added with vigorous stirring. The treating materials are suspended in a small quantity of juice and the suspension added to the large volume. After treatment the juice is allowed to stand for at least 1 hr and then is filtered.

Asti (1970) developed a patented process to provide an apple juice suspension having the body, viscosity, and texture of fresh natural apples in liquid form. Fresh apples are washed, and then passed to one of two paths—A or B. In path A, the washed sound fruit is peeled, cored, sliced, and cooked. The cooked and prepared fruit is then crushed and forced through a screen. After the crushing step, it is usually convenient to provide a storage tank for holding the product of path A in order to coordinate the whole process. The fruit in path B is milled but not cooked. Instead, an antioxidant is introduced into the crushed fruit at a point where the natural oxidation has not proceeded beyond return. The crushed and disintegrated fruit is pressed to express the juice from the pulp. The juice is then put through a screen to remove any coarse pulp, seeds, or skins. The screened juice is deaerated and may then be stored, if necessary, for coordinating path A with path B.

The products of path A and path B are mixed. The crushed cooked fruit of path A, primarily apple pulp, contributes body, texture, and viscosity to the mixture. The product of path B contributes fresh uncooked, unfiltered juice that retains many of the characteristics of the fresh fruit. Mixing may conveniently take place in a proportioning pump. The juice and pulp are proportioned at any desired ratio; preferably, the juice should be at least 70% of the total weight of the mixture to keep the product a pourable liquid. If over 95% juice is mixed, the benefits derived from the pulp are largely lost. The mixture is pasteurized and homogenized and then transported to container-filling equipment.

Canning. Cans for apple juice are generally lined with a special enamel or lacquer that is resistant to the corrosive action of the juice. As the cans travel along the line to the filter, they should pass through a can washer where all dust particles or other debris are removed. The cans are filled on special filling machines and immediately sealed with covers in a can-closing machine. The closed cans should be inverted or rolled on their sides for approximately 3 min to bring the hot juice into contact with the cover to sterilize it. The usual temperatures for flash pasteurization are between 77° and 88°C for 25–30 sec. The cans are then cooled in a cooler to 38°C.

Bottling. Bottling apple juice requires specialized equipment and more supervision than canning because of the fragility of the containers. Conveyor lines for glass containers must be designed and operated so that the bottles are not "bruised" or broken by impact.

Before being filled with hot apple juice, bottles should be cleaned by passing them through a special cleaning unit to remove all dust particles. If new bottles are used, it is rarely necessary to wash them. This is especially so with bottles that are placed neck-down in cartons immediately after they leave the annealing furnace at the factory. The bottles should be preheated to within 6.6°C of the filling temperature in a special section of conveyor in which steam jets impinge on the containers. The most satisfactory fillers draw the juice into the container by evacuating the container.

Closures for bottles and jugs can be screw caps, crown caps, or vacuum caps. The latter are the most satisfactory because there is less chance of breakage during application and the headspace vacuum is slightly higher than with other types.

Hot-filled glass containers should be cooled gradually in a special cooler, usually of the spray type. Where bottles enter the cooler, the sprayed water is hot; as the bottles move through the cooler, the sprayed water is gradually reduced in temperature. The water spray should be very fine so that cooling can be done by evaporation as well as by conduction. Bottles emerging from the cooler should still be warm enough to dry completely but not above 37.7°C to avoid deleterious heat effects. Recently, bottles made from polyester or polyolefin polymers with air-barrier coatings have been tried for commercial processing of apple juice.

Bulk Storage. Apple juice has been stored in bulk by heating and then pumping it while hot into storage tanks. These tanks, with capacities up to 7600 liters, are vented with an air filter and allowed to cool. This method of bulk storage has been largely replaced by presterilizing the tanks with hot water, steam, hydrogen peroxide, or sulfite solution. The air in the tank is replaced by CO_2 at 0.10 kg/cm^2 to prevent fungal growth and then pasteurized and cooled juice is pumped into the tank. The success of this storage depends on the maintenance of aseptic conditions following pasteurization and during transfer of the cooled juice into the tank. The temperature of a tank room is usually 15.5°C or below. Bulk storage of pasteurized apple juice at −1.1°C would extend the supply and permit blending to achieve a desirable flavor.

To overcome the difficulties encountered in maintaining sterility in bulk storage, the Boehi process was developed in Switzerland for the "return" bottle trade. Clean tanks are completely filled with water, which is then forced out with 3.2 kg/cm^2 CO_2. When empty, juice at 4.4°C impregnated with 0.6–0.8% CO_2 is pumped in until the tank is 95% full. The headspace of the tank is further purged with CO_2 to eliminate oxygen before it is sealed through a safety valve. If the storage temperature is maintained below 4.4°C, growth of yeasts and lactic acid bacteria is inhibited.

Preservation with Chemicals. The principal preservatives used in commercial apple juice are salts of benzoic acid, sulfurous acid or its salts, and sorbic acid. Sodium benzoate is used chiefly to increase the shelf life of unpasteurized apple juice; it is frequently used in the United States for juice packed in 3.78- or 7.57-liter jugs that often are labeled "apple cider." Benzoate prevents spoilage when present in concentrations of 0.1–0.3%, the quantity necessary varying with the acidity of the juice. The salt is dissolved in water and added to the juice at the time of preparation. Sulfurous acid is used mainly for preserving juice in bulk for export or for manufacturing purposes. Concentrations necessary to prevent spoilage vary from 0.02 to 0.1% calculated as sulfur dioxide, depending on the juice preserved. It is added in the form of sulfites or sulfur dioxide, as gas from a cylinder, or as a solution in water.

In many countries, benzoic acid and SO_2 or their salts are the only preservatives permitted by law. When added they have to be declared on the label.

Pure sodium benzoate, when added in concentrations of 0.05–0.1%, generally does not impart any objectionable flavor to fruit juices, particularly when they are to be diluted before use. The concentration perceptible to taste depends also on the ratio of benzoate ion to benzoic acid. The amount of preservative required depends on the character of the juice, particularly its acidity. The concentration of metabisulfite or sulfite required to prevent growth in an acid juice is about 0.1% calculated as SO_2. When only used to inhibit oxidation, about 0.02% of SO_2 is sufficient under ordinary conditions. The preservative should be completely dissolved and thoroughly mixed with all the juice to be treated. The two preservatives may be used to advantage in combination with each other: sulfurous acid to retard oxidative changes and benzoic acid chiefly to check spoilage organisms. Recent trends are to avoid use of chemical preservatives.

Although SO_2 is frequently used in fruit juices, in the United States it is seldom used in apple juice. In some states its use is not permitted. Even in cases where it is not intentionally added, minor amounts may become included in the final products. This originates in the SO_2 used for disinfecting utensils and equipment, particularly in smaller juice factories.

Sorbic acid, a 2,4-hexadienic acid, is metabolized by humans to carbon dioxide and water, the only known preservative with this important characteristic. Sorbic acid or sodium sorbate is effective for the inhibition of yeast fermentation in unpasteurized apple juice. It is also effective against many common molds, but generally not against bacterial fermentation. Sorbic acid seems to exert its suppression of microbial growth by the blocking the normal functioning of certain sulfhydryl enzymes. Sorbic acid has the advantage of not affecting the taste of fruit juices to the same extent as benzoic acid. The sodium salt of sorbic acid is, however, not quite as effective as that of benzoic acid.

Applesauce

Approximately 10 million bushels, close to 25% of the apples used by industry, are converted into sauce. Manufacture of applesauce is concentrated mainly in Maryland, Pennsylvania, Virginia, West Virginia, New

York, and the three Pacific Coast states. In California, 'Gravenstein' apples are most popular for sauce production, while 'Golden Delicious', 'York Imperial', 'Jonathan', and 'Stayman' predominate in the East.

In a typical commercial plant, after the apples are sorted, trimmed, and sliced, they are discharged directly into a continuous stainless steel thermoscrew cooker where they are heated rapidly to 98.9°C and held there for 3 min. The cooked apples are discharged into a Langsenkamp pulper with a 1.52-mm (0.060-in.) screen and operating at 1000 rpm. The apple pulp is pumped into a holding tank where water and sweeteners are added to adjust the soluble solids to 19°–20° Brix at 20°C. The applesauce is then pumped through a stainless steel tubular heat exchanger to reach 90.6°C and then filled hot into No. 303 cans (303 × 406), sealed hot with steam injection, inverted, heated 5 min in a steam box, and then cooled in water to reach a can center temperature of 37.8°C in 25 min.

Then quality of canned applesauce is affected by varietal characteristics, maturity of the fresh apples, postharvest storage conditions, and storage temperatures of the canned product. The flavor can be improved by fortification with apple essence and citric acid. Higher storage temperatures have been reported to cause faster corrosion of the tin coating and the formation of hydrogen gas in the headspace. For best storage stability, temperatures of 20°C or lower are recommended.

Preparation of Applesauce Using a Pressure Cooker. With the usual methods of preparing applesauce, the fruit is peeled, cored, trimmed, chopped, and conveyed to a cooker in which the prepared fruit and the requisite quantity of sugar are cooked to the desired degree. The volume of fruit is so large that for economical and efficient operations the cooking must be accomplished in a very short time, seldom more than 4 min. To achieve thorough cooking in such a short period, the apples are cooked under pressure at temperatures of about 102°–107°C. Cooking temperatures and pressures are generally obtained by the injection of steam into a closed cooking chamber.

Sauce cookers operate continuously with cooked sauce being discharged from the cooker at the same rate that the raw fruit and sugar enter. Fruit and sugar enter and leave the cooker through enclosed worms or butterfly valves which, when full, serve as seals that prevent loss of steam pressure in the cooker.

After cooking is completed, the cooked mass is conveyed from the cooker to a finishing machine in which the coarse fibers, seeds, and peel particles are removed. When the cooked sauce leaves the cooker and enters the finisher, pressure drops from superatmospheric pressure to normal pressure. The drop in pressure is accompanied by a drop in temperature, which is effected by the evaporation of the flash-off vapor.

The sauce is filled into cans or jars, and the containers are sealed immediately. Containers are then inverted or turned upside down to sterilize the lids. The hot sauce serves as the sterilizing medium. Then the containers are cooled quickly in water. In normal practice the sauce comes from the finisher at 98.9°C and is filled into the containers at 96°–98°C.

It is necessary to equip the cooker with a suitable means of cooling. In a batch process, the cooking kettle is a double-walled vessel with means to admit either a heating fluid or a cooling fluid to the space enclosed between the walls. In a continuous-type cooker, the cooling means is a double-jacked discharge worm. The length and diameter of the cooling section are such as to prevent steam pressure losses in the body of the cooker and to allow sufficient cooling surface to enable the sauce to be cooled to the desired temperature.

APRICOTS

Apricots are grown and canned mostly in California. The average annual pack of canned apricots varies between 3 and 5 million cases. Fruit that is smaller than 31 to the kilogram (14 to the pound) is used chiefly for canning whole or for production of nectar.

Cultivars

The 'Blenheim' apricot is the most popular cultivar for canning. It is medium in size, deep yellow in color, and excellent in flavor. When properly ripened, it has uniform texture from the skin to the pit and retains its shape in the can during processing.

The 'Royal' apricot is grown in southern California and in the hot interior valleys. It is somewhat smaller in size than the 'Blenheim' and has a more intense orange color. Many pomologists claim, however, that the 'Royal' and 'Blenheim' are identical and that the differences in appearance noted in commercial culture are due to the effects of locality and climatic conditions. When grown in hot, dry regions, 'Royal' apricots often become soft near the pit, a condition that renders them less suitable for canning.

The 'Tilton' is an important cultivar grown in the hot interior valleys of California, in eastern Washington, and in British Columbia. It is large, but is rather pale yellow in color. Recently, because of occasional texture softening in canned apricots, and because of the rapid conversion of the apricot orchards in Santa Clara county to industrial and housing development projects, more 'Tilton' apricots are being planted in the hot interior valleys of California to replace some of the 'Blenheim' apricots.

Ripeness Level and Horticultural Factors

Apricots for canning are harvested at the optimum ripeness level. When harvested at the "canning-ripe" stage, the fruit is firm, of good color, and of pleasing flavor. Yet, it will not have reached the maximum flavor at this stage of ripeness. As the fruit firmness decreases, the volatile reducing substances increase. The physiological and biochemical changes in maturing stone fruits include an increase in soluble solids, decrease in firmness, loss of chlorophyll, increase in specific pigments, and decrease in acidity.

The optimum period for storage of apricots at 0°–4°C and 85% relative humidity is about 20 days. Under modified atmosphere conditions (0°C, 81% RH, 3% O_2, and 5% CO_2), the shelf life is about 30 days. Organoleptic properties of the apricots are maintained better in modified atmosphere storage at all periods.

The fungus *Rhizopus stolonifer*, when present on apricot fruit, may cause texture breakdown after canning. The mold growth may be arrested by dipping the fruit in dichloran (2,6-dichloro-4-nitroaniline), a fungistat useful against *Rhizopus* rots in stone fruits. Processing apricot halves with $CaCl_2$ improves canned product texture.

Canning Process

Receiving. Most canners examine each delivery of apricots to determine roughly the percentage of the different grades, and payment is made to the grower on the basis of the test and whether the sample shows texture breakdown after canning on a trial run. If the sample shows texture breakdown right after canning, the lots are diverted for processing into nectars, baby foods, jams, and preserves.

Pitting. Apricots are washed, halved, and pitted but are usually not peeled. Some apricots are processed as whole fruit after lye peeling. Fruit may be cut by hand around the pit suture, and the pits removed; now, more commonly, fruit is cut and pitted by a machine.

Grading. Screens with openings of 3.18, 3.81, 4.45, 5.10, or 5.40 cm are used for grading apricots for size before pitting. The average diameters of Fancy, Choice, and Standard grades are usually 4.45, 4.29, and 3.97 cm, respectively. The grades are based more upon color, texture, and absence of defects than upon size (grading for quality is done after pitting).

Filling and Syruping. The graded fruit is conveyed to mechanical or hand-pack devices for filling. Filled cans are fed to vacuum syruping machines where syrups of the concentrations recommended by the California League of Food Processors (55°, 40°, 25°, 10° Balling) and plain water are used, according to whether the grade is Fancy, Choice, Standard, Second, or Pie.

Exhausting and Double Seaming. Apricots contain some imprisoned gas, which will cause pinholing in the can unless the gas is driven out by exhaust. Cans are exhausted up to 10 min at 82°C in an exhaust box and then closed in a steam-flow machine. A more common practice now is to prevacuumize the canned product and close it in an atmosphere of steam. This prevacuumizing gives less syrup loss, uses less floor space, and requires less steam than the exhaust box method.

Heat Sterilization. After exhausting and double seaming, canned apricots are heat-procesed at 100°C sufficiently long for the center temperature of the product to reach 90.6°C.

Most canned apricots are heat-processed in continuous rotary cookers at 100°C for 17–19 min for No. 2½ cans, and for 20–30 min for No. 10 cans, depending on the initial temperature and the texture of the fruit. Whole fruit requires longer processing than halved. The heat-processed cans are water-cooled to 40.6°C and then transferred to the warehouse for storage.

Yields and Drained Weight. The yield of halved canned apricots per ton varies from 52 to 55 cases of 24 No. 2½ cans. Loss in canning of unpeeled halved fruit is about 10–15%; where the fruit is peeled, the loss may exceed 30%. Yields of canned whole apricots usually exceed 70 cases per ton.

One day after canning, the drained weight is about 84% of the fill weight because apricot fluid is lost to the cover syrup. On storage, drained weight increases rapidly for the first 5–10 days, and then slowly until an equilibrium drained weight (90–97% of fill weight) is reached in 45–60 days.

Texture of Canned Apricots

The ripeness level of the fresh fruit and processing time are the most important factors influencing the texture of apricots. Canned apricot halves soften during storage; there is an increase in water-soluble pectin and viscosity in the syrup, and a decrease in protopectin. Riper apricots contain less protopectin and the syrup contains more water-soluble pectin.

Besides ripeness level and the processing condition, softening of apricots may also be related to intrinsic and/or parasite-originated pectic and cellulytic enzymes. Perhaps control of mold contamination in the orchard, better sanitation, more rapid and careful postharvest handling, and more slective sorting on the grading table would help to alleviate the softening problem.

High acidity in apricots is related to the softening problem. Acidity in the fruit is influenced by the cultivar, climatic conditions, and the level of nitrogen application. It is thought that softening in high-acid apricots with pH ranging from 3.3 to 3.5 may result from acid hydrolysis of cell wall constituents. Some canners have successfully eliminated softening by avoiding lots of fruit with high acidity and those with possible mold contamination.

Pectin degradation in canned apricots can lead to textural problems due to lack of firmness. Processing apricot halves with $CaCl_2$ improves the texture of canned products.

Canned Apricot Pie Fruit

Considerable pie-grade fruit is now pitted mechanically by Elliott pitters, then steamed and canned as solid-pack pie fruit, without the addition of water or syrup. The No. 10 cans require heat processing at 100°C for 45–60 min in an agitating cooker because of slow heat penetration. If the product is canned boiling hot, a shorter process time can be used. Paneling of No. 10 cans may occur unless the cans are of reinforced type.

Sieved Apricots as Baby Foods

The operations and equipment for canning sieved apricots may vary somewhat in various baby food plants. The following description summarizes the more important steps.

Whole ripe apricots are washed in a water tank, followed by a spray washer. Green and defective fruits are removed on a sorting belt. The sorted apricots are thoroughly washed by sprays of water under fairly heavy pressure and then cooked by steam at 100°C for 6–8 min in a screw-type, steam-jacketed continuous heater. They are pulped in a stainless steel cyclone-type pulper with a coarse screen to remove pits and coarse fiber. The hot puree then passes through a fine finisher 0.508-mm (0.020-in.) screen to remove small pieces of fiber. Sugar is added to give the proper balance in flavor between the acidity of the fruit and the sweetness of naturally occurring and added sugar. Usually 7–10% by weight of sucrose is added. A small amount of farina (tapioca starch) or modified starch may be added and cooked a short time before canning. The success of this process depends on control of the consistency of the product. The total solids of the final product are about 21–22%. After passage through a homogenizer to impart a smooth consistency, the product is deaerated under high vacuum. The deaerated product is then flash-heated in a closed continuous heat exchanger to 115.6°C, cooled to 93°–96°C in a second heat exchanger or through a flash cooler, filled into 202 × 214 cans or 4.85-fl oz glass jars at that temperature, sealed, inverted or passed through a steam chamber for a few minutes to ensure sterilization, and cooled in water in the usual manner. The jars are sealed by a high-speed jar sealer. Recent models can seal 500–800 cans/min. The conveyors, fillers, and sealers must be highly synchronized or else delay and pile-ups will occur. The canned product is labeled by a high-speed automatic labeling machine and cased. The cases are sealed and warehoused.

Apricot Puree and Apricot Beverages

Apricots for nectar manufacture should be so ripe that they are soft. Puree or nectar prepared from firm fruit, such as is used for canning, will be of inferior flavor and color. Tree-ripened fruit possesses a better flavor than that permitted to ripen after picking. Since apricots ripen unevenly, it is necessary to harvest three or four times in order to obtain the best-flavored fruit.

Apricot Puree. Washed and pitted apricot halves are steamed until soft; then they are passed through an expeller screw extractor with a 0.838-mm (0.033-in.) screen. One part of sugar is added to three parts of pulp. The product is filled into No. 1 plain cans, exhausted 8–10 min, sealed, processed at 100°C for 20–25 min, and cooled in water. The undiluted product prepared in this way requires dilution with water or sugar syrup before use as a beverage.

A continuous sterilization process for sterilization of apricot, sour cherry, plum, and tomato juices in 3-liter bottles using HTST counter-current equipment has been shown to be suitable and superior to sterilization in autoclaves.

Apricot Nectar. To make apricot nectar, the fruit is steamed in a continuous steam cooker for approximately 5 min. The hot fruit is then run through a brush finisher equipped with a 0.635- to 0.838-mm (0.025- to 0.033-in.) screen. The resulting puree is then passed through a steam-heated tubular heat exchanger where it is brought to a temperature of 88°–93°C. The puree is sweetened with approximately 1.8 times its volume with 15°–16° Brix sugar syrup; citric acid is added so as to maintain a constant total solids–acid ratio throughout the season. The resulting nectar is filled into plain cans, exhausted for approximately 6 min, and sealed. No. 1 tall cans are processed for 15 min at 100°C; larger cans are given a longer processing.

Apricot Concentrate. Apricot purees are concentrated in vacuum pans for shipment to consuming centers where they may be combined with syrup to prepare nectars for distribution in cans.

Apricot puree can be concentrated to a 2.5 to 1 ratio by vacuum evaporation and then packaged in 208-liter (55-gal) drums by the aseptic canning method. The apricot concentrate may be used to make a pumpkin-type pie, or it can be whipped with other ingredients to produce a chiffon or cream pie. It blends readily with other fruit juices and nectars to give added body, nutrients, and flavor. Another possibility is to market apricot concentrate in 170-g (6-oz.) cans for use in cake mixes, muffins, and fruit cakes.

Volatile Components of Apricots

Ripe apricots have a strong characteristic aroma. Tang and Jennings (1968) subjected a charcoal adsorption essence of 'Blenheim' apricots to repetitive gas chromatographic separations. The isolated components were characterized by infrared spectroscopy as benzyl alcohol, caproic acid, epoxy-dihydrolinalool IV, γ-octalactone, *S*-octalactone, *S*-decalactone, γ-decalactone, and γ-dodecalactone.

BANANAS

Bananas belong to the family Musaceae, genus *Musa,* comprising 32 or more distinct species and at least 100 subspecies. The majority of edible bananas are from a subsection of *Musa* called Eumusa and originate specifically from two wild species, *M. acuminata* and *M. Balbisiana.* Most commercial bananas are from the triploid group of *M. acuminata.* In this group are the 'Cavendish' and 'Gros Michel' which are by far the principal banana cultivars in world commerce.

The largest production of bananas occurs in Brazil, Ecuador, Hawaii, Honduras, Philippines, Puerto Rico, China, and Venezuela. Latin America produces 62% of the world's banana crop.

Approximately one-half of the bananas of the world are eaten as fresh fruit and as salads. The more important canned banana products are puree, baby foods, and tropical fruit cocktail. Banana puree canned in No. 10 cans or 208-liter (55-gal) drums by the aseptic canning process is a new product for the baking and ice cream industry. Bananas are also canned as pastes, drinks, and slices.

Banana Puree

Bananas are ripened until the cut flesh has a translucent appearance and has developed the full flavor. Peeling yields depend upon a number of factors, including fruit size and maturity, and have been found to vary from 57 to 67%. The peeled and trimmed bananas together with 0.4% by weight of citric acid are placed in a vacuum tumble blancher (VTB) which is then closed and revolved at 6 rpm. The vessel is evacuated using a two-stage steam ejector to 71 cm (28 in.) Hg vacuum in 55–60 sec, and the chamber is isolated from the vacuum system. The vacuum is then broken by admitting steam until a positive steam pressure of 0.14 kg/cm^2 is reached. This takes about 30 sec and the steam pressure is maintained at this level for approximately 7 min to heat the banana puree to 93°C. The pulp is discharged from the VTB at 93°C into a preheated screw press with the screw running at 380 rpm and 1.75 kg/cm^2 air pressure on the solids discharge cone. Puree discharged from the screw press at 85°C is filled directly into plain cans without leaving a headspace; the cans are then closed and inverted.

Banana Drink. Puree as discharged from the screw press is diluted in the ratio of 1:3 with water, and the pH is adjusted to 4.2–4.3 by the addition of citric acid. The diluted puree is centrifuged and the opalescent liquid obtained is adjusted to 12°–15° Brix by the addition of sugar to produce banana drink. The drink is then filled into 301 × 411 plain or enameled cans leaving a headspace of 7.9 mm, vacuum closed, spin-cooked at 100°C and 150 rpm for 2 min, and spin-cooled under water sprays for the same period.

Analytical determinations made at various stages throughout the process are set out in Table 6.2. Banana drink has a soluble solids of 13.0° Brix and acidity of 0.21% as malic acid.

Canned banana drink in plain electrolytic tinplate cans has maintained quality for 18 months at ambient temperatures.

Banana Slices

For processing banana at boiling water temperature, the pH of the product should be reduced to 4.2–4.3. This may be achieved by canning banana slices with acidic fruit such as passion fruit, pineapple, and grapefruit in tropical fruit salad or by acidification with citric acid. The United Fruit Company is canning acidulated banana slices in Honduras. The bananas are packed near the growing area in extra-heavy acidified syrup (28° Brix) to prevent color loss. Canned banana slices have a sugar content of 17–19% which can be carefully controlled. Heat processing for slightly over 2 min in the acid syrup deactivates enzymes and eliminates the possibility of bacterial contamination of other food products. Color was stable through at least 2 years of shelf life. The products can be stored in nonrefrigrerated areas.

Table 6.2. Characteristics of Banana and Its Products at Various Stages

	°Brix	Acid[1] (%)	pH	Spc Gr	Brix/ acid ratio	Total solids (%)
Raw peeled banana	20.5	0.37	5.4	1.027	55.4	24.24
Blanched pulp	21.5	0.61	4.3	1.099	35.2	23.52
Puree	21.5	0.63	4.3	1.097	34.3	22.71
Drinks	13.0	0.21	4.0	1.054	61.9	13.52

Source: Casimir and Jayaraman (1971).
[1]As anhydrous malic acid.

BLACKBERRIES

Moderate quantities of blackberries are canned in the Pacific Northwest for use in the preparation of pies. However, frozen blackberries are supplanting the canned product for pies.

