FRUIT JUICES

1. Introduction

The fruit juice industry was started in the United States in 1869. Concord grapes were juiced from their vines, and the juice was filtered, bottled, then pasteurized in a hot water bath (1). The European fruit juice industry began in 1896 with the publication of detailed instructions for commercial production of unfermented fruit juices. That same year, apple and grape juices were first produced commercially in Berne, Switzerland (2). In the United States, nationwide expansion of commercial juice production developed ~1929, when economic necessity forced American consumers into an unprecedented era of home canning, including fruit and vegetable juices. Consumers' acquired taste for these products led to the expansion of the commercial industry in the 1930s, mainly processing overripe products not suitable for whole fruit canning (3). During the 1930s, development of flash pasteurization and enamel-lined cans afforded superior juice quality and unprecedented growth for the industry.

During the 1940s, frozen single-strength fruit juices were introduced in the United States and frozen concentrated fruit juices were first sold in that market during 1945–1946. In the same decade, hot packed orange concentrate packed in small flat glass bottles was made available in the United Kingdom to supplement vitamin C intake for children and pregnant women.

Freezing technology had a dramatic effect on the industry and was responsible for most of the early growth of the Florida citrus industry as well as that of other producing countries, such as Brazil. Frozen concentrated fruit juices for reconstitution, and Frozen Concentrated Orange Juice (FCOJ) in particular, have become the principal juice products of international commerce. Consumers demanded more ready-to-serve juice products, especially chilled single-strength juices that are now known in the Industry as Not From Concentrate (NFC) juices. These have been developed in two principal forms. Freshly pressed juices that have had no further processing and have a very short shelf-life are now widely sold as are fresh juices that have been flash pasteurized to give them a chilled shelf-life of several weeks. Commercial aseptic packaging of direct (NFC) and reconstituted juices and juice drinks permits packaging in laminated packages that can be stored at ambient temperatures for convenience and economy for the consumer. Aseptic packaging is also used for more economical storage and transport at ambient temperatures of bulk single-strength and concentrated juices although the principal means of transporting and storing concentrated bulk juices remains freezing at around $-18^\circ C$ ($-0.4^\circ F$).

European Union (EU) legislation now regards "fruit juice" and "fruit juice from concentrate" as two distinct food categories. For example, orange juice that has been reconstituted from concentrate must be termed "orange juice from concentrate". "Orange juice" must only be used to describe a product that has not been subject to concentration (ie, NFC).

In 2006, the most important producing countries for the main juices of commercial interest (orange and apple concentrates) are Brazil and the United States for orange and Germany/Eastern Europe and, increasingly, China for apple. Main consumer markets are the United States and Europe with increasing consumption in Asia, especially Japan.

2. Raw Materials

The early juice industry was largely a salvage operation. The principal source of raw material was misshapen, poorly colored, or skin blemished fruit unsuitable for the fresh, canned, or frozen fruit market. For many years now, raw materials have been selected and bred especially for suitability for juice production. Apple juice production still uses some cull fruit (4).

Variety and maturity are important factors affecting suitability for juice production (5). For some juices, eg, citrus (5) or grape (6), only a few varieties have traditionally been used to provide a distinctive flavor or to ensure freedom from bitterness. Developments in processing technology now enable the use of a wider range of varieties as bitterness and other unwanted characteristics can be removed by processing. When a range of varieties is available, eg, apples, blends are used to achieve uniformity of flavor (4) or analytical characteristics. Blends are often perceived as having a better flavor or commercial advantage than a single varietal juice. Fruit grown in a warmer climate and having a high sugar content may be mixed with fruit from a cooler region or different variety to achieve a desired sugar–acid balance. This sugar–acid ratio is based on °Brix readings, ie, %w/w sugar, obtained with a refractometer, divided by the total acidity (%w/w) obtained by titration (7).

Juice factories frequently employ field persons to advise growers on the application of sprays to the growing crops so that residues on harvested fruit are within prescribed limits. They also may sample the crop before harvest for analysis, and coordinate harvesting with factory production schedules. Payment for raw materials is frequently based on specifications that are either official government grades or stated market standards. Official graders may be employed to test each load. In the twenty-first century, there is a small