In Oregon and Washington, the 'Evergreen' cultivar is most popular. In California, the principal cultivar is the 'Boysenberry', which is a hybrid and similar in composition and flavor to the loganberry.

Harvesting

Blackberries should be harvested in shallow boxes and should be picked daily if possible so that the fruit may be at the optimum stage of maturity. It is desirable that the fruit be canned on the same day it is picked; otherwise, serious deterioration may take place (see Chapter 2).

Canning Process

The berries are sorted and then washed thoroughly. Since most of the berries are used for pie making, they are generally packed in water or in light syrups. Fruit for dessert purposes is packed in syrup of 40°–55° Balling. The berries are dumped from small baskets into water, transferred to a sorting belt, given a preliminary sorting, graded by machine into five size grades, again sorted from slowly moving belts, and then canned.

The smallest berries are canned in No. 10 lacquered cans in water for use in pie bakeries. Larger berries are canned with syrup in No. 303 lacquered cans for use as dessert. The cans are thoroughly exhausted at 87.8°C for 4–5 min for No. 2 cans and for 6–10 min for No. 10 cans, double-seamed, and processed in boiling water. A steam flow closing machine may be used, and the syrup filling temperature can be 82.2°C or higher. Processing takes 11–14 min at 100°C for No. 2 cans, and 23–27 min for No. 10 cans.

In plain tin cans the color of the syrup and of the fruit bleaches rapidly. Therefore, it is customary to can blackberries in enamel-lined cans. The preferred can is one made of Type L plate and coated inside with two coats of so-called "berry enamel."

The fruit may also be canned as a light preserve after boiling 3–4 min with an equal weight of sugar. In this case no syrup except that formed in cooking is added.

Flavor Components

Sixteen volatile compounds have been identified in the ethyl chloride extract of blackberries. The compounds, indentified by combined gas chromatography and mass spectrometry, include acetals, esters, alcohols, ketones, terpenes, and an aromatic. Karwowska and Ichas (1969) reported that blackberry press cake can be used as a valuable raw material for production of natural aroma essence. From 100 kg of blackberry products, flavor concentrates were obtained at yields of 0.7 liter from pulp, 0.80–1.18 liters from juice, and 0.75–0.80 liter from press cake. The condensate from press cake had the most intensive characteristic aroma.

BLUEBERRIES

Blueberries are grown in the Atlantic Coast states, in Michigan, Wisconsin, Minnesota, and the three Pacific Coast states.

The lowbush cultivars yield small berries and grow wild in Maine, New Brunswick, and upper Michigan. Highbush cultivars yield large berries and are cultivated in New Jersey, Maryland, southern Michigan, and elsewhere. A third type, the Rabbit Eye Blueberry, also has large berries and is cultivated extensively in Florida, Georgia, and elsewhere in the South. Highbush and Rabbit Eye cultivars are handpicked and therefore require less cleaning than lowbush cultivars, which are picked by raking. Cleaning the fruit after mechanical harvesting appears to be one of the chief problems encountered in processing blueberries.

Ballinger and Kushman (1970) studied the relationship of ripeness to composition and keeping quality of highbush blueberries. The acid content increased during early stages of development but decreased rapidly during later stages of development. The pH, soluble solids, sugars, anthocyanin content, and berry weight increased as the berries developed on the vine. Dekazos and Birth (1970) developed a maturity index for blueberries using light transmittance. Light transmittance curves of intact blueberries (cultivars 'Wolcott' and 'Blue Crop') were recorded in the

visible and infrared region with the ASOĈ biospect. The index involves measurement of the optical density (OD) of intact fruit at two wavelengths and computation of the OD difference (760–800 nm) vs. anthocyanin content. A high correlation coefficient of 0.967 was found for 'Wolcott' blueberries in the IR region OD 760–800 nm.

Lowbush blueberry fruit contains 81–84% moisure, up to 13% sugar, a small amount of protein and phosphorous, a fair amount of calcium, and a relatively large amount of iron and manganese.

In the field, blueberries are cleaned mechanically through a fanning mill like that used for cleaning grain; this device removes the greater portion of the leaves, twigs and stems, and other light trash by air blast. In the cannery, berries are washed either in shaker washers or paddle washers. The washed berries are sorted for defects on white, slow-moving belts. They are then placed in enameled No. 10 cans and covered with water for the pie-baking trade, or with a sugar syrup (40% solids) for the retail trade and home use as a dessert fruit. The cans are exhausted in steam and sealed hot. The No. 2 cans are processed for 10–12 min in boiling water; No. 10 cans require 25–30 min.

Canned blueberries may vary from a highly attractive, free-flowing product to one that is clumped into a firm mass. Clumping can be greatly reduced by cooling with agitation, which apparently interferes with the binding together of berries by surface wax or cutin. Overcooking also contributes to clumping.

Blueberry Juice

Because blueberries contain more mucilaginous material than most other berries, the preparation of blueberry juice is rather difficult. Clear blueberry juice, like clarified tomato juice, possesses relatively little flavor. Therefore, the unclarified product is the type considered best. The washed blueberries are heated in a steam-jacketed stainless steel kettle with agitation. When the berries reach 82.2°C, they are put through a screw impeller-type juice extractor. The temperature of the extracted juice is raised to 82.2°C by passage through a heat exchanger. The hot juice is then run into carboys which are completely filled and then closed with a paraffined cork. After standing in a cool cellar for at least 2 months, the juice is siphoned from the heavy sludge on the bottom of the carboys. It is then flash-pasteurized at 82.2°C according to the usual procedure, filled into bottles or cans, sealed, and quickly cooled.

BLACK CURRANTS

Black currants have not been canned in large amounts owing to the high labor cost in harvesting and strigging the berries. The crop is used principally in the manufacture of jams and jellies, syrup, and beverages. The most suitable cultivars are 'Baldwin', 'Boskoops Giant', 'French', and 'Westeick Choice'.

Only firm, ripe fruit should be used for canning; smaller, underripe fruit is better suited for canning as purée or for syrup manufacture. Removal of stalks by hand is very costly. A new method has been tried out and very successfully developed. In this method the black currants are frozen and run over the strigging machine in a hard frozen state that allows the stem to be pulled from the fruit. After leaving the machine, the currants should pass over an inspection belt to remove split or broken ones. The fruit is filled into enameled cans either by hand or with a mechanical filler. After adding the syrup, filled cans are exhausted to reach a can center temperature of 82°C, sealed hot, heat-processed at 100°C in a rotary cooker for 8–12 min for No. 2 cans, and then cooled in water to 41°C.

Black Currant Puree for Reprocessing

Black currants are also processed as puree in enameled No. 10 cans, and reprocessed into jams, jellies, syrup, and beverages when needed. On arrival at the plant, the fruit is washed, sorted, and heated in stainless steel vats that have perforated steam coils situated at the bottom. The fruit is heated to a boil with a minimum amount of water. The batch is started with a small amount of water and one-fourth of the total amount of fruit; remaining parts are added in three lots as the pulp boils. The pulp should be stirred constantly while being cooked. Cooking time for a 182-kg batch should be between 15 and 20 min. On leaving the vats, the pulp is filled into enameled cans as quickly as possible with constant stirring to ensure a uniform mixture in all cans. The filled cans should be steam-exhausted to reach 88°C, sealed quickly, heat-processed at 100°C for 30–40 min, and water-cooled. This pack is largely used for jam manufacture.

Black Currant Syrup

Black currants are picked on the strig and brought to the plant in wooden boxes or trays, the depth of the fruit being 10 in. and 4 in., respectively. After inspection, the fruit is milled through a grater mill. The removal of pectin is achieved by adding Pectinol to the fruit as it enters the mill. The process of enzyme action is followed by checking the viscosity of the expressed juice. The pulp can be pressed in a matter of 24–36 hr using 0.3% of single-strength pectinase, or in 1–2 hr when the pulp is kept at 43.3°C in the presence of Pectinol. The entire quantity of pulp is pressed out in the normal type of cider press using cotton or nylon cloths and ash wood racks. When properly treated with enzyme, yields of 568–606 liters of juice can be obtained from 1 ton of fruit. This juice is cen-

trifuged and converted into a 55° Brix syrup by the addition of solid cane sugar. The necessary quantity of food color and 0.035% by weight of sulfur dioxide is added, and the syrup is clarified through a diatomaceous earth filter. Syrup produced in this way has a shelf life of 18 months. Its acidity of approximately 1.3–1.6% citric acid by weight is an important feature in its stabilization.

Black currant syrup of this type can be used for milk shakes at the rate of 22 ml of syrup to 207 ml of milk, mixed with constant agitation at 4.4°C. It is important to add the syrup to the milk and not vice versa.

Syrup made by this process can be acidified with 1.5% of citric acid by weight and diluted with carbonated water in the proportion of 1 to 5 for bottling and distribution as a sparkling fruit juice.

Black Currant Beverage (Sussmost)

To make Sussmost, pure black currant juice is diluted to contain approximately 25–30% of juice and then sweetened. The beverage is filtered and heated in a scraped surface heat exchanger to 73.9°C and transferred in a continuous fashion to the reservoir of the bottle filler (Fig. 6.1). The hot beverage is filled into warm, clean bottles almost to the top. Caps are applied at once. The additional precaution of previously sterilizing the

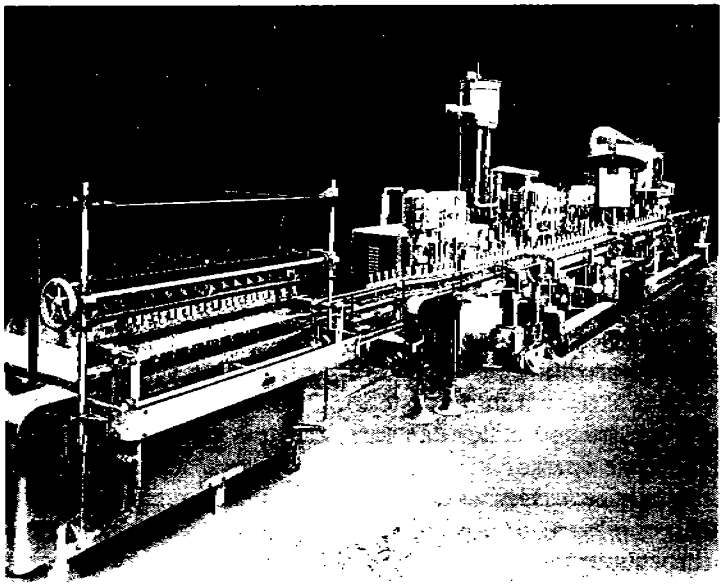

FIG. 6.1. Syncro bottling line including air cleaner, filler, and capper. (Courtesy Pneumatic Scale Corp.)

Table 6.3. Chemical Composition of Sweetened, Diluted Black Currant Beverages (Sussmont Type)

	From Boskoop giant fruit	Commercial black currant beverages		
		Min	Max	Mean
Specific gravity at 68°F	1.0590	1.048	1.0641	1.0573
Total acid (%)	1.03	0.97	1.27	1.04
Extract (%)	15.75	12.51	16.96	15.04
Sugar (%)	13.65	10.32	14.31	12.88
Sugar-free extract (%)	2.10	1.33	4.45	2.22
Ash (%)	0.234	0.176	0.482	0.204
Alkalinity of ash (ml *n*-NaOH/100 ml)	3.36	1.76	4.30	2.41
Alcohol (%)	0	0	0.48	0.12
Volatile acids (%)	0.01	0.008	0.035	0.016
Lactic acid (%)	0.005	0.002	0.017	0.004
Ascorbic acid (mg/100 ml)	37.1	15.0	54.2	25.0

caps with formaldehyde vapor is often taken, but this is not necessary with the hot-filled method if the bottles are inverted after filling.

The chemical composition of some black currant beverages is presented in Table 6.3. The beverage has a content of 1.04% as citric acid and 12.88% sugar.

Improved Production Methods

Technical improvements have streamlined the processing of fruit juices. Generally speaking, the methods of black currant juice extraction, clarification, pasteurization, and storage are similar to those used for other fruit juices. The following points in processing techniques have a special technical interest.

The pectic enzyme action is carried out on large batches of milled pulp held in stainless steel tanks with tapering sides leading to outlets to hydraulic presses.

Flash pasteurization of the centrifuged, filtered fruit juices for syrup production is at temperatures up to 93.3°C for 15 sec. Machines fitted with specially constructed plates can carry out this step with high efficiency, and in the same operation can reduce the temperature to 1.1°C. The lower temperature is necessary when juices are to be impregnated with CO_2 and filled under pressure (3.2 kg/cm^2) into tanks that will be maintained at 0°–1.1°C throughout the storage period.

The residue from the first pressing operation is repressed in a continuous fashion in expeller presses made of stainless steel.

For juices that are eventually destined to be diluted into consumable drinks with 25% of juice, it is necessary to extract the maximum amount of flavoring substances from the fruit. A satisfactory process is to apply steam to the fruit at 80°C. The apparatus often has a rotating central screw in the perforation along its length. The screw rotates at approximately 3 rpm. At this temperature undesirable astringent materials are not extracted, but the enzyme systems are inactivated. The pulp from the steamer can be pressed immediately after adding 2–3% of kieselguhr.

Large horizontal or vertical tanks are widely utilized for storage of black currant juice intermediates. Several new types of tanks are rapidly gaining in favor; resin-reinforced fiberglass tanks are prominent among the newcomers.

Chemical Composition of Black Currant Juices and Syrups

The chemical composition of black currants changes as the fruit approaches ripeness: sugar content increases, and ascorbic acid content, calculated on a weight basis, decreases. It is generally recognized that to produce a quality beverage, fruit should be at least 80% black before it is harvested. Black currant juice (or fruit) may vary greatly in acidity, sugar, tannin, and ascorbic acid contents.

Red Currant Juice

Although red currant juice is extensively used for making jelly and is used in a limited way for punches and other mixed fruit beverages, its use for beverage purposes is not of great importance.

The methods used for making grape juice may be employed in making red currant juice. However, since the juice does not contain potassium bitartrate, it is not necessary to hold currant juice to eliminate argols. The hot-pressed juice may be bottled immediately after filtration.

Red currant juice varies in acidity from 1.9 to about 2.9%. Juice of such high acidity is not suitable for use as a beverage without dilution with a sugar solution.

CRANBERRIES

Cranberries are canned commercially in Massachusetts, New Jersey, Oregon, Washington, and Wisconsin. The berries ripen in the fall and are picked by hand with a special rakelike device or by a machine that makes use of powerful air suction to strip the berries from the vines and convey them to a cleaner and hopper. At the cannery, berries are cleaned by screening and winnowing to remove leaves, trash, etc.

The ripe berries have an acidity of 2.90–3.17% as citric acid; total sugars, 3.5%; total solids, 13.0%; and ascorbic acid, 11–33 mg per 100 gm. The berries are canned in lacquered cans as strained sauce (jelly-like) or unstrained sauce (whole berry). Strained cranberry sauce represents a larger volume of the total pack.

The important cranberry cultivars for cranberry sauces are 'McFarlin' and 'Howes'. The 'Early Blacks' have a very deep color and may be used for blending with other cultivars that are lighter, as too dark a color is not desirable.

Unstrained Cranberry Sauce

Berries should be cleaned and washed, and then cooked in water in a stainless steel or enameled kettle for 8–10 min. The quantity of water used should be kept to a minimum to avoid the necessity of evaporation later. Sugar is added after the berries are well cooked, the quantity being determined by the product desired. Usually about 1 kg of sugar is added per kg of raw berries. The finish may be determined by cooking to 102.2°C, by the percentage of solids as determined by a refractometer, or by consistency. It has been observed that cooking equal weights of berries, water, and sugar to the temperature of 102.2°C gives a satisfactory product with about 43% solids content as determined by a refractometer. Whole cranberry sauce should not be cooked to a point where it sets to a solid gel, but should flow slowly when poured into a dish.

In another process, the cranberry pulp is utilized to manufacture whole cranberry sauce. The pressed cranberries, in the form of liquid crushed pulp, are placed in a kettle of water and brought to 85°–100°C. The mix attains a true cranberry color. Skins and seeds are removed by passing the mix through a 0.027- to 0.033-in. screen leaving a puree in the form of a strained aqueous suspension of cooked residue of crushed cranberries. Best-grade raw whole cranberries are then mixed with a sucrose–corn syrup solution and added to the cooked, pressed, strained cranberry puree. The mixture is brought to the boiling point as rapidly as possible. The resulting sauce is then filled into cans, sealed hot, and cooled in water to 38°C. The soluble solids content of the jellied product was 38%. The resultant product has a deeper red color and better flavor and consistency than a whole sauce prepared to the same soluble solids content by the same process, but lacking the added pressed cranberry purée. A whole cranberry sauce, made by boiling 10% whole cranberries with finely comminuted cranberries for 1–3 min, furnishes enough pectin to form a gel with water.

The cranberries that are to be introduced whole are processed in the usual manner, sorted, washed and stemmed. The process is equally well suited to the use of fresh or frozen cranberries. Likewise, the berries that are to be comminuted and mixed with the whole cranberries are sorted, washed, and cleaned, and finely comminuted by any suitable method such as by grinding or running through a blender. Once the whole cranberries are in the cranberry sauce, the soluble solids in the gel surrounding the whole berries gradually penetrate the whole berries since substantially all of them have been cracked open. The total soluble solids content of the sauce amounts to between 38 and 42% of the weight.

Strained Cranberry Sauce

Washed berries may be run directly into kettles containing water. The berries are then cooked 8–10 min and run through a cyclone, preferably with a nickel or monel metal screen with 0.03- to 0.04-in. openings to remove the skins and seeds. The pulp from the cyclone passes to another steam-jacketed kettle where sugar is added, and the evaporation may be determined by the usual jelly-sheeting test, by the boiling point (102.8°C), or with a refractometer when the solids reach 43%. The weight of sugar added is approximately equal to the initial weight of the berries. The amount of water added should be carefully controlled so that it will not be necessary to prolong the heating and evaporating process.

The sauce is filled at 88°–93°C into lacquered cans. For No. 10 cans, beaded cans are used to avoid paneling. The cans are sealed hot with steam injection and then pass directly to the cooler. The cans should be cooled to 38°C as they come from the cooler. It is desirable to stack them in a manner that will make thorough cooling possible and subsequent storage should be at a temperature below 20°C. Cans should not be disturbed after stacking until gel formation is complete.

Stainless steel of monel metal or other corrosion-resistant metal cookers should be used because of the high acidity and intense red color of cranberries. The No. 300 and No. 2 size cans are popular for home use; the No. 10 for institutional use.

Several constituents including pectin, pigments, flavor, and soluble solids that remain in the pressed cranberries are presently discarded after extracting the juice cocktail. This material, when utilized in the preparation of strained cranberry sauce, decidedly upgrades the resulting sauce with respect to color, flavor, and consistency, and lessens the weight of whole secondary-grade cranberries required per unit of production. In one study, highest-grade raw cranberries were crushed at room temperature in a Carver Press to extract 75–80% of the juice, which was subsequently diluted with water and sweetened with sugar to provide a deep crimson red cranberry cocktail. Light and mixed colored grade whole cranberries were placed in water to which was added the pressed pulp of the superior-grade cranberries. The aqueous suspension was heated to a temperature between 85° and 98.9°C. The mixture, while still hot, was strained through a finisher screen with 0.686- to 0.838-mm (0.027- to 0.033-in.) openings to reduce the average size of the contained particles and to remove seeds and skins. The resulting puree was blended with a sugar–corn syrup to obtain a 37°–40° Brix, and heated. The hot mix was then filled into consumer-size cans and cooled in accordance with usual practice. This procedure gave a jellied sauce that had a deeper color and firmer gel structure than would be present without the addition of the pressed cranberry pulp. Instead of screening, the seeds, skins, and other solids may be comminuted to fine particle size by passing the suspension through a suitable comminutor, disintegrator, or mill.

Cranberry–Orange Relish

Oranges have been used in combination with cranberries to form a fresh relish for some time. The relish contains the whole orange including peel, pulp, and juice. Such a relish tends to be watery due to the grinding of the cranberries and whole oranges, a process that extracts most of the natural juices as a liquid.

It is possible to make a cranberry–orange relish that can be processed and canned, thereby eliminating the necessity of immediate consumption in homemade relish or frozen relish after thawing. By using a small amount of orange peel, and by proper control of particle size, a true relish-type cranberry product that has a highly acceptable flavor and good textural qualities can be prepared. This process includes the steps of comminuting whole cranberries, reducing orange peel cuttings to form particles ranging in maximum size from about 3.18–12.7 mm, combining the comminuted cranberries and orange particles with sugar and water, and rapidly heating the mixture to between 93.3°–101.7°C to form a semi-jellied cranberry product with the orange peel distributed uniformly throughout; this product has a soluble solids content of 38–54% by weight.

In preparing cranberries for relish, the degree of comminution is important, for it is necessary to cut the cranberries so as to reduce the toughness of the skins without destroying the variation in texture resulting from discrete pieces of cranberries. The best source of orange is from freshly comminuted orange peel. This peel may be fresh or frozen and is conveniently the by-product peel remaining after the orange juice and pulp have been used in preparing frozen or canned products, such as forzen orange juice or canned orange sections.

In order to give the resulting relish a texture that exhibits a contrast between the size of the cranberry particles and orange particles, it is necessary to cut the orange peel to cubelike particles. After processing, there is a definite contrast between the size of the cranberry and orange particles present. Since the orange peel does not contribute additional liquid, the final processed relish possesses a certain homogeneity in the matrix surrounding the discrete pieces not exhibited by the fresh or frozen relishes.

Cranberry Sauce for TV Dinners

A quick-gelling cooked cranberry sauce may be mechanically handled in a pregelled state and will thereafter gel despite immediate subjection to commercial freezing environment, and remain gelled upon thawing. Such cooked cranberry sauce mix thus need not be held for any gelling period after cooking but may be rapidly metered hot directly from the cooking kettles onto individual TV dinner plates in the freeze-line of production without danger of losing gelation before or during the freezing operation or during thawing. Alternately, sauces of this type can be rapidly mechanically handled even after gelling without breaking the gel, provided appropriate delicate pumping mechanisms are used. Unlike previous gelled cranberry sauces, they may be metered cold into the TV package without losing the proper gel structure.

This sauce is composed of cooked whole or strained cranberry sauce mix prepared in accordance with conventional practice except for the addition of a small proportion of a gelling agent in the form of an acid- and freezing-tolerant gelling material before cooking. The preferred gelling material is one prepared from waxy maize starch, available on the market as a heat-soluble corn starch whose gelling capacity is not adversely affected by the acid content of cranberries, nor by freezing temperatures down to −40°C. Addition of the starch in an amount of between 1 and 2% by weight of the mix, whether a whole or a strained cranberry sauce, has been found effective in causing the mix to gel as it cools either before or during the freezing operation. In either case, it survives commercial quick-freeze processes and upon thawing, gives an attractive fully gelled cranberry sauce that does not liquefy or flow into the other ingredients of the TV dinner.

Jellied Cranberry Sauce

One of the more popular ways to market cranberries is in the form of a canned, jellied sauce. Previously, it had been thought necessary to remove the skins and seeds from cranberries via a screening process, add sugar and water to the resulting puree, and then cook the mixture to the desired end point. The removal of skins and seeds not only required extra steps and extra labor, but meant that there was a loss of approximately

10% by weight of the original cranberries. However, because skins and seeds contribute a distinct flavor to cranberries, they are desirable in a jellied cranberry sauce.

Nowadays, whole cranberries, either raw or cooked, either fresh or frozen and thawed, can be comminuted, heated with sugar and water, and canned. In preparing the puree from the entire cranberry, it is necessary to reduce the relatively tough skin and the seeds to a size such that the puree will pass through a screen having perforations no larger than 0.686 mm (0.027 in.) in diameter, without forming tightly rolled pieces of skin that could conceivably be forced through the perforations of the screen. A. Fitzpatrick comminutor or a Rietz disintegrator and their accessories are particularly well suited to attaining the desired degree of comminution of the whole cranberry.

Once the cranberries are properly comminuted, the resulting puree is then mixed with an amount of sugar and water sufficient to form a smooth

Table 6.4. Volatile Compounds Identified in Cranberry Juice

Compound	Gas chromatography				
	Peak no.	DEGS column	Mass spec	Infrared	Concentrate (%)
Aromatic					
Benzene	4	+	+		0.1
Benzaldehyde	18	+	+	+	9.6
Benzyl ethyl ether	19	+	+		1.0
Acetophenone	22	+	+		0.8
Methyl benzoate	23	+	+		1.0
Benzyl formate	24	+	+		0.7
Ethyl benzoate	28	+	+	+	1.0
Benzyl acetate	29	+	+		0.7
Benzyl alcohol	31	+	+	+	6.0
2-Phenyl ethanol	33		+		2.2
4-Methoxy	36	+	+		0.8
benzaldehyde	38	+	+		1.2
2-Hydroxy diphenyl	39	+	+	+	11.9
Benzyl benzoate	40	+	+		1.1
Dibutyl phthalate(s)					
Terpenes					
α-pinene	9		+		0.1
β-pinene	11		+		0.2
Myrcene	12	+	+		0.2
Limonene	14	+	+	+	1.1
Linalool	25		+		0.6
α-terpineol	30		+	+	13.0
Nerol	34		+		1.1

(continued)

gel. The water is adjusted to the amount of pectin contained in the cranberries. After the puree is mixed with sugar and water, it is heated to destroy all enzymatic and microbiological action and to cause the necessary interaction between the sugar, puree, and pectin to effect gel formation. The resulting hot liquid mixture is then sealed in cans or jars under vacuum.

Cranberry Juice Cocktail

The procedure for making cranberry juice cocktail is to put thawed cranberries through a tapered screw extractor. A yield of 66–70% of juice is obtained from each 100 kg of fruit. For cocktail, this product is diluted with twice its volume of water and sufficient sugar is added to bring the

Table 6.4. *(Continued)*

Compound	Gas chromatography				
	Peak no.	DEGS column	Mass spec	Infrared	Concentrate (%)
Aliphatic alcohols					
2-Methyl-3-buten-2-ol	6		+		0.9
2-Pentanol	7		+		0.8
Pentanol	10	+	+		0.9
Hexanol	15	+	+		0.7
1-Octen-3-ol	20		+		0.8
Octanol	26		+		2.3
Nonanol	32		+		0.8
Decanol	35		+		0.7
Octadecanol	37	+	+		0.8
Aliphatic aldehydes					
Acetaldehyde(s)	1	+	+		0.1
Pentanal	5		+		0.2
Hexanal	8		+		0.8
Octanal	17		+		0.9
Nonanal	21		+		1.0
Decanal	27		+		0.8
Other compounds					
Diacetyl	2		+		0.3
Ethyl acetate	3		+		0.7
2-Furaldehyde	13		+		0.8
Methyl hepanoate	16	+	+		0.6
Acids					
Benzoic acid	—	+	+	+	26.6
2-Methylbutyric acid	—	+	+		0.3
Total					95.2

Source: Croteau and Fagerson (1968).

specific gravity up to 15° Brix. The pomace may be used for making strained cranberry sauce.

Cranberry juice beverages are sometimes clarified by means of Pectinol or some pectic enzyme preparation. After treatment, the beverage is filtered using Hyflo Super-Gel as a filter aid. The filtrate should be heated to 85°C to inactivate the enzymes and thus prevent further action during storage. The hot product is filled into cans or bottles; these are then closed, turned on their sides, and cooled. Cranberry juice is very corrosive to tin plate; therefore cans lined with berry or fruit lacquer should be used.

The Standard of Identity states that cranberry juice cocktail (a juice drink under the Federal Food, Drug, and Cosmetic Act) is the beverage food prepared from cranberry juice or concentrated cranberry juice, or both, with water and nutritive sweetener (or nonnutritive sweetened product). It contains not less than 25% of the single-strength juice. The soluble solids are 14°–16° Brix as determined by refractometer. It may contain 30–60 mg vitamin C per 6 fl oz. The acid content, calculated as anhydrous citric acid, is not less than 0.55 gm/100 ml. It is sealed in containers and processed by heat so as to prevent spoilage (Anon. 1968). An aseptic HTST system has been applied to the canning of cranberry juice cocktail in brick packages made of Mylar-Al-Poly-Propylene laminated containers (Ito and Stevenson 1983).

Volatiles of Cranberry Juice

The major volatile components of the juice of the American cranberry are listed in Table 6.4. Forty-three compounds, comprising 87% of the concentration of the volatiles, have been identified. Twelve of these are aliphatic alcohols, 11 are aliphatic aldehydes and ketones, 5 are terpene derivatives, 8 are aromatic compounds, and 7 are other compounds. Terpineol (34%) is quantitatively dominant, while the amount of 2-methylbutyric acid is much smaller than in lingonberries (*V. vitis-idaea*) where it is the most important aromatic compound.

GOOSEBERRIES AND LOGANBERRIES

Gooseberries

Gooseberries are canned when they have reached their full size, but before they become soft or changed in color.

When brought to the plant they are first put through an Urshel snipper. The berries are then passed over a sorting belt to remove defective ones and foreign material, washed, drained, and filled into plain cans. Most gooseberries are packed in water in No. 10 cans for the bakery trade; some are packed in heavy syrup in No. 2 cans for the retail market.

After berries are filled into cans, boiling hot water or syrup is added and the cans are passed through a steam exhaust box at 100°C for 5–6 min. The cans are sealed under steam injection and then processed in boiling water. The amount of processing necessary depends on the temperature after exhausting. Assuming an initial temperature of 65.6°C, the processing time for No. 2 cans is 8–10 min at 100°C for water pack and 15–18 min at 100°C for syrup pack. Spin cooking in atmospheric steam for 3–4 min at 12 rpm improves the drained weight of the canned product. The cans should be cooled in water to 37.8°C after processing.

Loganberries

Oregon is a fairly large producer of loganberries, which are used for canning, frozen pack, jams, and juice. The berries are very large in size and deep red in color.

The canned fruit is used mostly for pie-making and therefore is canned in No. 10 enamel-lined cans, in water. The processes of harvesting, canning, and sterilizing are basically the same as for blackberries. "Double-enameled" Type L cans should be used to ensure the retention of color.

RASPBERRIES

Raspberries are canned in small commercial quantities in the northern and midwestern states, in New York, and on the Pacific Coast. Only 7000 cases of black raspberries and 26,000 cases of red raspberries were packed in 1971. The red raspberry is preferred to the black raspberry for canning, but is in even more demand for preserves of jam. The 'Willamette' cultivar accounts for more than half the acreage of red raspberries in Washington. Its popularity is based on its high yield of large, firm berries that are high in acid. Other cultivars include 'Puyallup', 'Summer', and 'Fairview'. In England, the best cultivars for canning are 'Cuthbert', 'Lloyd George', and 'Norfold Giant'.

Raspberries should be picked when they are ripe but firm. They are transported to the cannery in crates containing shallow 0.23- to 0.46-kg (0.5- to 1-lb.) baskets or perforated plastic containers. They should be canned promptly when received at the cannery and should not be held overnight except in a refrigerated room at −1.1° to 1.67°C.

Berries are washed and sorted to remove the deformed and overripe berries unfit for canning. Raspberries are size graded using slat riddles. The berries are canned in heavy syrup (50°–55° Brix) for dessert purposes, or in water for use in pies. Cans are exhausted until a center temperature of 18°C is reached. This requires approximately 5–6 min at 100°C. The choice of cooking method depends on the relative importance of the different quality characteristics. Still-cooking is preferred if wholeness, shape, and texture are of major importance; but spin-and-rotary cooking methods are preferred if drained weight is of greater significance.

Spin cooking of canned strawberries, raspberries, and gooseberries for 3–4 min in atmospheric steam at 12 rpm compares favorably with conventional cooking (15–16 min in boiling water). After 2 months, spin-cooked berries show higher drained weight, superior color, and firmer fruit than those cooked by conventional methods.

Mushiness and crumbliness occur commonly during processing of raspberries. Impacts during processing abrade and crush the fragile pulp tissues, freeing the pits and making the canned product mushy. Impact after cooling damages the berries only slightly. Crumbliness involves genetic and pathological problems that affect normal fruit structure. When cans are opened shortly after cooling, all the raspberries appear greatly shrunken, and many of the pits partly protrude. Those cooked in rotary cookers appear more shrunken than those still-cooked. Excessively rapid can rotation and, in particular, impacts during cooking and conveying abrade the shrunken berries and loosen the pits so they remain free after the berries have returned to normal size.

Increasing syrup concentration in canned raspberries does not affect their drained weight, but does tend to increase the proportion of broken fruit. The addition of 0.42% low-methoxyl pectin increases the drained weight of raspberries and improves their texture, but lowers acceptability for flavor and color. Syrups of 50°–55° Brix are preferred for flavor with raspberries and loganberries.

Tyramine Content of Raspberries

The tyramine content of fresh raspberries varies from 12.8 to 92.5 μg/g, and that of raspberry jams from 8.0 to 38.4 μg/g. The tyramine level in raspberries in comparison with that in other fruits indicates that tyramine is a useful indicator of the presence of raspberry in fruit products (Coffin 1970).

STRAWBERRIES

Strawberries are not a popular fruit for canning and are largely preserved by freezing in the United States. One reason for this is that addition of food coloring is not permitted by the FDA, and the color of canned strawberries is very unattractive compared with that of frozen products. The principal difficulty in canning strawberries is the softening of the fruit during heat processing, which results in the can containing only one-third its volume of berries. Canned strawberries are more common in England. The cultivars of strawberries used for canning in England are 'Huxley', 'Gautlet', and 'Talisman'. The 'Huxley' cultivar has a nonremovable plug but is the most reliable berry since it retains its shape in the can. The 'Huxley' has a dark red color and firm texture. It requires a longer processing than other cultivars to give complete sterilization.

The fruit is delivered to the plant in trays to prevent crushing during transport. When berries are held in cold storage, they should be removed only in small quantities as required. The canning must not be delayed, otherwise the strawberries will collapse as the temperature rises.

Berries are first delivered to the preparation belt where stemming is carried out. They are graded for quality and passed over a mechanical grader. Large berries are used for manufacture of jam or pulp; medium berries for canning. If strawberries are small, especially during the late season, the cost of stemming is high. Such strawberries should not be stemmed but pulped cold with SO_2 and used for jam manufacture.

It is advantageous to give the fruit a light spray washing. The washed fruit must be well drained before filling into enameled cans. The filled cans pass through an automatic drainer attached to the syruper, where 50° Brix sucrose syrup is used for fancy grade, and 30° Brix for the standard grade. Artificial color may be used in canning strawberries in England; 189 liters (50 gal) of syrup should contain 113.4 g of Ponceau 2 R, and 14.2 g of Erythrosine. Since there is a great deal of variation in strawberries, processors are advised to test a small batch before producing any quantity. At least 1 week should be allowed for dye penetration before judging the color of canned berries.

Canned strawberries should be clinched before exhausting because this fruit floats and the top berries will become soft during the exhausting and break up during processing. Exhausting time is usually 6–8 min at 82.2°C. Steam flow may be used here, but for better results the exhausting process is advised.

Attention should be paid to the exhausting of strawberries. The purpose of this process is to collapse berries slowly and to release the oxygen from their cell. If the exhaust is insufficient, berries collapse during cooking, with the result that the vacuum is not maintained and the berries will spoil quickly. The processing time for No. 303 cans is 7–8 min at 100°C.

The main aromatic substances in strawberries, as quantitatively determined by gas chromatography are methyl and ethyl butanoate, methyl and ethyl hexanoate, trans-2-hexenyl acetate, trans-2-hexenal, trans-2-hexen-1-ol, and 2,5-dimethyl-4-methoxy-3(2H)-furanone were.

CHERRIES

Two types of cherries—sweet and sour—are canned in this country and abroad. In New York, Michigan, and other eastern states the sour cultivars, 'Morello' and 'Montmorency' are commonly grown. On the Pacific Coast in Oregon and California the sweet cherry 'Royal Ann' predominates. Other sweet cultivars include Napoleon, Bigarreau, and Amber.

Since sweet cherries contain less acid, their keeping qualities are not as good as sour cultivars. On the other hand, sour cultivars require a heavier syrup to make them more palatable, and this tends to cause the fruit to shrivel. The main acid in cherries is malic, but citric and quinic acids are also present in reasonable quantities.

Whole Cherries

On arrival at the cannery the fruit is first stemmed by hand or mechanical stemmers. Mechanical stemmers have a series of rubber rollers on an incline, and the cherries roll down the incline from an automatic feed at the top of the machine. The rollers revolve toward each other, and as the cherry turns over, the stem is dropped between the rollers and pulled out. The cherries emerge uninjured with 95% or more of the stems removed.

After stemming, the cherries are thoroughly washed and graded for size. From here they go to the filler, syruper, and exhauster. Exhausting of cherries is most important because this fruit, containing stones, is very prone to pinholing and hydrogen swellls. An exhaust of at least 10 min at 73.9°–85.0°C is recommended for smaller cans. The center of the can should reach 82°C.

Most sweet cherries are canned without pitting, whereas most sour cherries are pitted. Pitting is accomplished by an automatic machine in which the cherries fall into small cups and the pits are removed by cross-shaped plungers. The loss in pitting is about 15% of the weight of the stemmed cherries. Considerable juice is expressed from the cherries in pitting and is usually recovered for canning as juice for use in syrups.

The standard pack of sour cherries in a No. 2½ can should be exhausted to give a can center temperature of 82.2°C and processed 16–20 min at 100°C. A No. 10 can of sour cherries requires 25–30 min at 100°C. After sterilization the cans should be quickly cooled before labeling and storage.

Red, tart 'Montmorency' cherries, when allowed to stand before being canned, either with or without having been previously bruised, are much firmer after canning than are similar cherries canned immediately after harvest. During the aging period a portion of the pectin is completely demethylated to form pectic acid, making the cell walls more rigid and less easily separated from each other.

A 1% increase in sugar content of raw fruit results in a 0.6% increase in the drained weight of the canned product. A copper spray results in

smaller cherries, less juice loss, higher soluble solids, higher drained weights, and more red color than other sprays. The firmness of canned cherries increases as harvest is delayed.

As storage time and temperature of canned cherries is increased, sugars (total and free reducing), acidity, and hydroxymethyl furfural increases, while anthocyanins, carotenoids, pectins, volatile reducing substances, syrup viscosity, and organoleptic quality decline. To maintain high-quality canned cherries, storage temperatures of 4.4°C or lower are preferable.

Cherry Juice

Cherry juice has an attractive color and pleasing flavor; nevertheless, its manufacture and use is very limited compared with that of the more popular juices. Perhaps the reason for this is that the acidity and flavor of cherry juice are so strong it requires dilution to be pleasing to most persons.

Cherry juice is produced chiefly in Wisconsin although small amounts are processed in Colorado, New York, and Pennsylvania.

Ordinarily, no single common cultivar of cherry yields a juice of the proper acidity and sugar content for an ideal beverage. As a rule, the unsweetened juice of some sour cultivars (e.g., 'Montmorency', 'Early Richmond', and 'English Morello') is too acid and too low in sugar content to be entirely pleasing to the average palate. If 'Montmorency' cherries, however, are allowed to reach full maturity, their sugar content increases and the acidity becomes proportionally less. Such well-matured fruit produces a very desirable juice without blending. Sweet cherries, on the other hand, may be too low in acid to yield a juice of pleasing flavor. The flavor of juice made from 'Montmorency' and 'English Morello' cherries is excellent.

If a juice of excellent flavor and color is desired, the best-quality cherries must be used. Juice prepared from cull fruit generally possesses an off-flavor derived from spoiled or spotted fruit. The benzaldehyde-like flavor is probably derived from the enzymatic hydrolysis of cyanogenic glucosides similar to amygdalin. Juice made from underripe fruit is sour and of poor color.

Composition of Cherry Juice. Although there is little difference in the sugar content of different cherry cultivars, the total acidity varies widely. Sweet cultivars yield juice that is low in acid (0.47% as malic acid), whereas the common sour cultivars contain 1.3–1.8%. Malic is the principal acid present; cherries also contain small amounts of citric, succinic, and lactic acids. The principal sugars of cherry juice are dextrose and levulose, with only small amounts of sucrose. The reducing sugars of cherry juices range from 7.9–10.6%.

Sorting and Washing. Cherries for juice production may be harvested with or without stems. The freshly harvested cherries should be sorted to eliminate spoiled and damaged fruit. The cherries should then be washed in cold water (10°C), preferably with some time allowed for soaking. The soaking period should not be longer than 12 hr, or there will be a notable loss in soluble solids and some change in flavor. The pitting loss in a mechanical pitter amounts to about 7%.

Hot Pressing. The simplest method of making cherry juice is to heat the washed cherries to approximately 65.5°C in a steam-jacketed stainless steel kettle and then press the fruit through nylon cloths before it cools. The heating extracts a large proportion of the pigments of the cherries, and in the case of 'Montmorency' and 'Early Richmond' cherries produces a deep red juice. The 'English Morello' yields a very dark red juice.

A hydraulic press of the type often used for pressing grapes is suitable for the pressing of cherries.

The hot juice from the press is strained through a fine wire screen, made of corrosion-resistant metal, or a muslin bag. The strained juice is chilled to 10°C or lower and allowed to settle overnight. The clear juice is siphoned from the sludge, and then is mixed with a small amount of filter aid (e.g., Hyflo Super Cel) and filtered through canvas in a plate and rame filter press or some other filter. The yield obtained by hot pressing 'Montmorency' cherries varies from 62 to 68%.

Cold Pressing. Cold-pressed juice is not as brilliantly colored as the hot-pressed product, but its flavor closely resembles that of fresh cherries.

The washed fruit is drained and then cut to a coarse pulp in an ordinary apple grinder, such as the ones used for the making of cider. The knives are set so that the pits are not crushed during maceration. This comminution of the fruit results in a better extraction of pigments. The cold, macerated cherries are pressed in a rack and cloth hydraulic press. The yield obtained by cold pressing varies from 61 to 68%. The freshly pressed juice is rapidly heated to 87.7°–93.3°C, and then cooled. This operation inactivates enzymes, kills microorganisms, and coagulates colloidal matter.

It is usually necessary to give the juice a special clarification treatment before filtration or else the filter is soon clogged by the pulp. A simple method of preparing the juice for filtration is to treat it with Pectinol. The juice is cooled to 37.7°C, then 0.1% by weight of Pectinol M is added and held at this temperature for 3 hr. After this period, the juice is heated to 82.2°C, then cooled and filtered through a plate and frame filter press.

Cold Pressing Thawed Fruit. Deep red juice having a color nearly as dark as that obtained by hot pressing and yet possessing the fresh flavor of cold-pressed juice may be obtained by pressing frozen cherries. The cherries may be prepared for freezing either by packing pitted cherries, with or without added sugar, into enamel-lined tin cans or barrels, or by crushing the unpitted fruit to release only enough juice to cover the cherries when packed in enamel-lined tin cans or barrels. The cherries are frozen and stored at −17.7°C or lower. When needed for juice, they are thawed until the fruit reaches a temperature of 4.4°–10°C, and the thawed fruit is pressed in a hydraulic press. Juice obtained from thawed cherries should be treated with Pectinol and filtered as described for cold-pressed juice. Thawed 'Montmorency' cherries yield 70–76% and 'Early Richmond' 60–75% of juice; higher yields are obtained at 62.7°C.

Sweetening and Processing. Cherry juice from the sour cultivars—'Montmorency', 'Early Richmond', and 'English Morello'—is usually too sour to please the average palate. Therefore, unless the juice has been produced from especially sweet cherries, it is necessary to sweeten it by adding dry sugar or sugar syrup to bring the density of the juice to about 17° Brix. A more palatable beverage may be obtained by diluting the juice with half its volume of water and adding sufficient sugar to bring the percentage of total solids back to the original point. This procedure reduces the total acidity to 1% or less and maintains the solids content at approximately 10%.

If sugar, sugar syrup, or water is added to cherry juice, the addition should be clearly indicated on the label. It should be noted that a diluted product cannot be labeled "juice."

The juice of sweet cherries, such as the 'Bing', is somewhat lacking in acidity. Furthermore, most sweet cherries yield a juice that is not deeply colored. Because sweet cherries are ordinarily more valuable than sour cherries, they are seldom used for juice. If the juice of sweet cherries is available, it may be greatly improved by blending with an equal volume of the juice of a sour variety such as the 'Montmorency'.

Since hot-pressed cherry juice is of better color and cold-pressed juice of superior flavor, a blend of the two is more attractive than either alone. Equal parts of each or two parts of cold-pressed juice blended with one part of hot-pressed juice gives a product more desirable than either alone.

Cherry juice may be packed in either cans or bottles. If cans are used, they should be lined with a berry enamel.

Cherry juice and cherry beverages, containing one-half water and one-half cherry juice may be preserved by either holding or flash pasteurization methods. Flash pasteurization temperatures as low as 73.8°C may be used if care is taken to eliminate air in the headspace of the bottled product.

Pasteurized cherry juice should be held under refrigeration if it is to be stored, otherwise its flavor deteriorates markedly.

Factors Affecting Stability and Color of Cherry Juices. Blanching cherries for 1 min at 85°C before pressing yields a juice that is more intensely red than is obtained from unblanched fruit. The subsequent degradation of the color during storage is less in the blanched fruit juices. With diatomite filtration, anthocyanin pigments are absorbed, decreasing the color of the juices. No significant color loss occurs following treatment with a pectinolytic enzyme to clarify the juice. The concentrated juice is more stable at temperatures approaching 0°C. Exclusion of oxygen also has a beneficial effect on the color stability of cherry juices at all storage temperatures, but more markedly at the lower temperatures.

Carbonated Cherry Juice. Cherry juice carbonated with about 3 volumes of carbon dioxide is a very pleasing beverage. Cold-pressed juice does not yield a satisfactory carbonated beverage since the carbonation causes the deposition of a great amount of sediment. On the other hand, carbonated hot-pressed juice remains clear during carbonation, pasteurization, and subsequent storage. The method used for the carbonation of apple and other fruit juices may be used in preparing the product.

Maraschino Cherries

Maraschino cherries are prepared from 'Royal Ann' and other white cultivars. The cherries are picked after they have reached full size, but are not fully mature. They are stored in a preservative brine containing 0.75–1.5% sulfur dioxide and 0.4–0.9% unslaked lime. If too much lime is used, the sulfur dioxide will have no preservative effect and spoilage by yeast will ensue. If too little lime is used, the resulting low pH will cause splitting of the cherries and cracking of the skin.

After about 4 weeks storage in the calcium bisulfite brine, the cherries are usually ready for subsequent processing. The sulfur dioxide bleaches the cherries to a translucent white or cream-yellow color, while the calcium hardens the tissues by combining with pectin material (see Chapter 9).

Insufficient bleaching with sulfur dioxide is not uncommon and has led to schemes employing secondary oxidative bleaches. Beavers and Payne (1969) suggest leaching out most of the sulfur dioxide from the cherries (down to 100–200 ppm free SO_2) followed by immersing them in a 0.75% sodium chlorite solution at pH 4.5–6.0 and at a temperature not to exceed 43.3°C. Bleaching is completed in 1–7 days after which the residual sodium chlorite is removed by leaching in water for 24–36 hr. The cherries are then placed in the sodium bisulfite brine for firming and storage. The storage brine should be adjusted between pH 3.0 and 3.5 in order to maintain good texture. After 2 weeks in the storage brine, the cherries can be finished. Sodium chlorite-bleached cherries are free from off-flavors and possess a firm texture and excellent white color. Sodium chlorite does not hydrolyze or degrade cellulose to the same degree as the hypochlorite bleaches and is therefore preferred.

After removal from the calcium bisulfite brine, the cherries may or may not be stemmed or pitted. They are leached in running water until most of the sulfur dioxide has been removed. They are then boiled in several changes of water until tender and until the sulfur dioxide content is reduced to below 20 ppm.

The cherries are next boiled a few minutes in a 0.02–0.05% erythrosin dye solution or FDC Red No. 4. The dye is precipitated by the acid in the fruit and therefore penetrates only a short distance into the flesh unless the pH is 4.5 or higher. The fruit is allowed to stand for 24 hr in this dye solution after which it is boiled a second time. About 0.25% citric acid may be added to the water used for this boiling. This method of dyeing the fruit greatly reduces it tendency to "bleed" and stain other fruits with which it might be canned.

For use in cocktails, the cherries are put in a cherry-flavored syrup whose final cut-out density is about 40° Brix.

FIGS

Figs are canned extensively in California and Texas, and to a lesser extent in Louisiana and other southern states. In California, the 'Kadota' fig is the most important cultivars for canning. It is a white fig of moderate size, globular or oval in shape, with thin skin, firm flesh, and a small seed cavity. In Texas, the 'Magnolia' cultivar is most commonly used, and in Louisiana, the 'Celeste'. 'Magnolia' figs are light brown in color, of moderate size, and of excellent canning quality. 'Celeste' figs are very small and elongated, but have a very rich flavor; they are firm and retains their form and texture remarkably well in canning.

The Fresno–Merced district is the principal fig-growing area in California. Figs are picked frequently at the firm-ripe stage during the season. They should not be picked underripe or they will have an unsatisfactory flavor. If picked overripe, they will break up during canning and present a poor appearance.

Harvested figs should be taken promptly to the cannery for processing. They are usually shipped to the cannery in lug boxes with a 11- to 14-kg capacity. In the cannery, the first operation is to sort figs on a slow-moving belt and to remove fruit unsuitable for canning. Figs are then mechanically graded for size. Some packers use a greater variety of size grades for a given can size than others. For instance, the number of figs in each No. 10 can be 30–50, 51–70, 71–90, 91–110, or 111–140; and in each No. 2½ can 9–14, 12–20, 21–24, and 25-28.

Canning procedures for 'Kadota' figs vary considerably from one plant to another. Where figs are canned by hand, they are washed and then given a preliminary light blanch to remove the waxy coating. This blanch may be 2–8 min, in warm water sprays or steam, or in a mixture of both. They are then canned from a belt. The split and less mature figs are canned separately from the more mature unbroken figs. If semiautomatic fillers are used, the figs are given no preliminary blanch.

After filling, the general practice is to "dry exhaust" the container of figs for a considerable time through a steam exhaust box at 98.9°C before any liquid is added to the cans. The purpose of this operation is to expel the air present in the figs, destroy the latex, and soften the texture. During this procedure the cans become about half full of condensate. The blanching time varies with the condition of the figs, from 15–20 min for the smaller can sizes to 45–110 min for No. 10 cans. Cans "dry exhausted" are not drained before the syrup is added.

An alternative to the "dry exhaust" process is to fill the cans with water and pass them through a steam box at 99°C for 30–40 min, depending on the size of the container. The cans are then drained.

After exhausting, sugar syrup of desired strength (30°–48° Brix) is added at about 48.9°–65.6°C. The cut-out Brix measurements, as applicable, for the various designations are as follows:

Syrup	Testing
Extra heavy	26°–35° Brix
Heavy	21°–26° Brix
Light	16°–21° Brix

The Standards of Identity require acidification of canned figs to pH 4.9 or below. This inhibits the development of spoilage bacteria and improves the flavor. The pH of the syrup portion of canned figs is tested 15 days after canning. The quality control department can also macerate the figs and acidified syrup in the right proportion and then test for the pH of the blend. It is preferable to make the test before heat processing in order to know the exact degree of acidification and to have a sound pH control and adequate processing time. Some canners prefer to use a syrup that will yield a cut-out Brix reading at 21°–22°. Most canners add lemon juice concentrate or citric acid to the in-going syrup.

After addition of syrup, the cans are sealed under steam injection and heat-processed. They may also be exhausted at 99°C for 6 min for No. 2½ cans, and 12 min for No. 10 cans prior to double seaming.

The heat-processing time for canned figs varies greatly from one cannery to another. Canned figs are heat-processed in a continuous cooker at 100°C for 30–41 min for 8Z (211 × 304) cans; at 98.9°–101.1°C for 30–50 min for No. 303 × 406 cans; at 98.9°–101.1°C for 30–55 min for No. 2½ (401 × 411) cans, and at 100°C for 30–70 min for No. 10 (603 × 700) cans. When a still retort is used, figs in glass are heat-processed at 100°–102°C for 32–60 min for No. 303 (303 × 411) containers; and at 100°–102°C for 40–65 min for No. 2½ (401 × 414) containers. Since figs are low in acid, they should be heat-processed with the same caution as for canned muschrooms, olives, etc., unless acidification with lemon juice is done properly to the right pH range. The glass packs are processed in still retorts, while canned figs are usually sterilized in continuous rotary cookers. The cans and jars are water-cooled immediately after heat processing.

When the addition of lemon juice (including concentrated lemon juice) or citric acid lowers the pH of the canned figs to less than 4.5, the label must bear the statement "with lemon juice" or "with citric acid." When two or more of the optional ingredients such as spice, flavoring (other than artificial flavoring), vinegar, unpeeled segments of citrus fruits, and salt are used, such words may be combined, as for example, "with added spices, orange spices, and lemon juice".

Canned Preserved Figs

In Texas, figs are peeled in a hot 2% lye solution for 10–15 sec. This is followed by washing the fruit in water. This treatment must be very thorough, and the mesh belt on which the fruit travels has heavy water sprays on both top and bottom, which also serves to remove the skins. The fruit is then put into a syrup of about 30° Brix and cooked in open kettles until a syrup density of 60°–65° Brix is reached. Cans are then filled hot, exhausted for 6 min at 82.2°C, and sealed at once. This product is called canned preserved figs. It must also be acidified with citric acid or lemon juice to a pH less than 4.9.

FRUIT COCKTAIL

Fruit cocktail is one of the more important canned dessert fruit items. The product consists of a mixture of diced yellow clingstone peaches, pears, seedless grapes, pineapple segments, and maraschino cherry halves, canned in medium syrup. The product is popular with consumers because of its attractive color, texture, and flavor. There are advantages of steriflame processing of canned fruit cocktail.

Diced Peaches

During the canning season, yellow clingstone peaches are harvested at canning ripeness based on a yellow skin color. The fruits are halved and pitted in a twist pitter or FMC knife pitter, peeled with 2% NaOH at 103.3°C for 20–38 sec in a cup-down spray-lye peeler, washed, and diced to give 1.27-cm cubes that will pass through a screen with 1.91-cm openings but will not pass through a screen with openings 0.953 cm sq (or size sections that conform with the regulations of the country concerned). The small fragments in the diced fruit must be removed in vibrating sieving machines.

Diced Pears

'Bartlett' pears are harvested in an average pressure test of 16–17 lb when tested with the Magness-Taylor pressure tester with 5/16-in. plunger. The pears are stored at 0°C under a relative humidity of 85% for 3–4 days to reach canning ripeness. For fruit cocktail, it is desirable to keep pears on the firm-ripe side so that they will not break down during dicing and canning. The pears are peeled either mechanically in an FMC peeler or lye-peeled in an FMC pear preparation system. The dicing operation is the same as that for clingstone peaches.

Because of the presence of polyphenoloxidase enzyme in pears, it is necessary to inhibit enzymic browning by handling and processing the fruit under controlled conditions. Enzymic browning in diced pears can be inhibited by rapid handling, spraying the diced pears with 2% citric acid or with 1% ascorbic acid, and inactivation of the browning enzymes by steam blanching at 90°C or higher for 2 min, followed by rapid water spray cooling or evaporative cooling.

Pineapple Segments

Canned pineapple segments or tidbits are usually used for fruit cocktail processing. The fresh pineapple should be cut in segments about 1.27 cm by 1.37 cm long, or in symmetrical segments or cubes the equivalent by weight of segments of the dimensions specified above, in keeping with the description of the peaches and pears used in fruit cocktail.

Other Fruit

Maraschino cherries are used in approximate halves, colored red with practically fast color approved by the USDA. Thompson seedless grapes at canning ripeness are stemmed by machine, sorted to remove unfit ones, and graded for size.

Each kind of fruit must be of a good color for that variety. A tolerance of 15% by weight of the pieces of pears and of 10% by weight of the pieces of each other variety of fruit that do not conform in size or shape to the above specifications is permitted by the USDA.

The proportion of ingredients for canned fruit cocktail is presented in Table 6.5.

Liquid Media and Brix Measurement

"Cut-out" requirements for liquid media in canned fruit cocktail are not incorporated in the grades of the finished product since syrup or any other liquid medium, as such, is not a quality factor for the purposes of these grades. The "cut-out" Brix measurement for the respective designations are as follows:

Designation	Brix measurement
Extra heavy syrup or extra heavy fruit juice syrup	22°–35°
Heavy syrup or heavy fruit juice syrup	18°–22°
Light syrup	14°–18°
Light fruit juice syrup	<14°
Slightly sweetened water	Not applicable
In fruit juice	Not applicable

Filling

Container fill for canned fruit cocktail is a fill such that the total weight of drained fruit is not less than 65% of the water capacity of the container. Canned fruit cocktail that does not meet this requirement is "Below Standard in Fill."

Diced pears and peaches are mixed continuously on their way to filling machines in some plants. More commonly, they are not mixed before addition to the can. Filling of the cans is usually done by automatic machines; syrup of desired concentration is added; the cans are exhausted and then processed for 20 min at 100°C in an atmospheric rotary cooker or for 15 min at 104.4°C in a continuous pressure cooker. Vacuum syruping and steam-flow seaming can be used. Fruit cocktail in No. 2½ glass jars is processed 18 min at 104.4°C in a continuous pressure cooker with added air pressure to give a total pressure of 1.41 kg/cm^2.

Quality Factors

The grade of canned fruit cocktail (Fancy, Choice, Substandard) is ascertained by considering, in conjunction with the requirements of the respective grade, the respective ratings (total of 100 points) for the clear-

Table 6.5. Proportions of Fruit Ingredients in Canned Fruit Cocktail

Fruit ingredient	Style	Proportions: Not less than	Proportions: Not more than
Peaches (any yellow cultivar)	Diced	30% by weight of drained fruit	50% by weight of drained fruit
Pears (any cultivar)	Diced	25% by weight of drained fruit	45% by weight of drained fruit
Grapes (any seedless cultivar)	Whole	6% by weight of drained fruit	20% by weight of drained fruit
Pineapple (any cultivar)	Diced or sectors	6% by weight of drained fruit; but not less than 2 sectors or 3 dice for each 4.5 oz avdp of product and each fraction thereof greater than 2 oz	16% by weight of drained fruit
Cherries (any light, sweet cultivar; or artificially colored red; or artificially colored red and artificially flavored)	Approximate halves	2% by weight of drained fruit; but not less than 1 approximate half for each 4.5 oz avdp of product and each fraction thereof greater than 2 oz	6% by weight of drained fruit

Source: U.S. Dept of Agriculture (1971).

ness of liquid media (20), color (20), uniformity of size (20), absence of defects (20), and character (20). For the details of grading canned fruit cocktail refer to U.S. Dept. of Agr. (1971) and Chapter 13.

FRUITS FOR SALAD

Canning of mixed fruits for salad and dessert has become a fairly important part of the fruit-canning industry.

Pears and clingstone peaches are prepared by halving and peeling or coring as described earlier. Peaches are given a preliminary steaming to soften them sufficiently for canning with other fruits. Pear and peach halves are cut in half lengthwise or in thirds. Canned sliced pineapple in No. 10 cans cut to give 16 segments/slice is used. Apricot halves canned in No. 10 cans at the firm-ripe stage in Choice grade syrup with a light processing sufficient to prevent spoiling but not sufficient to soften them unduly are used. Maraschino cherries, dyed with erythrosin dye, are prepared in bulk during the season for canning fruits for salads or are purchased in bulk from cherry processors.

The syrup from the canned pineapple and apricots is recovered, mixed with a Hy-Flo infusorial earth or other filter aid, and filtered hot. Then it is mixed with sufficient water and sugar syrup to reach the desired Brix for canning the fruits for salad. In some cases it is strained to remove coarse particles of fruit.

Cans or jars are conveyed by straight-line conveyor. The required quantity of each variety of fruit is added. The sequence consists in adding peaches first, then pears, apricots, maraschino cherries, pineapple segments, and, last, one or more pieces of peach to top the filled can and give the desired fill weight. After the syrup is added in a syruping machine, the cans are exhausted, sealed, and processed in a rotary cooker. The process time is about 10 min at 98.9°–100°C for No. 1 tall cans, and slightly longer for No. 2½ cans. Exhausting should be thorough. However, prevacuumizing and steam-flow seaming can be used. Glass jars may be used and sterilized at 103.3°C in a continuous pressure cooker. They are cooled under air pressure in order to hold the lids in place.

Fancy Grades

The Canners' League of California has established specifications for Fancy grades of canned fruits for salads as follows. The fruit should be of good color, ripe yet not mushy, of uniform size, symmetrical, and free of serious blemishes. Maraschino cherries must not be smaller than seven to the ounce. Apricots must be in halves; pears and peaches in quarters, sixths, or eighths; pineapple in sectors; and the cherries whole. Apricots constitute 18–30%, pears 21–33%, peaches 24–40%, pineapple 9–16%, and cherries 4–8% of the total drained weight.

The syrup after canning and reaching equilibrium with the fruit should be at least 24° Brix, with a permissible tolerance for any single package of 10%, i.e., it may be as low as 21.6° Brix.

Choice Grades

The specifications for Choice grades are similar to those for the Fancy except that the fruit must be at least equal to the regular Standard canned fruit in quality and the pineapple equal to or better than Standard tidbits. The syrup after canning should test 20° Brix or above with a tolerance of 10%, i.e., not below 18° Brix for any package.

GRAPES

There are three broad classes of grapes that are grown in the three principal growing areas of the United States: the northeastern euvitis or bunch grape *Vitis lubrusca;* the grape, *Vitus vinifera;* and the southeastern Muscadine grape, *Vitis rotundifolia.*

In the United States, Thompson seedless grapes are used in canned fruit cocktail. There is a direct relationship between the soluble solids content of the berries and the percentage of berries that develop internal browning. Fruit susceptible to internal browning has high levels of polyphenoloxidase and low levels of dihydroxyphenolic substrate.

The unfermented grape products industry in the United States is developed largely around the Concord grape, which is grown throughout the cooler areas of the United States and Canada. The state of Washington now leads in the production of Concord grapes in the United States. The high cost of grape harvesting can be substantially reduced by using mechanical harvesters.

Concord Grape Juice

The majority of grape juices are made from Concord grapes. Approximately 96% of the juice made in New York state is prepared from Concord grapes. They are largely processed in 0.68- or 3.78-liter bottles for the retail market. Hot pressing of the grapes is important to extract the anthocyanin pigments, flavor components, amino acids, organic acids, sugars, minerals, tannins, and other ingredients. Maturity of the fresh grapes is an important factor affecting composition and quality of the grape juice. Usually, grapes at 16° Brix or higher are considered ripe for juice processing. If the juice contains more than 0.85% acid as tartaric acid, it may taste too tart to the consumer.

Hot Extraction. Grapes are washed with a spray of water and then fed through a conveyor into the hopper of a machine where they are forcibly moved into the receiving end of the drum by a rotating device. The grapes fall into the path of the rotating blades which not only beat the berries but also force them outward against beating bars and the surface of the drum. The beating and propulsion action breaks up the grapes, but not the seeds and stems. The centrifugal action produced by the rotating beating blades causes the juice and pulp to escape through slots and the opening in the drum. The stems are discharged from the outlet end by the propelling action of the spiral blades.

The juice and pulp are pumped into steam-jacketed stainless steel kettles equipped with rotating paddles to extract the pigments and other solubles. The grapes may be preheated first to 54.4°C and held there for 10 min. Then the product is heated to 62.8°C and held there for 10 min. more. It is necessary to adjust the time of heating to extract the desired color and soluble materials. The temperature and time of heating should be controlled and recorded by automatic devices.

Pressing the Juice. After removing about half of the free-run juice, more juice can be pressed from the heated grape mass in a hydraulic press through layers of nylon cloth over the racks. About 1–2% of diatomaceous earth can be added as a filtering aid. Hydraulic pressure is applied gradually until it reaches a pressure of 17–20 kg/cm^2. The yield of juice is 75%, or about 662–700 liters per ton of grapes. This method is time- and labor-consuming, and yeast fermentation may occur if the time of operation is delayed.

Continuous Screw Press. The hydraulic press method has been gradually replaced by continuous screw presses (Garolla Press) that require destruction of the pectin in grapes with pectic enzymes. The hot pulp is pumped into large stainless steel holding tanks equipped with slowly moving paddles. Pectic enzyme preparation is added at a rate of 0.09 kg/ton of grapes. The mixture is kept at 60°C for 30 min or longer to hydrolyze the pectin. Then 4.5–9.0 kg of wood fiber is added as a bulking agent. The digested pulp is drained through a 4-mesh screen or on sloping vibrating decks equipped with trapezoidal shaped rods. The free-run juice may contain 10–30% suspended solids as determined by centrifugal tests. The remainder of the pulp is then pumped to a continuous screw press. The residue from the press may have a moisture of 40–50%.

The free-run and expressed juice are combined, and 1–2% by weight of diatomaceous filter aid is added to aid filtration through a rotary vacuum filter or a pressure leaf filter. In the latter case, pressures of 5–6 kg/cm^2 are applied by filter pumps. Continuous desludging centrifuges may be used to remove suspended solids, followed by plate-and-frame filters using diatomaceous filter aids. The yield of juice may vary from 700–738 liters/ton of grapes. The cake from the screw press may be further extracted with water in a countercurrent system; this process can increase the juice yield by 5%.

Other types of presses also can be used for recovery of grape juice. The Willmes Press consists of a perforated rotating cylinder with an inner rubber sleeve into which compressed air is applied to inflate it and press the juice cake. It is desirable to apply the pectic enzyme treatment prior to pressing.

The serpentine fruit press (Fig. 6.2) is a very useful press for the grape juice industry. This continuous-flow fruit press can be constructed in a large number of configurations and sizes. Its light weight, low power requirements, and feeding flexibility make it possible to place this machine in any part of a processing line without disrupting the existing layout. Fruit can be fed to the bottom or top of the press by reversing the perforated belts. As the material rides on the belt into the press, guides and scrapers shape it to a height of 1.91 cm and leave a 2.54-cm margin on each side. As the material moves into the throat, the upper and lower belts meet and move at the same velocity and pressing begins. The juice flows by gravity into trays all along the operation and the finished pulp is released at the end of the operation. Between stages the pressure is lessened and the pulp has a chance to relax. Then the pulleys reverse the

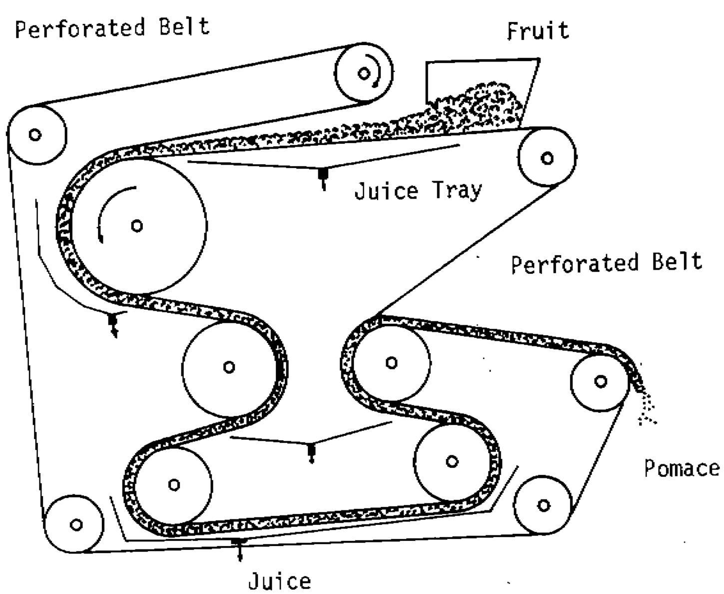

FIG. 6.2. The serpentine fruit press. (From Coffelt 1965.)

flex direction to open up new channels for the escape of liquid. The nylon belts are resilient and cup the crushed material, forming a tube while pressing, which keeps the material from leaking out the sides.

The prototype has 15.2-cm-wide belts, which move 100 meter/min, and operates the five pressing stages with a 1-hp motor. Commercial-size machines have been built with 30.5-, 61.0-, and 91.4-cm-wide perforated belts with from five to fifteen pressing stages. A press with a 91.4-cm-wide belt and nine pressing stages can handle 125 tons of crushed grapes per hour with only a 10-hp motor. The tension in the belts exerts a pressure of 0.5 kg/cm^2 on the material. Much greater pressures could be exerted through the pneumatic control system activators, but this has not been necessary for materials handled to date. The Serpentine fruit press is lower in operating cost than the basket or screw press by 25% or more.

Low-Temperature Storage. Extracted grape juice is flash-heated at 79.4°–85.8°C in a tubular, plate, or scraped-surface heat exchanger and then cooled in a second heat exchanger to 0°C. In many plants, the entire pasteurizing and cooling of grape juice is accomplished in single-unit heat exchangers. The cooled juice at 0°C is pumped into glass-lined metal tanks or concrete tanks with plastic coatings.

The juice is stored at 0°C for 1 month or longer to allow crystallization of tartrate salt (argols). The tanks usually are covered and sealed, although open tanks with ultraviolet lamps are also used to inhibit mold growth on the surface of the juice.

In an older method less used now, the grape juice is pasteurized at 77°–82°C and filled hot into steam-sterilized carboys or jugs through a tube leading to the bottom of the container. Sufficient juice is added to the container to cause the foam formed during filling to flow over the top and out of the container. A hot paraffined cork closes the opening, and melted paraffin is poured over it to obtain a tight seal. The carboys are cooled in a conveyor with a fine water spray, and then kept on racks in cool cellars.

The soluble solids content of ripe Washington-grown Concord grapes may vary from 16°–19° Brix at harvest and the total sugars from 14°–16°. The minimum soluble solids for U.S. Grade A Unsweetened Canned Grape Juice is 15° Brix, and the minimum acidity is 0.60% as tartaric acid.

The average solids content of cold-pressed grape juice is 16.36% sugars, 13.9% nonsugars, 2.43% acidity, and 0.78% as tartaric acid. After heating, the pressed juice has a solids content of 17.43% sugar, 14.03% nonsugar, and 3.40% total acid with 1.09% as tartaric acid.

Processing of Grape Juice in Bottles. The grape juice is reprocessed after the argols have formed and settled out. After removal of the clear juice, the thick juice and argols are partially filtered through a screen or through heavy cotton cloths on a frame. The juice flowing through is still muddy and thick and must either be resterilized and stored again to permit a second precipitation of argols, or filtered in a filter press using infusorial earth or other substances as a filter aid. Juice stored in large containers is more easily handled. The draw-off pipes in the sealed storage tanks are extended sufficiently above the bottom to prevent disturbance of the argol sediment. The contents of the tank are drawn off. The juice and argols remaining in the bottom of the tank are drained and treated as described for carboy juice, or are separated by means of a continuous bowl centrifuge. A continuous stream of centrifuged juice is obtained simultaneously with discharge of partially dry argols.

Improvements have been made by the industry in pasteurizing and bottling grape juice so that the deteriorative effects caused by oxygen and by prolonged heating are eliminated. The juice from which argols have been removed is conveyed to holding tanks. From there it flows by gravity through a tubular or plate that exchanger into the filler. The temperature employed is high enough to obtain a temperature in the bottled juice of 76.7°C or above. The hot juice from the heat exchanger is filled by means of an automatic filler into preheated bottles that have passed through an air cleaner and preheating hood. In the preheating hood, the bottles are subjected to steam heating.

After filling, bottles are capped under steam and are then discharged to a conveyor that carries the hot bottles to the pasteurizer. The pasteurizer serves to hold the bottles at pasteurizing temperature. The bottles are next subjected to mist sprays of cool and then cold water.

Muscadine Grape Juice

Well-ripened grapes are washed and crushed between rollers. One-third of the grapes are heated by simmering in a stainless steel steam-jacketed kettle with constant stirring. The one-third heated portion is pressed and the juice is blended with the juice obtained by cold pressing the other two-thirds of the grapes. The blended product is said to be more pleasing in color, flavor, and aroma than is the product obtained from either hot-pressed or cold-pressed juices alone. This is especially true if ascorbic acid is added to the crushed grapes immediately before pressing.

The yield of juice from Muscadine grapes is somewhat lower than that obtained from Concord. About 60–62% yields may be obtained by hot pressing and 50–55% by cold pressing. In juice cooled to 4.4°C, tartrates crystallize and settle within a few days. The cold storage and processing procedures are the same as those described for Concord grape juice.

Grape Juice Concentrate

Grape juice concentrate has assumed an important role in the grape processing industry. Concentration permits economies in storage and

transportation. It also results in a more complete deposition of tartrates during low temperature storage at −5.6° to −2.2°C.

The unflashed juice from the separator may be concentrated in a forced circulation, falling-film or a single-pass evaporator having a relatively short retention time. Forced circulation evaporation may be carried out in one or several stages using temperatures ranging from 57.2° to 71.1°C and with a retention time of 1 hr. The retention time and heat exposure have been reduced to approximately 20 min by use of a falling-film evaporators at 54.4°–65.6°C under a vacuum of 68.6°–73.7°C Hg. More recently, in a single-pass evaporator of special design, the exposure time has been further reduced to approximately 2–3 min for complete concentration to 48° Brix in a multiple-stage unit using temperatures of 65.6°–71.7°C in the first effect and 46.1°C in the second effect. The same type of evaporator may be used to achieve a concentration of 72° Brix if the juice has been depectinized.

Grape juice concentrates are shipped in large tanks for remanufacturing purposes. They do not need refrigeration because the osmotic pressure of the grape sugars at 72° Brix can preserve the product provided that attention is paid to proper sanitation and aseptic filling operation.

Essence Recovery

The volatile components are removed by heating single-strength juice to 104.4°–110.0°C for a fraction of a minute in a heat exchanger, flashing a percentage of the liquid into vapor in a jacketed tube bundle, and then discharging the liquid and vapor through an orifice tangentially into a separator. The separator should be of sufficient size so that the vapor velocity is reduced to 3 m/sec or less. From 20–30% by weight of the original juice flashes off as a vapor that is led into the base of a fractionating column filled with ceramic saddles or rings. A reflux condenser on the base of the column is used to provide the necessary reflux ratio. The vent gases from the reflux condenser are then chilled in a heat exchanger and the condensate containing the essence is collected. The recovered essence can be added back to the grape concentrate.

Grape Drinks

The utilization of grape juice in grape drinks and in blends of juice has expanded considerably. Blends of apple and Concord grape juices have found a large market, and blends of apple with juices from several grape cultivars are also popular. Blends of grape with grapefruit and other juices are also very pleasing. It would be desirable to standardize the content of grape juice in grape drinks and juice blends.

GRAPEFRUITS

Grapefruit can be classified into two types: the common grapefruit and the pigmented grapefruit. The color of the pigmented fruit is due to the presence of lycopene, a carotenoid. Both seedy and seedless grapefruit cultivars exist. The most popular cultivar is 'Marsh Seedless', followed by 'Duncan', a seedy cultivar. The pigmented cultivars, such as 'Thompson' and 'Ruby,' however, are becoming more popular. Grapefruit is grown largely for the fresh fruit market except in Florida, where more than 60% of the crop is processed as single-strength juice, frozen concentrates, or canned sections.

Only tree-ripened grapefruits are used for canning. After size grading and sorting, the whole fruit is heated in boiling water for 4–7 min to loosen the pulp from the membrane covering the outer ends of the juice cells and to soften the rind. Then by quarter-scoring the rind through the pulp, the outer skin is peeled off, leaving a membrane-coated fruit. Highly developed mechanical equipment has been designed to perform almost the entire job of peeling, segmenting, and filling into cans. It is necessary to remove the membrane by passing the fruit through a boiling 2–3% sodium hydroxide (lye) solution for 15–20 sec or under a spray of boiling lye. This operation disintegrates the thin white membrane as well as the bitter element, naringin. The lye-treated fruits then enter a vigorous cold-water washer, followed by a water spray of sufficient pressure to wash off the particles of membrane and the residual alkali. If a lye-peeling facility is not available, knife peeling may be used.

The peeled segments are sorted to remove broken and defective pieces. They are then filled by hand into cans, often with the convex surface of the segment toward the can wall, in order to present a neat appearance. The fill weight for a No. 2 can is approximately 483 gm of fruit. It is preferable to weigh each can so as to assure a uniform fill weight. The usual syrup is 35°–40° Brix, depending on the sweetness desired. It may be added at 82°–90°C. Some canners add it cold, in which case the exhaust time has to be increased.

Cans are exhausted at 82.2°C, sealed hot in a double seamer (Fig. 6.3) or under steam flow, and processed at 82.2°C for 25–35 min or at 100°C for 10 min for No. 2 cans. For 404 × 707 cans, processing time is 35–50 min at 87.8°C. The can center temperature must reach 76.7°C. After leaving the process bath, cans are passed to a cooling bath by means of a conveyor that is adjusted so cans will enter the cooling bath after a lapse of 6 min. Cans remain in the cooling water bath until the average temperature has dropped to 40.6°C. Thorough exhausting to remove air and the use of Type L tinplate is desirable. Canned grapefruit should be stored in a cool place, preferably at 10°–15.6°C in order to retain the quality of the product.

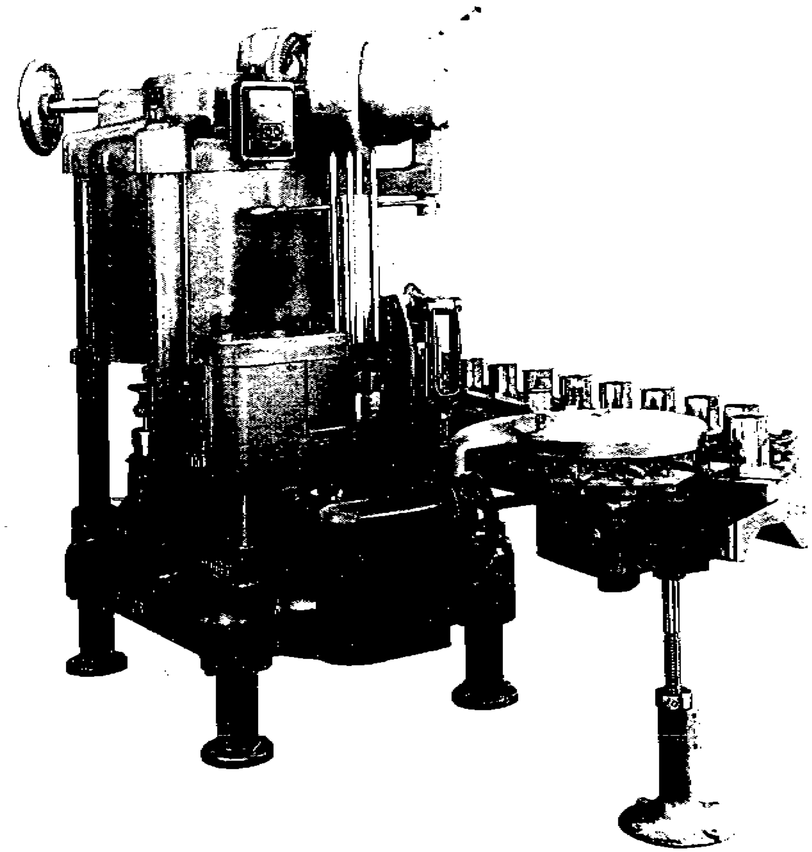

FIG. 6.3. Angelus model 40P MSLF double seamer with capacity of 275 cans/min. (Courtesy Angelus Sanitary Can Machine Co.)

Grapefruit By-Products

Citrus fruit processors have found it economically feasible to produce dry citrus peel, citrus molasses, and D-limonene (Lopez 1981). The peels and pulp residues are collected and ground in a hammermill. Sufficient amount of lime is mixed with the ground mixture to neutralize the acids present in the peels and pulps. The product is pressed to remove excess moisture. The pressed peel is conveyed to a direct-fired hot-air drier. The liquid from the press is screened to remove large solids, which are recycled back to the press. The press liquor is concentrated to molasses in an evaporator. The exhaust gases from the peel drier supply the heat energy for the concentration of the press liquor into molasses. D-limonene is recovered from the exhaust gases through condensation as they are released from the peel drier.

Grapefruit Juice

The canning of grapefruit juice is a well-established industry. Most of the commercial product is packed in citrus-enameled tin cans. Research is under way to use composite cans (Mylar–paper–aluminum–polypropylene) for aseptic canning of grapefruit juice. Results are very encouraging because of the improved quality of the canned juice.

Ordinarily, differential electrolytic tinplate lined with citrus enamel should be used in order to minimize development of a tinny flavor, although most grapefruit juices are packed in plain tin cans. In the early days of the industry considerable loss was encountered from hydrogen swelling by reaction of the acids of the juice with the tinplate. With improvement in tinplate quality and in processing and storage of the juice, such losses are now relatively slight.

Grapefruit juice can be canned in its natural state or slightly sweetened with sucrose or high-fructose corn syrup, depending on the composition of the grapefruit used.

In the recommended procedure for canning grapefruit juice, well-ripened grapefruits are washed and cut in half; then the juice is extracted by reaming, using a light squeeze and finishing process to avoid expressing essential oil from the rinds. The juice is strained through a finisher (Fig. 6.4), deaerated under a high vacuum (680–736 mm Hg) or in a continuous vacuumizer, flash-pasteurized at 190°–196°C for about 1–2 min, and cooled to 80°C. The hot juice is filled into citrus-enameled cans. The cans are sealed hot, inverted for 3–4 min to sterilize the lids. The canned juice is cooled thoroughly under sprays of chlorinated water to 38°C.

Soluble solids, % acid, Brix–acid ratio, and the levels of limonin and naringin are important factors influencing the acceptance of grapefruit juice. According to Nagy and Shaw (1980), the average soluble solids of mature California grapefruit was about 12° Brix, acidity about 2%, and Brix–acid ratio about 6. The average soluble solids of Texas grapefruit was 11° Brix and that of Florida 7°–10°. The acidity of Texas grapefruit was considerably lower than that from the other states. Texas grapefruit juice has a higher Brix–acid ratio and a sweeter taste. Both the FMC In-Line and AM Rotary juice extractors yield juice of a lower quality with higher bitterness when a harder squeeze is used.

Excessive bitterness results when immature grapefruit are processed and when excessive yields (45–48%) are obtained through hard squeezing and/or hard finishing. As a result of these findings, regulations were enacted in 1976 by the Florida Citrus Commission limiting the amount of limonin and naringen allowed in processed grapefruit juice during the early weeks of the season. The lemonin values in the grapefruit juice

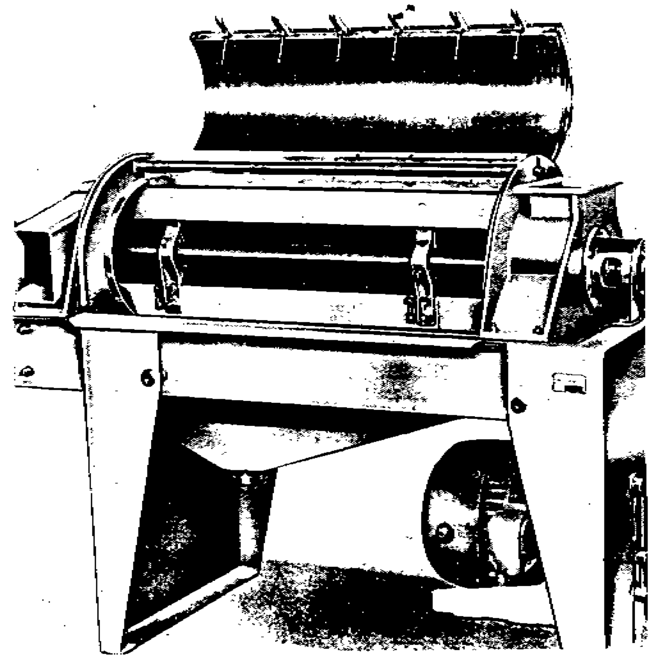

FIG. 6.4. Brown model 202 pulper-finisher. (Courtesy Brown International Corp., Covina, CA.)

averaged 4–5 ppm. The early-season juice (Aug. to Sep.) contained 8–10 ppm limonin and late-season juice (Dec. to Jan.) only 2–3 pm. The average naringin value of the juice was 350–421 ppm.

The undesirable effect of prolonged storage on canned grapefruit juice at elevated temperature (above 21.1°C) can be measured by the increase in furfural content. Storage conditions that produce furfural levels approaching 1000 μg/liter cause flavor changes that can be detected by a taste panel.

To improve the acceptance of canned grapefruit juice, juice with low Brix–acid ratio should be blended with high-ratio juice to achieve a balance between tartness and sweetness. The ratio of the blend should be as high as practicable. Early-season or late-bloom fruit should be squeezed as gently as possible to minimize the extraction of naringin and limonin. Canned single-strength grapefruit juice should be stored at 21°C or lower.

Bitter Flavonoids in Grapefruit Juice. The bitterness in grapefruit is associated with the flavanone glycoside naringin and the triterpenoid lactone limonin. Two isomeric glycosides of naringenin have been isolated, both containing one mole each of the sugars rhamnose and glucose. One of these, naringin, is intensely bitter; the other, naringenin rutinoside, is not. It is the glycosidic linkage of the two sugars comprising the disaccharide unit that largely determines the bitterness. The neohesperidosyl group found in naringin consists of rhamnose and glucose linked C_1 to C_2, whereas in the rutinoside the linkage is the more usual C_1 to C_6. The neohesperidosyl group is associated with, although not essential for, bitterness. Thus, prunin (7-β-D-glucoside), although lacking the disaccharide linkage, still exhibits some bitterness.

Naringin—the main bitter component of grapefruit—is present in the albedo layer and in the carpellary membranes. The method of extraction of the juice or preparation of segments influences the amount of bitterness entering the product. If the fruit is hand-peeled, much of the naringin is removed with the albedo layer and outer membranes, but this method gives a lower yield of segments than if the segments are lye-peeled. Here the fruit is calded to soften the skin, and then the albedo layer is removed by an alkali dip and subsequent water spray to remove the loosened tissues. The efficiency of this process determines the bitterness of the product.

The level of naringin is highest in immature fruit. In one study, fruit sampled in November had only 38% of the level of bitter flavanone glycosides found in fruit harvested in July. However, it was shown that part of this decrease in bitter flavanones can be related to the increase in physical size of the fruit over this period. A solution to the problem of bitterness in canned grapefruit is the selection of mature fruit for processing.

Commercially canned Florida grapefruit juices contain more naringin than those from Texas. The juice from pink- and red-fleshed cultivars processed in Texas contains 0.026% naringin, while those from white cultivars contain 0.033–0.039% maringin. Under normal processing conditions, grapefruit processing residue (consisting principally of peel, membrane, and seeds) generally contains about 0.75% naringin (Nagy and Shaw 1980). The amount depends largely upon the maturity of the fruit, since naringin is more abundant in immature fruit.

The naringin content of the whole fruit ranges from 3.2% for fruit 5.9 cm in diameter to 0.4% in mature fruit. About 62% of the naringin is in the peel, 36% in the pulp and rag, and 2.4% in the juice. This illustrates how improper juice extraction and finishing can easily extract additional naringin from the pulp, rag, or even peel and increase bitterness.

Naringin is the bitter 7-β-neohesperidoside of naringenin; its tasteless isomer, the 7-β-rutinoside of naringenin is also present in grapefruit juice at one-third to one-half the level of naringin. Generally, flavanone glycosides with the neohesperidose linkage are bitter and those with the rutinose linkage are tasteless.

The Davis (1947) test has been widely used as a quality control index in grapefruit juice since it is proportional to naringin content. It measures total glycosides, including naringin and its tasteless isomer.

Naringin was formerly thought to occur only in grapefruit and the closely related shaddock, but it is now known to exist in several other plants including bitter orange and other citrus species. Naringin can occur in processed products as a fine crystalline suspension, which can impart a cloudy appearance to the syrup, or it can give rise to larger crystals forming "glassy" lumps in the fruit segments. It can be recovered as a by-product.

In order to obtain grapefruit juice of satisfactory appearance, the pulp should be blended and added to the juice to give 22–26% suspended solids. The use of the enzyme naringinase at 4°C partially hydrolyzes the naringin to give the less bitter prunin or, at 50°C, effects complete hydrolysis to the nonbitter aglycone, naringenin.

Other bitter flavanone glycosides containing the characteristic neohesperidosyl group have been isolated from citrus fruits. These include poncirin found in *Poncirus trifoliata* and neohesperidin isolated from Seville oranges. Recently, polyvinylpyrrolidone resins have been proposed to remove some of the undesirable flavonoids from grapefruit juice.

GUAVA

Guava is one of the more important pomiferous fruits of the myrtle family. It is used largely preserved as puree, juice, nectar, and beverages. The processing methods for guava products have been reviewed in Nelson and Tressler (1980).

LYCHEE

The lychee is a delicious fruit thought to have originated in southern China. The excellent flavor and aroma of this fruit is largely retained after canning.

Firm, ripe lychees are washed, peeled, and pitted by hand. To each No. 2 enamel can, 468 gm of fruit and 156 gm of 40° Brix sucrose syrup are added; 0.1–0.2% citric acid may be added to the syrup to improve the flavor. Cans are exhausted for several minutes to a can center temperature of 71.1°C prior to double seaming, or cans are sealed under vacuum at 38.1 cm Hg. The sealed cans are heat-processed in a high-speed spin cooker to 90.6°C for 2–3 min or in a boiling water bath for 12 min, followed by rapid water cooling. Excellent results are achieved when the fruit is processed in a spin cooker.

Excessive heat processing of lychees may cause phenols, leucoanthocyanins, and flavanols to leach into the syrup, causing pink discoloration in the canned product. It is believed that the level of leucoanthocyanins in lychees may be related to the pink discoloration problem. Excessive heat processing and delayed cooling of the canned product should be avoided.

ORANGES

The citrus fruits of commerce may be classified into four horticultural groups: oranges and mandarins; hybrid fruits; grapefruits and pummelo; and acid fruits such as citron, lemon, and lime. Citrus fruits also may be classified into 10 botanical groups: *Citrus sinensis* (sweet orange); *C. aurantium* (bitter or sour orange); *C. reticulata* (Mandarin orange); *C. paradisi* (grapefruit); *C. grandis* (pummelo or shaddock); *C. limon* (lemon); *C. aurantifolia* (lime); *C. medica* (citron); *Fortunella* sp. (kumquat); *Poncirus trifoliata* (trifoliate orange).

The USDA has reported that the combined orange and tangerine production in 22 selected countries was 36.2 MMT (million metric tons) for the 1980/1981 season. The fruit processed was 16.6 MMT, or 45.8%, of the orange and tangerine crops.

Single-Strength Orange Juice

Oranges intended for canning as juice should be of a quality comparable with that suitable for direct consumption. They should have a suitable balance of acidity and sugar, with fully developed aroma and flavor.

The major orange-producing areas have regulations concerning the maturity of the fruit that may be harvested. In order to ensure optimum quality, further selection is made. Most fruit used is well above the minimum values listed in the regulations. Attention is given to the blending of different lots to achieve a balance in solids, acidity, color, and flavor.

In California, the principal orange cultivar used for canning as juice is 'Valencia'. The 'Washington Navel' orange is used for certain types of beverage bases where the tendency for bitterness is not objectionable. In Florida, the principal cultivars oranges used for processing are 'Pineapple' (midseason) and 'Valencia' (late season). 'Parson Brown' and 'Hamlin' (early season cultivars) are also used but are considered less desirable because of somewhat lower soluble solids content, color, and flavor.

Harvesting

Sweet oranges for processing are harvested in the same way as are fruit for shipment as fresh fruit. A ladder is laid against the tree and the picker climbs the ladder carrying a canvas bag that holds 22–27 kg of fruit. Fruits are clipped and placed in the bag. The worker then descends and dumps the contents in a bin or other container. A number of mechanical tree shakers are in various stages of development and a number of abscission chemicals are being tried to loosen the fruit. Some devices have been developed for raking the fruit to the center of the aisle between tree rows and loading it into trucks (see Chapter 2).

Processing. Upon reaching the processing plant, the fruit goes through inspection lines for removal of bruised or broken fruit. The sorted fruits are conveyed to storage bins until enough fruit accumulates for continuous operation of the cannery. The fruit is never piled to a depth of more than 1.3 m.

As the fruit is conveyed to the bins, automatic devices divert a small portion to a laboratory where the titratable acidity, Brix, and juice yield are determined. These values are used to determine which bins are to be blended.

From the bins the fruit is conveyed to the washer, where it is soaked briefly in water containing a detergent, scrubbed by revolving brushes, rinsed with clean water, and inspected again to remove damaged fruit. The fruit is then separated into sizes automatically and conveyed to juice extractors. After finishing, the juice flows to large stainless steel tanks where it is checked for acidity and soluble solids. Sugar is added, if needed.

Control of Volatile Peel Oil Content. The standards for U.S. Grade A orange juice permit not more than 0.035% of peel oil by volume. Normally, it varies between 0.015 and 0.025%. One may control the peel oil content by adjusting the extractor or by softening the peel by immersing the fruit in hot water for 1–2 min. Excess peel oil in the juice can be removed by heating the juice at 51.7°–57.2°C in a vacuum evaporator until about 4–6% of the juice is evaporated. The vapors are condensed, the oil separated by centrifugation, and the water layer returned to the juice. This treatment can remove three-fourths of the peel oil present in the juice. The level of peel oil can be determined by distilling the juice with 2-propanol and oxidation of the recovered d-limonene with a standard potassium bromide–potassium bromate solution under acid conditions.

Pasteurization. Pasteurization of citrus juices is done to destroy microorganisms that would otherwise cause fermentation in the can and to inactivate enzymes that would otherwise cause cloud and other changes in the juice. Generally, higher temperatures are needed for enzyme inactivation than for destruction of microorganisms.

The juices are heated in tubular or plate-type heat exchangers for 30–60 sec, and then piped hot directly to the filling machine.

Filling and Storage. Juice is maintained at 85°C in the filler bowl and filled directly into cans. The juice is in the filler bowl from 1 to 2 min in most cases. The cans are closed in automatic steam injection sealers, inverted for about 20 sec, and rapidly cooled to 37.8°C by spraying with cold water while spinning in a conveyor. Plain tin cans are used for single-strength orange juice.

The temperature at which canned orange juice is held is a major factor influencing the flavor and vitamin content of the juice when it is consumed. At 21.1°C there is slight flavor change and approximately 85–90% of the ascorbic acid is retained for 1 yr. At higher temperature deterioration in flavor and loss of ascorbic acid progress more rapidly. At 0°–4.5°C the quality and ascorbic acid content of canned orange juice change very little during storage for 1–2 years.

Spectral Characteristics of Orange Juice. The visible and ultraviolet absorption curves of alcoholic solutions of orange juices from 'Hamlin', 'Pineapple', and 'Valencia' oranges are similar, except for their intensities. Absorption maxima for carotenoids were observed at 465, 443, and 425 nm, and for phenolic and flavonoid compounds at 325, 280, and 245 nm. A shift in wavelength or unusual change in intensity may be indicative of some type of additive. Maturity influenced the spectra of 'Hamlin' and 'Pineapple' orange juices, causing a general increase in the visible and ultraviolet absorption with increasing maturity. Extractor pressure also affected the spectra, the hard-squeeze juices having a higher ultraviolet absorption than the light squeezes.

Absorption characteristics such as spectral shapes, absorption wavelengths, intensities, and the ratios (443/325; 280/325 nm) may be helpful in analyzing and determining the quality of juice products. Spectral characteristics may be used to determine the orange juice content in citrus products.

Bitter Fractions in Orange Juice. Limonin, the main bitter fractions of 'Navel' oranges, is a triterpenoid derivative. It is a dicarbocyclic compound with two lactone rings, a cyclic ether ring, an epoxide group, a furan ring, and a ketone group. A nonbitter monolactone of limonic acid also has been isolated from citrus fruits. This compound is rapidly converted to the bitter-tasting dilactone limonin at pH 3.0, but slowly at pH 5.6.

Limonin is an intensely bitter limonoid of importance to citrus juice quality. The metabolically active form of limonin is the nonbitter limonoate A-ring lactone (LARL). LARL is synthesized in the leaves and transported to the fruit; it is gradually degraded in the fruit to nonbitter products by at least two pathways. LALR undergoes acid-catalyzed lactonization to limonin when fruit tissues are disrupted in juice preparation (Brewster *et al.* 1976).

Casas and Rodrigo (1981) studied changes in the limonin monolactone content during development of 'Washington Navel' oranges in Spain. From the start of development of the fruits, limonin monolactone accumulated to a maximum of 47 mg/fruit—around 130 days after anthesis. Throughout the development of the fruit, the total limonin monolactone content in the endocarp was greater than in the peel. The limonin monolactone content in the leaves decreased gradually from the start of the experiment until 130 days after anthesis.

Two theories are proposed to account for the delayed bitterness of citrus products. One hypothesis ascribes the delay to a physical phenomenon dependent on the solubility of the bitter fraction; the second hypothesis is that a chemical change occurs in which a nonbitter precursor is converted into a bitter compound by the process of extraction of the juice. This latter type of reaction is now accepted as the explanation of the delayed bitterness; the pH has an important influence on the reaction. In the growing fruit the bitter precursor is separated from the acids of the sap and no reaction occurs, but when juice is prepared this precursor comes into contact with the acidic juice and the reaction proceeds, liberating the bitter compound.

There are several methods by which the bitterness in citrus products can be reduced. During the preparation of the product, excessive extraction of bitter fractions from the rag and pulp should be avoided; also raising the pH to about 4 can prevent formation of limonin dilactone. The use of pectic enzymes to reduce bitterness has also been suggested. The dispersed colloids are coagulated by the enzymes, and in the subsequent precipitation they carry the bitter principles with them.

Polyamide resins have been used to remove limonin from 'Navel' orange juice. The bitterness was reduced by stirring juice with dry polyamide powders and subsequent centrifugation. Although the method is convenient for the removal of bitterness, a loss of up to 25% of ascorbic acid may also occur.

Mandarin Oranges

Mandarin oranges are canned in Taiwan and Japan on a commercial scale. The raw material of the canned product is a very popular fruit known as Mikan or Tunkan. In Japan 82.5% of the Mandarin oranges grown are used for the fresh market, 16% for processing, and 1.5% for export as fresh fruit.

Processing of Canned Mandarin Orange Segments in Syrup. The fruit is graded according to size ranging from 5.08–5.26 cm in diameter), blanched in hot water at 80°C for about 1 min, peeled by hand with bamboo knives, and dried slightly in the wind before being separated into segments. This segmenting is also done by hand, women being employed for this work as well as for the peeling operation. Then, acid and lye segment peeling is done automatically to dissolve the segments' outer skin. The divided segments are soaked in dilute acid solution (0.5% HCl) for 40 min at 30°C and then in dilute lye solution (0.15% NaOH) for about 20 min at 25°C. Peeled segments are then soaked in cold running water about 60 min. Segments are graded according to size by automatic grading machines and sorted for quality by hand while they are being conveyed by a wire net conveyer. Most mandarin oranges are placed in No. 5 cans, which are automatically filled with syrup by syruping machines. After sealing in a vacuum-sealing machine, the cans are heat-processed in a continuous-agitating cooker and cooler. The heating time for No. 5 cans at 82.2°C is about 13 min.

Prevention of Turbidity in the Product Syrup. Hesperdin contained in raw Mandarin oranges is found in the syrup of products in the form of needle-shaped crystals, which produce white turbidity and lower quality grades. Addition of gelatin, sodium carboxymethyl cellulose (CMC), or methyl cellulose (METHO-CEL) to syrup has proved to be very effective in preventing turbid syrup. Methyl cellulose is most effective and is added at a level of about 10 ppm. Segment peeling with a more dilute lye solution (0.1% NaOH) also is helpful in preventing turbidity.

Tangerine Juice

Because tangerine oranges are quite fragile and cannot be hauled at the usual depth in trucks or in bins, they are handled in boxes in trucks. Some orange conveyers and washers may crush tangerines and need remodeling in order to efficiently handle them. Regular citrus juice extractors, especially those fitted to handle small fruit, can be used. Special juice extracts (e.g., FMC Model 191 with a 60-mm cup size and AMC Model 1700) are often required to accommodate smaller tangerines (Nordby and Nagy 1980). Processed tangerine juice is highly susceptible to off-flavor development during storage. The extent of off-flavor development appears to be closely related to the amount of peel extractives and suspended materials that are processed into the juice. After finishing, the juice is centrifuged to remove excess pulp. The capacity of a given plant handling tangerines is only half that when handling oranges.

The procedures for canning are the same as those for canning of orange juice. The 'Dancy' tangerine is the predominant cultivar. More tangerines are used in the manufacture of frozen concentrate than single-strength juice because canned tangerine juice has a very limited shelf life, whereas frozen concentrate is quite stable. Tangerines are grown primarily for fresh market use and only the surplus is available for processing.

PEACHES

Peaches are usually classified either as clingstone or freestone types. In freestones, the fruit can be easily separated from the stone or pit; in clingstones, the flesh adheres tightly to the pit. Both types have yellow-fleshed and white-fleshed cultivars. Yellow-fleshed cultivars are most common and are preferred for both processing and fresh market use. Clingstone peaches are firmer in texture than freestones and hold their shapes well after canning. For this reason, processors prefer clingstones for canning, and only 17–25% of the U.S. peach pack are freestones. The share of the total peach crop used for canning is 55%, and that for fresh consumption is 39.0% (see Chapter 16).

California produces nearly all the U.S. clingstone peaches plus a substantial volume of freestone peaches. Most peaches produced in the East are freestone. However, Georgia and several eastern states have shown increasing interest in producing clingstone peaches for processing.

Total U.S. peach production for fresh use and processing averages 1.45 billion kg a year. California, South Carolina, and Georgia account for 60%, 10%, and 6% respectively, of total production. Other peach-producing states are New Jersey, Pennsylvania, Michigan, and Washington. Annual peach packs varied between 22 and 35 million standard cases (24 No. 2½ cans) during the years 1972–1981.

Cultivars

California, with its fertile soil, adequate irrigation water, and favorable climate, is ideally suited for growing canning peaches. This is particularly true in the great interior Sacramento and San Joaquin valleys where the climate is modified by coastal influences. Growers can expect regular crop production if they choose the proper location, select suitable cultivar, and manage their orchards properly.

Qualities that make a clingstone peach cultivar acceptable to growers and processors are good shape and symmetrical size; small pit with little or no red flesh color; clear, yellow-colored flesh that will withstand hauling, refrigeration, and handling; pleasing taste, aroma, and texture that will be retained and enhanced in the canned product; and regular production of good-sized fruit throughout the life of the tree. The important California clingstone cultivars include the following: extra early—'Fortuna', 'Carson', 'Loadel', 'Vivian', and 'Dixon'; early—'Cortez', 'Jungerman', 'Andross', 'Paloro', 'Johnson', 'Klamt', 'Peak', 'Andora'; late—'Gaume', 'Carolyn', 'Everts', 'Halford', and 'Stanford'; extra late—'Starn', 'Wiser', 'McKune', 'Sullivan No. 4', 'Stuart', 'Gomes', and 'Corona'.

Several freestone peach cultivars have been used for canning. In California, the 'Elberta' and 'Fay Elberta' are used commercially for canning. Other cultivars having good color and flavor after canning are 'Redhaven', 'Summergold', 'B-53624', 'B-53625', 'Redglobe', 'Southland', 'Keystone', 'FV-7-1226', and 'Loring'. Because of lower case yields and difficulties in canning, freestone peaches are less popular than clingstones in the canning industry. (Li *et al.* 1972.)

Peach Halves and Slices

The commercial canning of clingstone peaches in California is regulated by the provisions of the California Agricultural Marketing Act, which is administered by the State Director of Agriculture in cooperation with the Cling Peach Advisory Board. If needed, the size of the pack in a given year may be limited to a certain specified number of cases, each canner being assigned a quota based on his past pack. The fruit for passing the grade must be 6.03 cm or more in diameter, free of blemishes, of proper maturity, and of good canning quality in other respects.

If peaches need to be held several days or longer for canning, they should be placed under refrigeration at 0°–2.2°C. Peaches should be held no longer than 2 weeks to avoid development of off-flavor.

Receiving, Cutting, and Pitting. When delivered, the peaches may be graded according to maturity and size before pitting, since each machine is usually adjusted for peaches of approximately one size. The canning process for clingstone peaches starts with halving and pitting. All cling peaches nowadays are pitted and halved by machine because of the high labor costs associated with hand cutting and pitting. The fruit in 455-kg bins is dumped into flumes and then onto a sorting belt that delivers the fruit to the peeling machine. Several types of machines are used for pitting and peeling.

The FMC peach aligning and pitting system can feed, align, and pit clingstone peaches at rates up to 100 peaches/min (Fig. 6.5). The system consists of a horizontal aligner and a rotary pitter. The aligner incorporates 27 plastic carriages on an oval-shaped conveyor that delivers peaches to the pitter. Each carriage contains a finding device that rotates the fruit until it assumes a stem-down position and a positioning device that turns the fruit until the suture is aligned with the center line of the machine. An automatic detection and rejection device, located immediately in front of the pitter, rejects any improperly positioned or misaligned fruit. The rejected fruit is then recycled in the system.

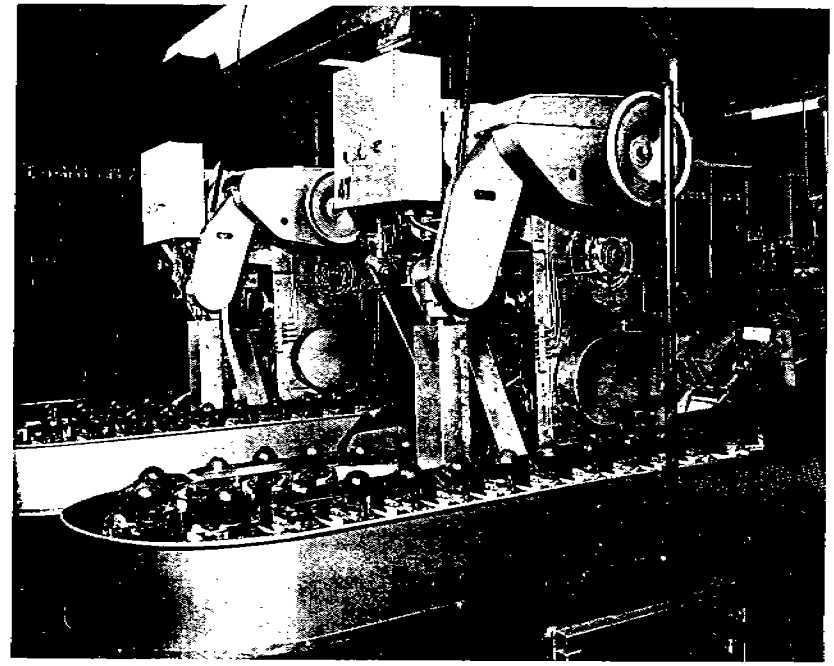

FIG. 6.5. Clingstone peach aligning-pitting system. (Courtesy FMC Corp.)

Size-graded clingstone peaches are fed into the aligner section from the conveyor. Each fruit is fed in sequence and deposited onto a carriage. The pitter employs a series of rubber transfer cups positioned on a turret. The cups are indexed with each carriage, enabling gentle transfer of fruit from the carriers into the pitter. Upon being transferred, the fruit is carried to, and impaled by, two stationary blades, cutting the flesh of the peach around the pit's longitudinal axis. The peach is then engaged by a second turret with cups to carry it through a circular saw, cutting the pit in half. The two peach halves are then transferred to a pitting position in which the divided pit halves are cut from the fruit. The fruit and pits are subsequently discharged to a shaker-type separator.

The Filper torque pitter (Fig. 6.6) has been used for cutting and pitting

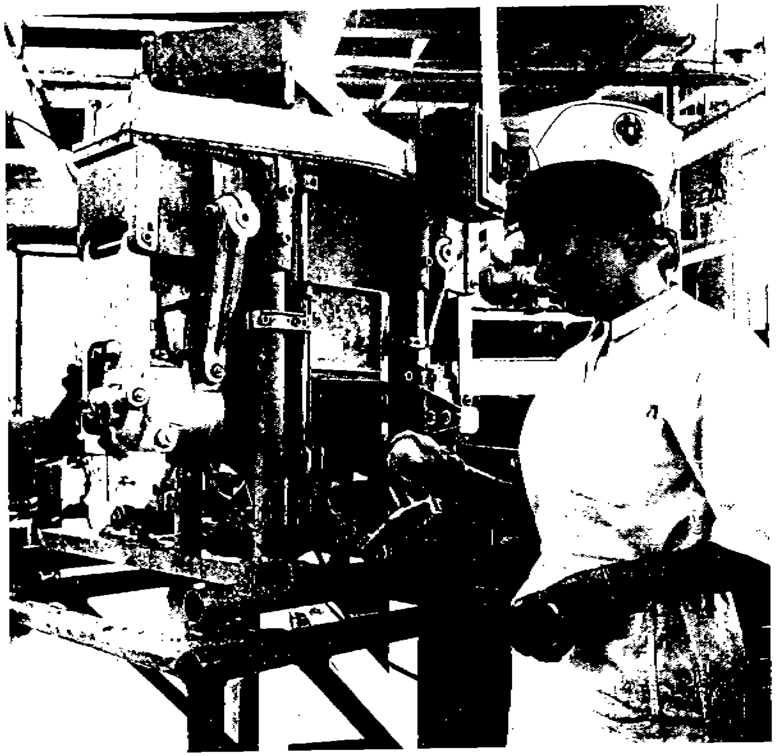

FIG. 6.6. Filper torque pitter for peaches. (Courtesy Filper Corp.)

clingstone peaches for canning. Automatic alignment systems are available to feed and align the peaches in the correct position prior to the cutting and pitting operation. The peach is first cut around the suture by the machine. Then the two halves in the tight grasp of the two cups are twisted in opposite directions to free them from the whole pits. The pits are separated from the peach halves by falling through a screen. The pitted peach halves pass through a mechanical shaking device that arranges them in single layers in the cup-down position. They are then conveyed on a moving stainless steel conveyor into the spray-type hot lye peeler.

Lye Peeling. Clingstone peaches are usually peeled cup down by a 1.5–2.5% hot lye spray for 15–60 sec. In the Dunkley peeler the hot lye is applied as a spray to the peach halves in the cup down position as they are carried through the peeling compartment on a perforated stainless steel conveyor. The lye is circulated by pump and is heated by steam in a heat exchanger.

The concentration of the lye is maintained by additions of 50% lye solution, controlled by a Honeywell electronic controller based on conductivity of the solution. Such a controller is necessary because the peeling process reduces the lye strength rapidly. If an automatic controller is not available, the operator can judge when lye addition is needed by observing whether the fruit is peeled satisfactorily or not. In many plants, the lye is titrated frequently with standard sulfuric acid or hydrochloric acid, using a 1% solution of phenolphthalein in 95% alcohol as indicator. A 50% solution of the lye (NaOH) is stored in a large metal tank from which it is pumped as needed.

Lye-treated peach halves are passed through a warm-atmosphere holding section for 30–60 sec to allow the lye to react with the peach skin; next the lye and skin are washed off with high-pressure sprays of cold water. Little difference is found in the flavor and composition of canned peaches peeled by the cup-down lye-peeling and the steam-peeling methods. (See Chapter 3 for additional discussion about peeling methods.)

Freestone peaches harvested at 5.9–7.7 kg (M2 maturity) pressure test ripen successfully at 20°C and 80% RH within 6–8 days; those harvested at 2.7–5.5 kg (M3) need 4 days for ripening.

With all pitters and peelers, large peaches have subsequently lower losses than smaller fruit. For example, in one study the average loss with the rotary knife pitter was 11.64% for smaller peaches (6.03–6.35 cm) and 9.90% for larger ones (7.30–7.62 cm). Likewise, loss with the torque pitter was 8.6% for smaller fruits and 7.76% for larger ones; loss with the cup-down lye peeler was 5.89% for smaller peaches and 5.15% for larger ones; and that with the immersion peeler was 13.48% for peaches of 6.35–6.99 cm, and 9.45% for peaches of 7.30–7.62 cm.

The amount of lye required to peel 1 ton of peaches may vary from 2.7 to 4.1 kg.

Dry-Caustic Peeling. Many canneries once located on the outskirts of cities are now surrounded by city growth. These plants usually have to dispose of their effluents through municipal sewage treatment plants, paying a charge for the volume of effluent and the biological oxygen demand (BOD). In many cases plants have to install systems to continually correct the pH of their effluent to avoid damaging sewage equipment or upsetting operation of sewage disposal systems. In addition, disposal of salt or caustic solution into the sewage contributes to water pollution problems.

Hart *et al.* (1970) developed a dry-caustic peeler for continuous removal of alkaline peach peel as a solid rather than the dilute slurry of common industrial practice. In this system, the peaches are first washed, halved, and pitted. The peach halves are placed face down on a stainless steel mesh belt and 3% boiling lye solution is poured over them for a specified time between 5 and 10 sec. After a short draining period, the peach halves are placed in a disk peeler. The peeler consists of rows of soft rubber disks rotated in such a manner that peel material is gently wiped from the surface of fruit and flung into collectors as a wet solid. Any remaining residue consists of peel material already wiped loose from the surface but not flung off by the disks, and is easily removed by a brief water rinse. Cling peaches have been successfully peeled by this method with peeling losses comparable to those normally obtained commercially by the cup-down hot lye spray method. A scrubber for peel removed from soft fruit is shown in Fig. 6.7. It is likely that this method will be applied more widely to minimize the water pollution problem facing the canning industry.

Steam Peeling. Freestone peaches, especially when thoroughly ripe, can be peeled with live steam at 100°C for 1–2 min and then chilled with sprays of cold water. The peels can then be slipped off the fruit easily with the fingers. For commercial operation, the lye-peeling method is more economical.

Washing. It is necessary to use water sprays to wash off the residue skins and excess lye, and to cool the fruit. The spray water should have sufficient pressure to remove lye-softened tissue from the outer surface. When peaches are delayed in heat processing after lye peeling, the enzyme polyphenoloxidase catalyzes the oxidation of natural phenolic compounds to form quinones, which subsequently polymerize to form brown pigments. The browning problem may be controlled by thorough washing of the peeled peach halves with a water spray, followed by a bath containing 1% citric or malic acids to inhibit polyphenoloxidase activity. The acidity of the bath should be carefully controlled so that the pH of the peach surface will always be below 4.0.

The phenolic compounds in cling peaches have been identified as chlorogenic acids, leucoanthocyanidins, catechin, epicatechin, isoflavone, *p*-coumaryl-quinic acids, and caffeic acid (Luh *et al.* 1967). Among these, chlorogenic acids, leucoanthocyanidins, and catechin are thought to be involved in enzymic browning.

The principal polyphenols separated from extracts of mature 'Elberta peaches' are, in order of prominence on paper chromatograms, leucoanthocyanins, chlorogenic acids, catechin, and flavonols. After enzymatic oxidation of blended peach tissue by endogenous phenolase, a major portion of the total phenols and leucoanthocyanins are no longer detachable, and presumably have been enzymatically oxidized.

Sorting and Grading. Peeled and washed peaches pass from the lye peeler on a slowly moving belt from which sorters remove blemished, broken, and partly peeled pieces. The prime fruit travels to a size-grading

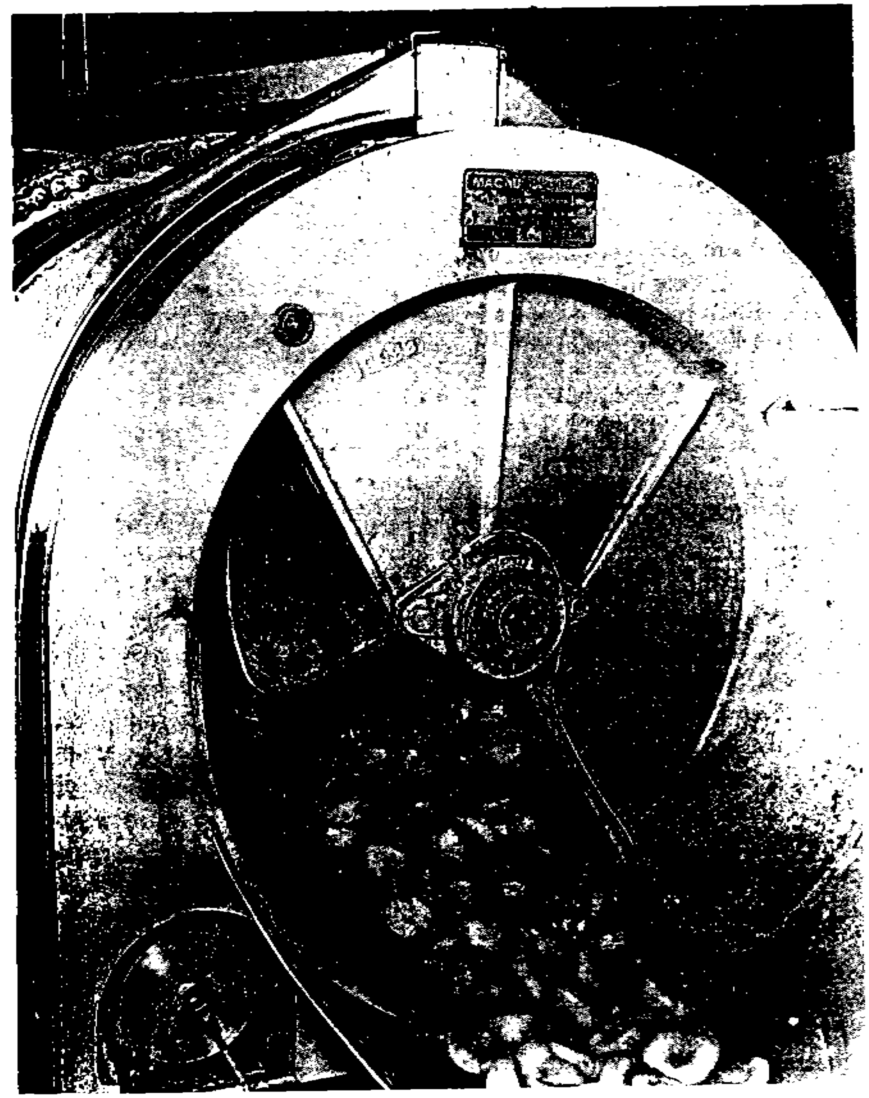

FIG. 6.7. Magnuscrubber unit for removal of peels from peaches after lye treatment. Peaches emerge from discharge and with sharp corners intact. (Courtesy Magnuson Engineering Corp.)

machine, and the Pie Grade fruit is sent by separate conveyor to the pie-fruit department without size grading.

Peach halves are graded into five sizes in size graders. The smallest peach halves usually go to the Pie Grade line and the largest to the slicers.

The most nearly perfect fruit of large size is Fancy Grade; next are Choice, Standard, and Second, in that order. Fruit below Second in quality is canned as Pie Grade. The Pie Grade comprises blemished fruit, trimmed, overripe fruit, and green fruit. Second and Pie Grades are not graded for size.

Slicing. Sliced peaches are usually of Choice and Standard grades. Considerable Pie Grade peaches are also sliced in order to make them more uniform in appearance.

A peach-slicing machine consists of several circular revolving knives against which the halved, peeled peaches are carried by a rubber belt. A vibrating device automatically places the halves cup-side down before slicing.

Filling and Weighing. After size grading, sorting, and inspection, the halved or sliced peaches are conveyed to canning stations. The empty cans are carried to the canning stations by gravity conveyors. The cans are filled by semiautomatic hand-pack fillers, which greatly reduce the labor cost. The filler consists of a circular revolving stainless steel table or traveling stainless steel belt, in both of which are circular holes of the diameter of the cans to be filled. Workers scoop the fruit into the cans through the holes in the table or belt. The filled cans are delivered to a conveyor that carries them to the syruping machine. Most of the cling peaches are processed in No. 2½, 2, 303, and 1 Tall cans, with the exception of the Pie Grade, which is canned in No. 10 cans for use by bakeries, hotels, and other similar establishments. A limited quantity of the higher grades is also canned in No. 10 cans for the hotel trade. Sliced peaches are frequently canned in 303, No. 1 Tall, and 8-oz cans.

The weight of peaches placed in a No. 2½ can may vary from 511 to 596 g. Government regulations require that a No. 2½ can of peaches contain at least 524 g oz of drained fruit. Immediately after canning, the drained weight falls below the fill weight because peach fluid is lost to the cover syrup. Drained weight increases rapidly during the first week after canning and then slowly until a maximum is reached in 90 days as a result of penetration of syrup into the fruit.

Great care must be employed in filling the cans in order that they contain the required amount of fruit. Some factories fill the cans according to the number of pieces per can rather than by weight. If a semiautomatic filling machine is used, filling is by volume rather than by weight.

Syruping. Cans are automatically filled with syrup by a vacuum syruping machine. The peaches may receive a syrup of 40°, 25°, 10° Balling or water. Some canneries use syrups richer in sugar than these, but seldom use syrups more dilute. Peaches low in sugar should be given syrups of

higher Brix degree than recommended by the Canners' League Standards. Fancy peaches should test at least 26° Brix on a cut-out test, Choice at least 21°, Standard at least 17°, and Second at least 11° Brix. The Standard of Identity for canned peaches specifies the Brix readings of the cut-out syrup that correspond to label names such as "heavy syrup" or "light syrup." Most of the canned Choice grade peaches have a cut-out Brix reading of 21°–22°. According to surveys, consumers prefer both the flavor and texture of canned clingstone peaches having a cut-out Brix of 22°–23°.

Sucrose sugar is bought in the form of a syrup of 67° Brix (liquid sugar), and corn sugar is delivered in a similar manner. Often a blend of the two—containing not more than 25% of corn syrup solids—is used in canning. High-fructose corn syrup is a new sweetner used in fruit canning.

Exhausting. Filled cans may be conveyed from the syrupers through a steam-filled exhaust box for 5–6 min at 93°–96°C. The exhaust box has been replaced to a large extent by prevacuumizing the can contents and sealing the cans in steam-flow double seamer which can save syrup loss, floor space, and steam. Cans sealed cold require about 5 min more processing than do cans exhausted in steam before sealing.

Marking and Sealing Cans. Coding of the cans is used to designate cultivar, grade, and date and hour of packing. Coding consists in embossing on each lid the letters and numbers of the code by means of metal dies as the lids pass to the double seamer. One may also allow the cans to roll through a device that marks the cans with the number of bands corresponding to the grade, the bands being in indelible ink. The label covers the bands completely, so that they are not visible to the purchaser.

From the vacuum syruper, the filled and syruped cans go to the double-seaming machine, which automatically places lids on the cans and seals them. Modern seaming machines can seal 275 cans or more per minute.

Double seaming is very important to the keeping quality of canned peaches. Can samples taken from the line after double seaming are cut and critically examined by experienced operators every 30–60 min so that faulty seaming can be detected.

If cans have been exhausted in steam, they are sent directly to the double-seaming machine, which automatically places lids on the cans to draw air out of the fruit and syrup. If they have not been heated in an exhaust box, the double seamer must be equipped for sealing the cans under a jet of steam, or a vacuum-sealing machine can be used in place of steam-flow.

Sterilization and Cooling. Heat sterilization of canned peaches should be thorough enough to cook the fruit sufficiently, but not to overcook it. The required processing time depends on the maturity and cultivar of the fruit. The usual time is 20–25 min at 100°C for No. 2½ cans in still cookers, and 14–20 min in rotary agitating cookers. The main factor is the initial temperature obtained just prior to processing, which depends on whether the cans are exhausted prior to double seaming or sealed with steam injection at room temperature. Cans sealed at room temperature with steam injection require a 5-min longer processing than those sealed at 71°C or higher. Other factors to be considered are the time and temperature of the exhaust, reel speed, can size, and the maturity and cultivar of peaches. A minimum can center temperature of 90.6°C prior to water cooling after processing is generally satisfactory for achieving commercial sterility.

Steriflamme heat processing of canned cling peach halves and fruit cocktail is a new method of thermal processing in which butane or natural gas flames at temperatures ranging from 1370° to 1650°C are utilized to sterilize canned fruits with rapid spinning of the container. The high-temperature short-time treatments provide good retention of the color, flavor, texture, and sensory appeal of the canned products. By steam blanching and virtually eliminating the covering liquid, and by implementing flame deaeration in place of steam heating, one can achieve a pack with high vacuum, retaining all the advantages of high-temperature, short-time flame sterilization.

Solid-pack pie fruit is largely trimmed, overripe, and low-quality peach slices or quarters. These are carried through a long steam box on a wire mesh belt, heated with steam at 100°C for 10–12 min, filled into No. 10 cans at 93°C with as little free liquid as possible, sealed hot, and heat-processed at 100°C in a rotary agitating cooker for 35–45 min or for 40–50 min in a nonagitating cooker at 100°C. In order to obtain the desired texture, solid-pack pie fruits are sometimes filled at 93.3°C, sealed hot, and cooled in air.

After sterilization canned peaches should be cooled in water to 38°C, at which temperature drying will take place satisfactorily and can rusting will not occur. Cooling is done in a rotary water spray cooler similar to a continuous sterilizer. The cooling water should be chlorinated with 2 ppm of available chlorine to preclude infection of the can contents by spoilage microorganisms.

Labeling, Packing, and Postcanning Storage. Canned peaches can be stored on a warehouse floor in stacks approximately 4–7 m high, with laths between each two tiers of cans to bind them, or on pallets. Cans may be labeled and packed into cardboard cases when needed, labeled and cased immediately after cooling and drying, or cased unlabeled for storage in the warehouse.

Canned peaches are labeled by portable automatic machines, except for those in lithographed cans. Cans may be delivered by conveyor directly from the can cooler after rolling and drying, then passed by gravity through the labeling machine. They pass first over small rollers that apply label paste, which may be rosin, glue, mucilage, casein preparation, or some chemical adhesive. They next roll across a stack of labels, one of which is picked up by the label paste on the can and is smoothed in place automatically by the machine. The adhesive is applied automatically to the end of the label, and the label end is sealed to the can. Labeled cans are packed by automatic casers into cardboard cases, 24 No. 2½, 48 small size, or 6 No. 10 cans/case.

The warehouse should be kept at 20°C with good ventilation. The cans must be protected against condensation of moisture caused by fluctuations of temperature and humidity. In cold climates, it is desirable to heat the warehouse in order to prevent freezing of the cans and condensation of moisture upon them with resulting rusting.

Postcanning storage conditions greatly affect the extent of brown discoloration of canned peaches. In one study, samples stored at 20°C for 4 months showed no brown discoloration, whereas those stored at 36.7°C showed 4% brown peach halves. A progressive increase in the percentage of brown peach halves was observed as the storage time lengthened. At 43.3°C, there was an abrupt increase to 26% brown peach halves during the 4-month storage period. Corrosion of the internal lining of canned peaches was related to the storage temperature. Higher storage temperature results in accelerated dissolution of the tin lining.

Steril-Vac Canning. The Steril-Vac flame sterilization process is a vacuum packing and sterilizing procedure. In the hot-fill process, sliced peaches are blanched to remove air from the fruit tissue. The blanching process permits higher fill weights and better control of the final headspace. After adding 426 g of blanched peach slices and 28 gm of 70° Brix syrup to each No. 1 can, the lids are clinched onto the cans. Clinching corresponds approximately to a loose first operation roll in the closing machine. The clinched can is deaerated by rotating it over a direct flame; during deaeration the can is tilted and the flame applied at the bottom. The flame vaporizes some of the liquid packed with the product. The steam generated in the can causes air to be vented past the loosely clinched lid. When the air is displaced, as indicated by a continuous discharge of steam, the can is sealed. The sealed can is flame-sterilized. The residual steam in the can acts as the heat transfer medium during processing.

When the steam condenses during cooling, high vacuum levels (greater than 63.5 cm Hg) are achieved. The high vacuum results from the removal of air from the fruit tissues during blanching, and from removing the air from the can. By eliminating the covering liquid, which may constitute approximately one-third of the weight of the pack, the tree-ripened fruit flavor is retained, undiluted. Alternatively, sugar or 70° Brix syrup may be added in sufficient amounts to enhance the flavor. This process works equally well in both three-piece and two-piece cans.

The time of flame application from the start of deaeration to the end of the holding section is approximately 3 min for the hot-fill process and approximately 7 min for the cold-fill process. The product is blanched, raising the temperature to 88°C. During filling, the temperature drops to 77°C. In flame deaeration, the vaporized water raises the temperature to 100°C, which is maintained through a steam-flow closing machine. The rising, holding, and cooling sections resemble conventional flame sterilization sequences in which the temperature is raised to 104°C for peaches.

The Steril-Vac flame sterilization process has the advantage of heating cans to sterilizing temperatures in a shorter time than the conventional process. Results indicate that the Steril-Vac process retains the quality of peaches better than the conventional continuous retort process. The process also is superior to the conventional one by eliminating the cover syrup, thus allowing more fruit in the container. A preliminary energy utilization study indicates that the elimination of covering liquid combined with hot-fill flame sterilization of peaches leads to a reduction in energy consumption of approximately 30% on an energy per mass of fruit basis compared with conventional packing in liquid media and steam retorting (Carroad *et al.* 1980).

Cut-Out Data and Case Yield. The quality factors for canned peaches are vacuum, headspace, drained weight, color, uniformity of size, absence of defects, character (texture), and flavor.

The case yield of canned peaches may vary from plant to plant, and with the season. On the average, the yield should be around 45–50 standard cases per ton.

Consumer Acceptance. Large-scale surveys of consumer response to the sweetness and acidity of canned clingstone peaches in Australia indicated that canned peaches with soluble solids to titratable acid (SS/TA) ratios of 54 and 40 and titratable acidities of about 0.35% were liked significantly better than sweeter products with SS/TA ratios of 73 and 80 and titratable acidities of about 0.26%. The optimum SS/TA value for canned peaches for the Australian market appears to be well below 70.

In another survey, samples of canned cling peaches prepared from these differently colored cultivars were viewed by 2808 individuals at the 1965 and 1966 Royal Agricultural shows in Melbourne. The medium-orange fruit was liked significantly better than the deep-orange and pale-yellow fruit.

Tests of consumer acceptance of canned freestone peaches varying in sucrose content from 18.46° to 31.40° cut-out Brix indicated that the optimum sweetness in all-sucrose packs was approximately 22.5° Brix.

Prepared Peach Baby Food

Clingstone peaches are more attractive for making prepared peach baby food, mainly because of the bright yellow color of the puree compared with that from freestone peaches. In genral, clingstone peaches store better than freestones and the flesh is nonmelting and thicker in consistency. In the southwestern United States emphasis has been placed on the 'Baby Gold' and 'Amber Gem' cultivars. They are used in blends with freestone cultivars such as 'Sullivan', 'Elberta', and 'Southland'. In California, many clingstone cultivars are used for preparation of baby foods.

On arrival at processing plants, peaches are weighed; tagged according to grower, cultivar, and arrival time; and placed in cold storage at 1°C. Fruit can be kept under cold storage for 2–3 weeks. At the time of actual manufacture, 20-bu pallet boxes of peaches are moved by lift truck to bulk hoppers from which the peaches start their movement through the processing line. Care is taken to see what the recommended blend is maintained. All equipment surfaces that actually come in contact with peaches are made of stainless steel or rubber belting.

The peaches are washed, halved, and pitted in a torque pitter, cup-down lye-peeled, and washed several times to remove spray residues. They are inspected and trimmed on a continuous belt. Finally, the prepared peaches are conveyed through a screw steamer at 100°C where they are rapidly and fully cooked in the flowing steam, inactivating enzymes. The time needed for blanching and preheating may vary from 10 to 16 min, depending on the size, maturity, and variety of the fruit. The emerging peaches are passed through a pulper with a 1.524-mm (0.06-in.) screen, and then a finisher with a 1.016-mm (0.040-in.) screen for junior baby foods or 0.686-mm (0.027-in.) screen for ordinary strained baby foods. The speed of the pulper and finisher may be kept at 800–1000 rpm. The distance between the paddle and the screen should be carefully adjusted to get the best yield and quality.

The hot puree is pumped to batch tanks where sugar syrup is added to maintain a balance with acid content. The batch is then heated to the proper temperature, adjusted to correct volume and consistency with water or syrup, and pumped to a holding tank where continuous blending takes place and surge condition is maintained for flash heating. The product is sterilized by heating in a Votator-type scraped surface heat exchanger to 110°C and held at this temperature under pressure in the product line. The sterilized product is discharged into a vacuum deaerator where the occluded air is removed and the product temperature is reduced to 93.3°–96.1°C.

At the filler, prewashed jars of 135- or 213-g capacity, or 202 × 214 cans, are filled within very narrow limits to ensure adequate fill with minimum waste due to overfills. The hot filled jars pass to the capper where jar headspace is steam evacuated immediately before twist caps are applied. For baby foods in cans, double seaming is done with steam injection at 0.21 kg/cm^2. The hot packages are conveyed to a sterilizer-cooler, a combination heating and cooling unit. The jars are carried on a belt through a steamheated section for 5–6 min at 100°C, and then gradually cooled by water spray at 82°C for 3–7 min, then at 66° and 49°C for 20 min each. When jars exit from the unit, they are cooled to 38°C.

The cool jars or cans arrive by conveyor to the labeling operation where they are washed, dried, labeled, cased, and taken by lift truck to the warehouse for storage. All case identification must be clearly and neatly printed.

The final peach baby food has a soluble solids content of 21–22%, a pH of 3.9–4.1, acidity of 0.35–0.45% as citric acid, and a Bostwick consistometer reading of 7.0–8.5 cm.

Freestone Peach Nectar

Yellow freestone peaches are preferred for the manufacture of peach nectar because of their delicate flavor and thin consistency after heat processing. Ripe 'Elberta' freestone peaches are generally used for nectar processing. Ripe 'Elberta' freestone peaches are generally used for nectar manufacture. The 'J. H. Hale', 'South Haven', and 'Golden Jubilee' cultivars are also suitable. 'Champion' is a suitable white cultivar.

Peaches are thoroughly washed, halved, pitted, and passed over an inspection belt to remove damaged fruit and foreign material. Peeling is also required for most cultivars, especially if the fruit is not fully ripe. Peaches are halved and pitted in a Filper torque pitter. The halves are peeled in a cup-down peeler by spraying with 1% sodium hydroxide solution at 100°C for 15 sec. They are held in the holding section for 60 sec and then spray-washed with cold tap water. Fully ripe freestone peach halves can be peeled with steam at 100°C for 1–2 min. Immediately after scalding, the fruit should be cooled either with water sprays or by immersion in cold water. After cooling, the skins are rubbed off. This method is more time-consuming than the lye-peeling method.

The peeled peach halves should be heated in a steam-jacketed kettle or a continuous steam cooker to 82°C and run through a fruit disintegrator. The resulting puree is then run through a finisher with a 0.508- to 0.838-mm screen. A ton of fruit yields approximately 492 liters of puree. To each 378.5 liters of puree 240 liters of 30° Brix sucrose syrup should be

added. The syrup may be prepared from 3 parts sucrose and 1 part glucose.

It may be necessary to add a small quantity of citric acid to adjust the pH of the nectar to 3.7–3.9. It is advisable to pass the finished nectar through a vacuum deaerator prior to pasteurization. This procedure will eliminate the air that has been incorporated in the product during preparation. Excess air in the nectar will lead to deterioration of color and flavor.

The high-temperature short-time flash pasteurization process is the most convenient method of heat treatment for fruit nectars. If the pH of the product is below 4.5, the product may be flash-pasteurized for 30 sec at 110°C. Continuous flow, plate, or tubular heat exchangers are used for this purpose.

For peach nectars, cans made from differential electrolytic tinplate bodies and enameled ends are recommended. The empty cans should be protected from dampness and steam, and kept as clean as possible during storage.

Immediately after pasteurization, the nectar should be filled into the cans, closed at a temperature of 88°C, inverted, and given a holding period of approximately 3 min prior to cooling. If flash pasteurization methods are not available, the nectars can be filled hot, closed, and processed for 20–30 min at 100°C when packed in cans larger than No. 1 size. No. 1 cans and smaller ones should be processed at 100°C for 15–20 min. Some packers practice a method of filling at 88°C, closing, holding, and cooling, but this practice may not adequately ensure against spoilage caused by heat-resistant bacterial spores.

After holding or processing, the cans should be cooled immediately in water until the average temperature of the contents reaches 35°–41°C. The cooling water should contain 2 ppm available chlorine. If cooling is not thorough before the cans are cased, serious discoloration and a poor flavor may result.

Canned fruit nectars should be stored in a cool dry place. The warehouse must be dry at all times to prevent rusting of the cans, staining of the labels, and weakening of the fiber cases. Storage at 10°–16°C considerably increases the shelf life of canned nectars.

Peach Puree for Drinks. The steps in the preparation of the peach puree base, after washing and trimming of peaches, are as follows (Heaton *et al.* 1966):

1. Heat whole fruit in a continuous thermoscrew for 2 min at 93°C to aid in pulping, prevent oxidation, and stabilize cloud in puree. A jacket around the screw should maintain 1.41 kg/cm steam pressure.
2. Pulp by passing through a continuous rotary unit with 0.62-cm perforated screens to remove soft flesh from seed and unripe portions.

3. Finish the pulp by passing through a rotary unit with 0.838-mm or 0.610-mm perforated, stainless steel screen. This reduces pulp to liquid and removes fiber.
4. Accumulate in tank, add 0.14% ascorbic acid and mix, then feed uniformly to pasteurizer.
5. Pasteurize at 88°–93°C and cool quickly to 2°C.
6. Fill aseptically into sterile 208-liter (55-gal) drums or large cans for refrigerated storage. Filling hot in No. 10 or smaller size cans may also be used.
7. Close cans using vaccum and nitrogen, or vacuumize with steam jet.
8. Cool cans in canal or water spray.
9. Dry cans with warm air to remove water drops and avoid rusting or staining of labels.
10. Label containers, use code identification.
11. Store in cool dry place.

PEARS

The 'Bartlett' pear is the most commonly used cultivar for canning because of its uniform shape, fine texture, and excellent flavor. The 'Hardy' cultivar is sometimes used in canned fruit cocktail.

Harvest and Ripening

Pears for canning are usually harvested at full size while they are still hard and green, and are shipped in this condition direct to the cannery in bins for ripening. The bins should be stacked to insure good air circuilation. 'Bartlett' pears with average pressure test of 0.9–1.35 kg (2–3 lb) immediately before peeling are best suited for canning.

The use of ethylene gas is of no great benefit if ripening is satisfactory and uniform without the treatment. On the other hand, where several sortings are necessary because of nonuniform ripening, the use of ethylene is profitable and desirable. Ethylene not only hastens coloring and ripening of pears but also increases the rate of respiration as evidenced by carbon dioxide evolution.

Size Grading

'Bartlett pears' are graded for size mechanically in diverging cable or roller graders prior to peeling. They must have a diameter of 6.03 cm or larger for canning as halves. According to the Standards of the Canner's League of California, Fancy Grade canned pears must contain 8–10 pieces, Choice 10–12, and Standard 12–17 pieces per No. 2½ can.

Peeling and Coring

Peeling of 'Bartlett' pears is carried out either by mechanical peelers or lye peelers. A typical mechanical Atlas-Pacific pear peeler is shown in Fig. 6.8. This mechanical peeler is designed to achieve micro-thin peeling. As the machine is peeling, removing the stem, core, and seed cell, it is also being loaded for the next operation. The unit will handle up to 66 pears/min (six at a time) with one operator. The peeling heads are unique in that they peel from the inside out, thus lifting the majority of skin blemishes from the pear. Three sizes of quick change cups can handle practically all sizes of pears. The operator places the fruit stem end down into the self-centering cups. Removal of the stem end, coring, and peeling occur simultaneously. As the loading cups deliver and release the fruit, they return to their original positions for reloading and remain stationary while the fruit is being processed, thus allowing the operator ample time to reload.

In the FMC mechanical peeler, the pear is placed in a cuplike carrier or impaled on a forklike device by the operator. The fruit is then carried between safety-razor-like blades that remove the skin to a uniform depth. Other knives cut the pear in half and remove the core and stem. In the

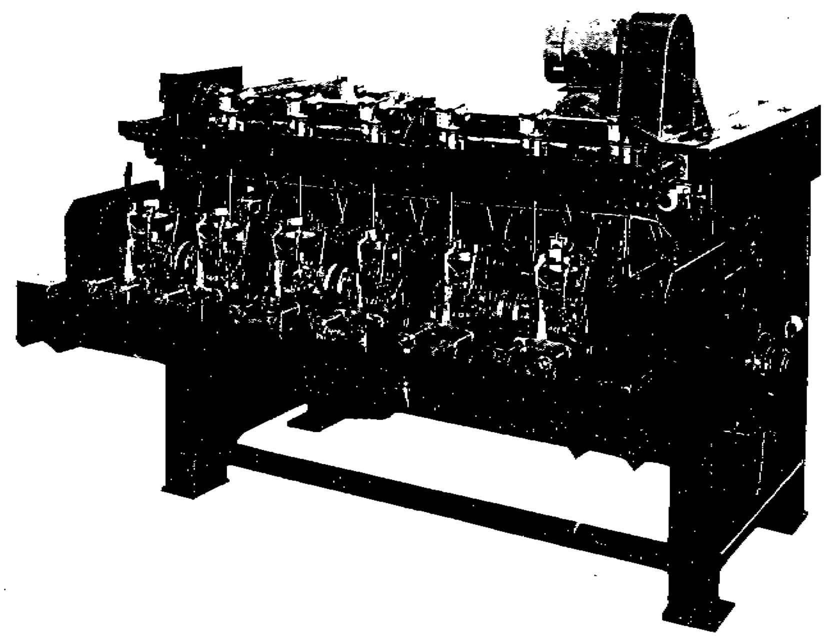

FIG. 6.8. Mechanical pear peeler. (Courtesy Atlas-Pacific Engineering Co.)

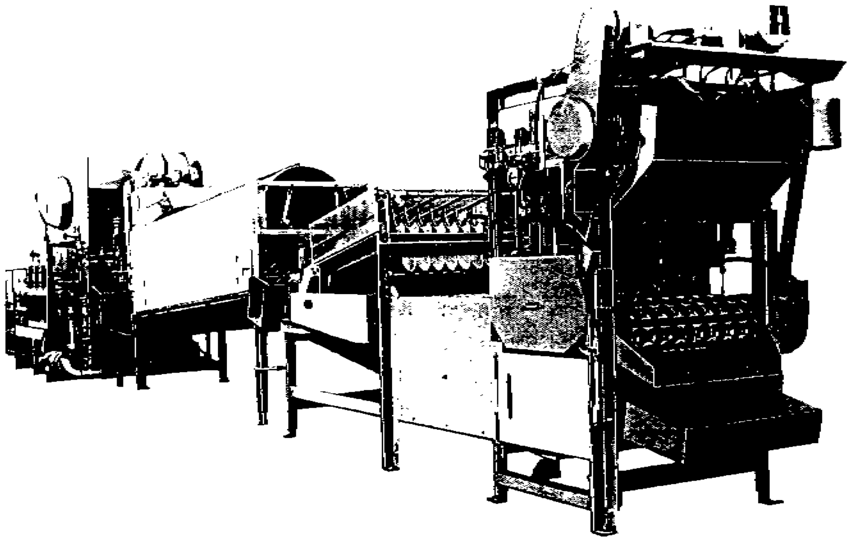

FIG. 6.9. FMC trushape pear preparation system. (Courtesy FMC Corp.)

Edwald peeler, the pear is held in a clamshell-like cup the size of the pear. Knives peel the pear in uniform size and shape. Hand trimming may be required to remove blemishes and bits of skin.

The FMC Corporation of San Jose, California, has developed the C8 TRUSHAPE pear preparation system (Fig. 6.9). The system is designed to peel, stem, core, and optionally slice pears in a high-speed, continuous operation. The system can be used interchangeably for canned cocktail and sliced pears. It reduces operating costs substantially by eliminating the need to presize the pears. Self-adjusting flights and coring knives used in this system handle practically all sizes of pears, at random, with maximum yields. Only two attendants are required to check fruit alignment, thereby saving most of the feed labor required with hand-fed knife peelers. Maximum yield is achieved by peeling with boiling hot lye, which eliminates the peeling away of the flesh.

'Kieffer' pears are first blanched in steam or boiling water for about ½ min, followed by cooling and hand peeling with a special guarded knife. The direction of peeling is from the stem toward the calyx end, not around the pear. Because of the tough skin of 'Kieffer' pears, it is more difficult of peel them with a mechanical peeler.

The loss during peeling, coring, and stemming of pears is usually 30–35% of the original weight. The type of peeler and size of the fruit can influence the case yield.

Pears start to undergo browning very soon after peeling, due to polyphenoloxidase enzyme activity, in the presence of air. Because riper pears are more susceptible to browning, they should be handled promptly or dipped in a 1–2% salt solution or a 1% citric acid solution to inhibit the polyphenoloxidase activity before going to the canning line.

The cores and peels from pears can be used in the preparation of vinegar, brandy, or alcohol. However, in most plants, the waste material is discarded or used as a stock feed for livestock after drying.

Sorting and Filling

After peeling, coring, and washing, pear halves are sorted on a belt and filled into cans in semiautomatic or hand-pack fillers. Defective or off-color halves are sorted to the cocktail line or the sliced pear line. High speed in sorting, filling, and canning is essential in order to avoid enzymic browning.

Syruping

Pears are lower in acidity than peaches and apples and therefore require syrups of lower Brix readings for canning. The syrup may be 40°, 30°, 20°, or 10° Brix or water. Ingoing syrups of higher than 40° Brix will impart too sweet a taste. In many operations 25° Brix sucrose syrups are used for canning. A prevacuumizing syruper is shown in Fig. 6.10. This machine uses less syrup than other types, provides a constant fill of syrup, and eliminates the exhausting process when used in conjunction with a steam-flow sealer. Syruping may also be done with a piston filler with the syrup added at 71°–82°C. With a special filling valve, the headspace can be accurately controlled. If either hot syrup at 88°C or deaerated syrup is filled with this valve, the cans are double-seamed with steam-flow closure, eliminating the exhausting process. By varying the sweetness and acidity of the canning syrup according to the characteristics of the raw fruit, a more acceptable flavor in canned 'Bartlett' pears can be obtained. An addition of small amounts of citric or malic acid has significantly improved the flavor of the canned pears; however, the fruit is rated somewhat softer than untreated pears.

Exhausting and Double Seaming

Cans of pears and syrup are exhausted by passing through a steam box until the temperature at the center of the cans is at 77°–82°C. The time of exhaustion may be 7 min for No. 303 or 2½ cans, and 9–12 min for No. 10 cans.

Following the exhausting period, cans are closed in a double seamer at

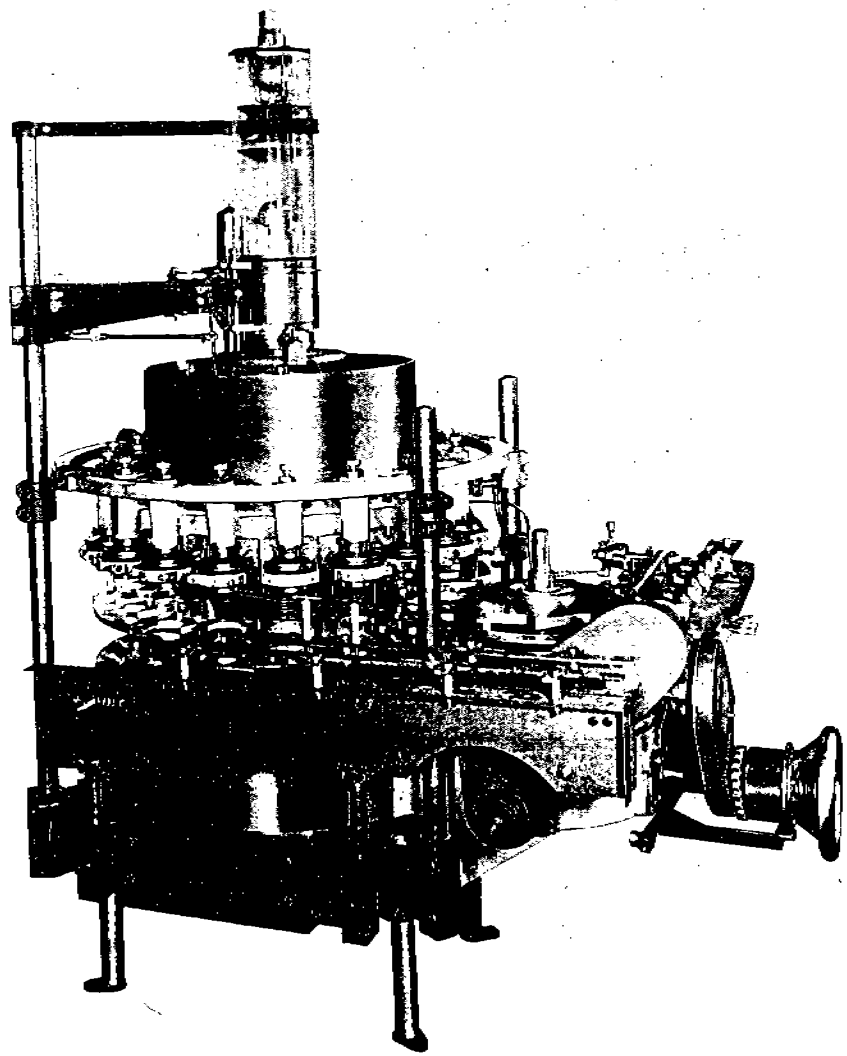

FIG. 6.10. FMC prevacuumizing syruper. (Courtesy FMC Corp.)

77°–82°C. If the minimum average closing temperature is below 71°C, then a steam-flow closure is needed to obtain a satisfactory vacuum. If a prevacuumizing syruper is used, cans must be sealed with a steam-flow closure or a mechanical vacuum seamer. The cans should have a head-space of 0.95 cm (3/8 in.).

Heat Sterilization

In an agitating cooker, 'Bartlett' pear halves are processed in No. 2½ cans for 17–20 min at 100°C or 14 min at 104.4°C. If non-agitating cookers are used, the processing time is 25 min at 100°C. The processing time for No. 10 cans is from 25 to 35 min at 100°C. Rapid cooling after heat sterilization is very important; otherwise, some of the canned products are liable to turn pink.

Pink Discoloration in Canned Pears

Pink discoloration in canned pears is due to growing the fruit on acid soil, excessive cooking; or delayed cooling.

The pink discoloration in 'Bartlett' pears results from conversion of colorless leucoanthocyanidins in pear tissue to a water-insoluble pink-colored leucocyanidin. The discoloration occurs in pears high in leucoanthocyanidin content, especially when excessive heating and delayed cooling are applied. The formation of pink pigment may be related to localization of leucoanthocyanins in certain parts of the fruit exposed to sunshine. A positive correlation exists between the intensity of skin blush on the fresh fruit and pink color formation in the canned product. The type of sweeteners used and acidification of the syrup with 0.2% citric acid also influences the extent of pink discoloration. In one study, pears sweetened with 27° Brix high-fructose corn syrup were distinctly pink when heat-processed at 110°C for 20 min in No. 2½ cans, whereas those in 27° Brix sucrose syrup processed under the same conditions did not turn pink. Addition of stannous ions to susceptible pear puree before processing partly or completely inhibits the discoloration.

Aseptic Canning of Pear Puree

Aseptic canning of pear puree involves a high-temperature short-time (HTST) sterilization process followed by cooling in a heat exchanger; sterilization of the containers and covers with steam; aseptic filling of the cold, sterile product into sterile containers; and sealing of the filled containers in an atmosphere of saturated or supersaturated steam. The four operations are done as a continuous process. The aseptically canned product is usually better in color and flavor acceptance and higher in vitamin content than products subjected to conventional heat sterilization. The aseptic canning process has been applied successfully on a commercial scale to fruit concentrates made from apricots, bananas, peaches, pears, and tomatoes.

The procedure for aseptic canning of pear puree with essence recovery is as follows: The pears are harvested at pressure tests of 7.3–8.6 kg on a

Magness-Taylor fruit tester (7.94-mm plunger). The fruits are stored at 1°C and then ripened at 20°C under 85% RH until an average pressure test of 1 kg is reached. The pears are washed, sorted, and fed into a Rietz thermoscrew at a rate of 9 kg/min. They are then heated rapidly to 100°C, disintegrated, and held at 100°C for 20 sec. The volatile compounds from the pears are condensed in three vertical condensers in series, held at 99°, 77°, and 11°C and trapped as aqueous essences.

The pear pulp is passed through a Langsenkamp paddle pulper with a 0.686-mm (0.027-in.) screen. The paddles are operated at 475 rpm. The puree is deaerated in a Dole centrifugal deaerator, and cooled in a creamery package heat exchanger to 21°C. The recovered essence is added to the puree at a rate of 5% (v/n) puree. The product is mixed, heated to 110°C in a creamery package heat exchanger, held there for 20 sec, cooled to 49°C in a second heat exchanger, and filled aseptically into containers. Filled containers are sealed aseptically in an atmosphere of saturated or supersaturated steam.

PINEAPPLES

Four cultivars account for virtually all pineapples grown for canning. 'Cayenne', the major canning cultivar, is grown exclusively in Hawaii, China, and the Philippines, and is increasing in popularity in other areas throughout the world. The 'Singapore' cultivar is grown in the Malaysian Peninsula; the 'Queen' in Australia and South Africa; and the 'Red Spanish' in the Caribbean. The chief sources of the world's canned pineapple and pineapple juice are Hawaii, the Philippines, China, Malaysia, South Africa, Australia, Thailand, Ryukyus, and the Ivory Coast.

In its first fruiting year, some 18–22 months following planting, a pineapple plant bears a single fruit on a central stalk or peduncle. Approximately 12 months later, one or more axillary suckers give rise to ratoon fruit, which are usually smaller than plant crop fruit. The pineapple is a composite fruit, that is, it is a collection of small fruits called fruitlets. As a result of evolutionary processes the individual fruitlets became fused, thus forming a composite fruit.

Quality Factors

Cultivar, nutrition, weather conditions, and ripeness are the more important factors affecting pineapple quality. Hawaii's warm days and cool nights are considered ideal growing conditions for pineapples and for the development of maximum fruit quality. Fruit size and weight are determined primarily by the adequacy of essential nutrients and mositure. In Hawaii 'Cayenne' pineapples reach peak fruit quality in June and July.

Every effort is made to provide adequate labor and canning capacity to maximize production during this period. During winter, the fruit tends to be paler, lower in Brix, higher in acid, and somewhat lacking in volatile flavor constituents.

Harvesting

Since the relative ripeness of the fruit is of primary importance in determining the ultimate quality of all products derived from pineapple, harvest control is a vital factor in the total production process. In general, pineapples do not improve after harvest. If harvested prior to prime ripeness, they remain inferior with respect to quality. Also, overripe fruit should be downgraded or rejected because of the deterioration of physical and chemical properties and, accordingly, of taste and appearance.

Processing

Harvested pineapples are unloaded from bulk bins at the cannery and mechanically graded for size. Each size goes to a Ginaca machine that has been adjusted for the proper fruit size. This machine is entirely automatic and removes the inedible portion of the fruit from the edible parts. It cuts a cylinder from the center portion of each fruit, removes the shell, and cuts off about 1.27 cm of shell portion at the bottom of the cylinder and approximately 1.91 cm at the top of the cylinder. The final operation of the Ginaca machine removes the core from the center of the fruit. The Ginaca machine handles some 90 pineapples/min. One part of the machine—called an "eradicator"—scrapes the edible flesh from the shell as completely as possible for use in crushed pineapple or for juice. Semiautomatic shelling or coring machines are used in pinapple canning plants in the Oriental countries. These machines can remove the shell and core from pineapples but at a slower rate of production than that of the Ginaca machine.

Pineapple cylinders from the Ginaca machine are conveyed to trimming tables where each cylinder is hand-trimmed to remove the last traces of shells and blemishes. The trimmed cylinders pass through a spray washer on their way to the slicing machine. This machine slices the cylinders transversely into rings about 1.27 cm (½ in.) thick for No. 2½ cans and 1 cm (25/64 in.) thick for No. 2 cans. Pineapple slices are visually graded and manually packed in cans. Slices that have been cut either too thick or too thin, and broken pieces not good enough for canning as slices, are used in crushed pineapple or juice.

Filled cans enter a chamber under vacuum (64 cm Hg) for 5–10 sec where air is removed from the fruit tissue, changing the appearance of the fruit from chalky white to semitranslucency. The cans are syruped in a conventional syruper, sealed under vacuum (38 cm Hg), and processed in a continuous pressure cooker at 102°–104°C until the center temperature of the can reaches 91°C. The process usually takes about 7–10 min for No. 2½ cans. The cans are then cooled, trayed, and stored until required for labeling.

Color

Carotenoids play an important part in the color of canned pineapple, and much of the carotenoids are lost during exhausting and processing. This color loss is due to the isomerization of highly colored 5,6-epoxides to the less intensely colored 5,8-furanoside form, rather than the actual destruction of the carotenoids. The isomerization takes place in an acid medium. Bruising of fruit during postharvest handling also will lead to pigment isomerization in the damaged areas. The isomerization causes a characteristic hypsochromic shift in the absorption maxima of the carotenoid pigment. The sharp absorption peak at 466 mlc is lost as isomerization progresses. Thus the ratio of absorbances at 466 and 425 μm can serve as a measure of the extent of isomerization of the pigment.

Standard of Identity

Canned pineapple, according to the U.S. Federal Food, Drug and Cosmetic Act is the food prepared from peeled, cored mature fruit of the pineapple plant. It can be sold as slices, half slices, broken slices, tidbits, chunks, diced cubes, spears, or crushed. It can be packed in either water, pineapple juice, clarified juice, light syrup (14°–18° Brix), heavy syrup (18°–22° Brix), or extra heavy syrup (23°–35° Brix). The syrup density measurements are those determined 15 or more days after the pineapple is canned. Optional ingredients include spices, vinegar, and flavoring other than artificial. Depending on the form of the canned pineapple no more than 5–15% defects (off-size, -shapes, etc.) based on drained weight are allowed. In all forms of canned pineapple, not more than 7% of core can be present in the drained fruit, and not more than 1.35 g of citric acid can be present in 100 ml of liquid drained from the product 15 days or more after canning.

Crushed Pineapple

To make crushed pineapple, shredded pineapple is pumped into steam-jacketed kettles and heated to 91°C. Some of the juice is drained away to give a product of optimum consistency. If it is to be sweetened, sufficient heavy sucrose syrup is added to give the desired sugar content. The hot mix is packed into cans automatically, sealed, given a short heat processing to ensure keeping quality, and cooled.

By-Products

Shells, trimmings, and other by-product material from the canning of pineapples are shredded and pressed in a continuous press to recover as much juice as possible. The juice is refined and is used in canning the pineapple after mixing with cane sugar syrup. The press cake is dried in rotary drum driers, and the dried product used for feeding livestock. Citric acid is recovered from the juice.

PLUMS

The plum is one of the important fruits canned in Great Britain. The principal canning cultivars are 'Pershore' (Golden), 'Purple Pershore', 'Victoria', and 'Early Laxton'. It was a favorite canned fruit at one time in California, but has been supplanted to a certain extent by canned apricots, cherries, peaches, and pears.

The large sweet cultivars of white plums, such as the 'Green Gage' and 'Yellow Egg', are preferable to the dark-colored 'Lombard' cultivar for canning. In Russia, Crimean plums and cherry plums are used in canning as juices, preserves, jams, and purées.

Plums are washed and stemmed simultaneously in a Herbort Strigger and washer. The machine has rubber-covered rollers running in opposite directions to grab and remove the stems. From this machine the plums pass over a sorting belt and then into a size grader with vibrating screens having circular openings of 2.54, 3.17, 3.81, and 4.45 cm (1, 1¼, 1½, and 1¾ in.) in diameter. A final inspection on the belt is made after size grading to remove imperfect fruits. Light-colored plums are then filled into plain tin cans made of Type L plate or glass jars. For dark-colored plums rich in anthocyanin pigments, lacquered cans may be advisable. The filling operation can be done either in a hand-pack filler or an automatic filling machine.

Since plums tend to soften badly during the heat sterilization process, it is important to pay attention to the filling and exhausting operations. Either hot syrup or water at 88°–93°C is added, depending on whether the plums are to be sweetened or unsweetened. The concentration of syrup for different grades of canned plums is as follows: Fancy, 55° Brix; Choice, 40°; Standard, 25°; Second, 10°; and Water or Pie, none. It is preferable to exhaust the cans thoroughly at 88°–93°C for 8–10 min to reach a can center temperature of not less than 82°C. The cans should be sealed with a headspace of 8 mm (5/16 in.), and the sealing temperature should be 82°C or higher. The average processing time for No. 2 cans is 12–15 min at 100°C and 28–35 min for No. 10 cans. For plums packed in water, the processing time is 10 min in boiling water for No. 2 cans and 25 min for No. 10 cans. The heat-processed cans are then cooled in a rotary cooler with water spray to 38°C.

PRUNES

'Italian' cultivars of prunes are canned in Oregon in the fresh state, sometimes labeled as purple plums. Prunes are a less important crop than peaches and pears.

Well-colored and properly ripened prunes are washed, sorted to remove imperfect ones, size-graded in a roller-type grader, and packed with 40° Brix syrup in enameled cans. The container should be made of Type L plate. The exhausting and processing procedures are the same as those described for canned plums.

French prunes are grown in California largely for dehydration. For canning fresh, they should be harvested firm-ripe. The fruits are washed, sorted, lye-peeled with 10% boiling hot sodium hydroxide for 1–2 min, washed thoroughly, sorted again, and then canned in plain Type L plate cans or glass jars with 30° Brix syrup. The cans are exhausted at 93°C for 4–6 min, sealed hot, heat-processed at 100°C in a rotary cooker for 20 min, and cooled in a rotary water cooler.

Canned Dried Prunes

Large (110–132 counts/kg; 50–60 count/lb) unprocessed dried prunes of the French cultivar 'Prune d'Agen' are used for canning. The dried fruits contain about 18% moisture before canning. They are sorted on a belt to remove defective ones, washed, blanched in boiling water for 4–5 min, rinsed, and packed in Type L cans or cans or similar plate. The "going-in" weights of the processed prunes are 397 g per No. 2½ can and 1.36 kg per No. 10 can. Allowance must be made for the dried prunes to take up a part of the syrup during processing and storage. The syrup for canning is usually 20° Brix. Cans are exhausted at 93°C for 12–15 min. The headspace should be 0.79 cm (5/16 in.). Cans are sealed at 88°C or higher, and processed 20 min at 100°C for No. 2½ cans and 35 min for No. 10 cans. Steam-flow closure is advisable to obtain a higher vacuum. The canned products are cooled in a rotary water cooler to 38°C.

The shelf life of canned, dried prunes is greatly prolonged if the syrup used in canning is acidified with 0.40% citric acid or an equivalent amount of concentrated lemon juice. It is important that the syrup used for canning be 20° Brix. If a syrup of higher Brix reading is used, the canned prunes will be shriveled.

"Dry-Pack" Prunes

To prepare "dry-pack" prunes, dry prunes of a French cultivar are heated in boiling water for 4–5 min, drained, and packed scalding hot in enameled cans. The lids are placed on the cans and given the first rolling operation. The cans are then exhausted 20 min in live steam, sealed, and allowed to cool in the air. The product is cooked later in water before serving.

A high-moisture prune that may be eaten satisfactorily without further treatment has been developed. The dried prunes are graded for size and are then cooked in boiling water until the flesh attains about 33% moisture. The scalding-hot prunes are packed into double-enameled Type L plate cans rather loosely in order to minimize hydrogen swelling. The cans are exhausted at 93°–96°C for 5–6 min, sealed, and processed at 100°C for about 30 min for 8 oz and No. 1 cans. No. 2 and No. 2½ cans should be processed 40–45 min and then cooled thoroughly. Such canned prunes are used as a between-meal snack.

Fresh Prune Juice

The fruits are sorted to remove unfit material, washed, and drained. They are steamed 8–10 min to soften the prunes and prevent browning by the fruit's enzymes. Then the heated fruit is passed through a pulper equipped with a very coarse screen to remove pits and obtain a coarse purée containing the skins. Next, the purée is cooled to below 49°C in a heat exchanger; 0.2% of Pectinol 0 or other pectic enzyme preparation of similar activity is added and mixed thoroughly. It is left to stand until juice can be obtained readily when tested by draining a sample on cheesecloth, normally about 6–12 hr. Then 2% of diatomaceous earth such as Hyflo Super Cel is added to aid in pressing. The purée is placed on light canvas or heavy white muslin which lies on heavy press cloth. This gives double press cloths and a cleaner juice.

The juice is filtered and its Brix adjusted to 22.5°–23°. Then it is flash-pasteurizied in a continuous heat-interchanger type pasteurizer to about 88°C and filled into steamed bottles or into reenameled (double enameled) Type L berry cans at 82°–85°C and sealed. The containers are placed on their sides to sterilize the tops and then cooled.

Alternatively, bottles are filled with cold juice, crown capped, and pasteurized by placing the bottles in cold water on their sides, and heating the water to 82°C for 30 min for quart and smaller bottles. They are cooled slowly with tempered water.

Inactivation of pectolytic enzymes in prunes improves the viscosity and consistency of prune juice. The optimum conditions are 2.5 min at 85°C.

Under the Federal Food, Drug and Cosmetic Act, vitamin C in the amount of 30–60 mg/180 g may be added to canned prune juice (Anon. 1966).

REFERENCES

ANON. 1966. Prune juice; order amending standard of identity. Federal Register *31,* 5957–5958, Apr. 19.

ANON. 1968. Artificially sweetened cranberry juice cocktail—a juice drink; order establishing identity standard. Federal Register *33,* 5617–5618, Apr. 11.

ANON. 1970. Fruit situation. USDA Econ. Res. Serv. TFS 175, July.

ASTI, A. R. 1970. Apple juice containing pulp. U.S. Pat. 3,518,093. June 30. *In* Food Process. Rev., Vol. 21. M. Gutterson (Editor). Noyes Data Corp., Park Ridge, N.J.

BALLINGER, W. E. and KUSHMAN, L. J. 1970. Relation of stages of ripeness to composition and keeping quality of highbrush blueberries. J. Am. Soc. Hort. Sci. *95*(2), 239–242.

BAZAROVA, V. I. 1964. Change of some sugars in the process of ripening of bananas. Sb. Tr. Leningr. Sov. Torgovli No. 23, 71–80 (Russian); cf CA 64, No. 1, 1966, No. 1269 b.

BEAVERS, D. V. and PAYNE, C. H. 1969. Secondary bleaching of brined cherries with sodium chlorite. Food Technol. *23* 175–177.

BEDFORD, C. L. and ROBERTSON, W. F. 1955. The effect of various factors on the drained weight of canned red cherries. Food Technol. *7,* 231.

BREWSTER, L. C., HASEGAWA, S., and MAIER, V. P. 1976. Bitterness prevention in citrus fruits. Comparative activities and stabilities of the limonoate dehydrogenases from Pseudomonas and Arthrobacter. J. Agric. Food Chem. *24,* 21–24.

CANSFIELD, P. E. and FRANCIS, F. J. 1970. Quantitative methods for anthocyanins. 5. Separation of cranberry phenolics by electrophoresis and chromatography. J. Food Sci. *35,* 309–312.

CARROAD, P. A., LEONARD, S. J., HEIL, J. R., WOLCOTT, T. K., and MERSON, R. L. 1980. High vacuum flame sterilization: Process concept and energy use analysis. J. Food Sci. *45,* 696–699.

CASAS, A. and RODRIGO, M. I. 1981. Changes in the limonin monalactone content during development of Washington Navel oranges. J. Sci. Food Agric. *32* (3) 252–256.

CASIMIR, D. J. and JAYARAMAN, K. S. 1971. Banana drink. A new canned product. Food Preserv. Quart. *31* (1/2) 24–27.

CHUNG, J. I. and LUH, B. S. 1971. Effect of ripening temperature on chemical composition and color of canned freestone peaches. Confructa *16* (5/6) 275–280.

CHUNG, J. I. and LUH, B. S. 1972. Brown discoloration in canned peaches in relation to polyphenol-oxidase activity and anthocyanin. Confructa *17* (1) 8–15.

COFFELT, R. J. 1965. A continuous-crush press for the grape industry. The Serpentine Fruit Press. Calif. Agr. *19* (6), 8–9. U.S. Pat. 3,130,667, Apr. 28, 1964.

COFFIN, D. E. 1970. Tyramine content of raspberries and other fruit. J. Assoc. Offic. Anal. Chemists *53,* 1071–1073.

COONEN, N. H., and MASON, S. I. 1970. Recent advances in rigid metal containers. *In* Third Intern. Cong. SOS/70 Food Science and Technology. Institute of Food Technologists, Chicago.

CREVELING, R. K. and JENNINGS, W. G. 1970. Volatile components of Bartlett pear high boiling esters. J. Agric. Food Chem. **18,** 19–24.

CROTEAU, R. J. and FAGERSON, I. S. 1968. Major volatile components of the juice of American cranberry. J. Food Sci. **33,** 386–389.

CZERKASKYJ, A. 1970. Pink discoloration in canned Williams' Bon Chretien pears. J. Food Sci. **35,** 608–611.

CZERKASKYJ, A. 1971. Consumer response to sweetness and acidity in canned cling peaches. Food Technol. (Australia) *23* (12) 606–611.

DAVIS, W. B. 1947. Determination of flavanones in citrus fruits. Anal. Chem. *19,* 476–478.

DEKAZOS, E. D. and BIRTH, G. S. 1970. A maturity index for blueberries using light transmittance. J. Am. Soc. Hort. Sci. *95* (5) 610–614.

FAO. 1971. FAO Production Yearbook. U. N. Food and Agriculture Organization, Rome.

FERNANDEZ DIEZ, M. J. 1971. The olive. *In* The Biochemistry of Fruits and Their Products, Vol. 2. A. C. Hulme (Editor). Academic Press, London and New York.

HART, M. R., GRAHAM, R. P., HUXSOLL, C. C., and WILLIAMS, G. S. 1970. An experimental dry caustic peeler for cling peaches and other fruits. J. Food Sci. *35,* 839–841.

HARTMANN, H. T. and OPITZ, K. W. 1966. Olive production in California. Calif. Agric. Exp. Stn. Circ. 540.

HEATON, E. K., BOGGESS, T. S., JR., WOODROOF, J. G., and LI, K. C. 1966. Peach purée as a base for drinks. Peach Products Conf. Rept. Georgia Exp. Stn., Experiment, Ga.

ITO, K. A. and STEVENSON, K. E. 1983. Sterilization of packaging materials by aseptic systems. Abst. #415. *In* Proc. 43rd Annual Meeting, Packaging Developments Related to Advances in Food Processing, Institute of Food Technologists, New Orleans.

JACKSON, J. M. 1979. Canning procedures for fruits. *In* Fundamentals of Food Canning Technology. J. M. Jackson and B. M. Shinn (Editors). AVI Publishing Co., Westport, Conn.

JACKSON, J. M. and SHINN, B. M. 1979. Fundamentals of Food Canning Technology, AVI Publishing Co., Westport, Conn.

KRAMER, A. and TWIGG, B. A. 1970. Quality Control for the Food Industry. Vol. 1, Fundamentals. 3rd ed. AVI Publishing Co., Westport, Conn.

KRAMER, A. and TWIGG, B. A. 1973. Quality Control for the Food Industry. Vol. 2, Applications. 3rd ed. AVI PUblishing Co., Westport, Conn.

LAWRENCE, L. N., WILSON, D. C., and PEDERSON, C. S. 1959. The growth of yeasts in grape juice stored at low temperatures II. The types of yeast and their growth in pure culture. Appl. Microbiol. *7,* 7–11.

LI, K. C., BOGGESS, T. S., and HEATON, E. K. 1972. Relationship of sensory ratings with tannin components of canned peaches. J. Food Sci. *37,* 177–179.

LOPEZ, A. 1981. A Complete Course in Canning, Book I and II. 11th ed., Canning Trade, Inc. Baltimore, Md.

LUH, B. S. 1980. Tropical fruit beverages. *In* Fruit and Vegetable Juice Processing Technology, 3rd ed. P. E. Nelson and D. K. Tressler (Editors). AVI Publishing Co., Westport, Conn.

LUH, B. S. and DIRDJOKUSUMO, S. 1967. Processing apricot concentrate in laminate and aluminum-film combination pouches. Fruchtsaft-Ind. *12,* 210–219.

LUH, B. S. and PHITHAKPOL, B. 1972. Characteristics of polyphenoloxidase related to browning in cling peaches. J. Food Sci. *37,* 264–268.

LUH, B. S., HSU, E. T., and STACHOWICZ, K. 1967. Polyphenolic compounds in canned cling peaches. J. Food Sci. *32,* 251–258.

MAIER, V. P. and DREYER, D. L. 1965. Citrus bitter principles. IV. Occurrence of limonin in grapefruit juice. J. Food Sci. *30,* 874–875.

MAIER, V. P. and GRANT, E. R. 1970. Specific thin-layer chromatography assay of limonin, a citrus bitter principle. J. Agric. Food Chem. *18*, 250–252.

McCARTHY, A. I., PALMER, J. K., SHAW, C. P., and ANDERSON, E. E. 1963. Corrleation of gas chromatographic data with flavor profiles of fresh banana fruit. J. Food Sci. *28*, 379–384.

MOHAMMADZADEH-KHAYAT, A. A. and LUH, B. S. 1968. Calcium and oxalate ions' effect on the texture of canned apricots. J. Food Sci. *33*, 493–498.

MOYER, J. C. and AITKEN, H. C. 1980. Apple juice. *In* Fruit and Vegetable Juice Processing Technology, 3rd ed. P. E. Nelson and D. K. Tressler (Editors). AVI Publishing Co., Westport, Conn.

NAGY, S. and SHAW, P. E. 1980. Processing of grapefruit. *In* Fruit and Vegetable Juice Processing Technology, 3rd ed. P. E. Nelson and D. K. Tressler (Editors). AVI Publishing Co., Westport, Conn.

NELSON, P. E. and TRESSLER, D. K. (Editors). 1980. Fruit and Vegetable Juice Processing Technology. 3rd ed. AVI Publishing Co., Westport, Conn.

NORDBY, H. E. and NAGY, S. 1980. Processing of oranges and tangerines. *In* Fruit and Vegetable Processing Technology, 3rd ed. P. E. Nelson and D. K. Tressler (Editors). AVI Publishing Co., Westport, Conn.

O'BRIEN, M., CARGILL, B. F., and FRIELEY, R. B. 1963. Causes of fruit bruising on transport trucks. Hilgardia *35* (6) 113–124.

O'BRIEN M., CARGILL, B. F., and FRIDLEY, R. B. 1983. Principles and Practices for Harvesting and Handling Fruits and Nuts. AVI PUblishing Co., Inc. Westport, Conn.

PALMER, J. K. 1963. Banana polyphenoloxidase preparation and properties. Plant Physiol. *38*, 508–513.

PEDERSON, C. S. 1980. Grape juice. *In* Fruit and Vegetable Juice Processing Technology, 3rd ed. P. E. Nelson and D. K. Tressler (Editors). AVI Publishing Co., Westport, Conn.

SILVERSTEIN, R. M. 1971. The pineapple: Flavour. *In* The Biochemistry of Fruits and Their Products, Vol. 2. A. C. Hulme (Editor). Academic Press, London and New York.

SIOUD, F. B. and LUH, B. S. 1966. Polyphenolic compounds in pear purée. Food Technol. *20* (4) 182–186.

STARK, R., FORSYTH, F. R., HALL, I. V., and LOCKHART, C. L. 1971. Improvement of processing quality of cranberries by storage in nitrogen. Can. Inst. Technol. J. *4* (3) 104–106.

STRAND, L. L., OGAWA, J. M., BOSE, E., and RUMSEY, J. W. 1981. Bimodal heat stability curves of fungal pectolytic enzymes and their implication for softening of canned apricots. J. Food Sci. *46*, 498–500, 505.

TANG, C. S. and JENNINGS, W. G. 1968. Lactonic compounds of apricot. J. Agric. Food Chem. *16*, 252–254.

TRESSLER, D. K. and JOSLYN, M. A. 1971. Fruit and Vegetable Juice Processing Technology. 2nd Ed. AVI Publishing Co., Westport, Conn.

U.S. DEPT. OF AGRICULTURE. 1971. U.S. Standards for Grades of Canned Fruit Cocktail. Effective Aug 5, 1971; see Federal Register Sect. 52, 1054. Amended Aug. 5, 1971, Federal Register *36*, 14377.

VAUGHN, R. H., MARTIN, M. H., STEVENSON, K. E., JOHNSON, M. G., and CRAMPTOM, V. M. 1969C. Salt-free storage of olives and other produce for future processing. Food Technol. *23* (6) 124–126.

VAUGHN, R. H., MARTIN, M. H., STEVENSON, K. E., JOHNSON, M. G., and CRAMPTOM, V. M. 1953. Lactobacillus plantarum, the cause of "Yeast Spots" on olives. Appl. Microbiol. *1* (2) 82–85.

VELDHUIS, M. K. 1971A. Orange and tangerine juices. *In* Fruit and Vegetable Juice Processing Technology, 2nd ed. D. K. Tressler and M. A. Joslyn (Editors). AVI Publishing Co., Westport, Conn.

VELDHUIS, M. K. 1971B. Grapefruit juice. *In* Fruit and Vegetable Juice Processing Technology, 2nd ed. D. K. Tressler and M. A. Joslyn (Editors). AVI Publishing Co., Westport, Conn.

VON SYDOW, E. and KARLSSON, G. 1971. Aroma of black currants. V. Influence of heat measured by odor quality assessment techniques. Lebensm. Wiss. Technol. *4* (5) 152–157.

VYAS, K. K. and JOSHI, V. K. 1982. Canning of fruits in natural fruit juices I. Canning of peaches in apple juice. J. Food Sci. and Technology *19* (1) 39–40.

WYMAN, H. and PALMER, J. K. 1964. Organic acids in the ripening banana fruit. Plant Physiol. *39*, 630–633.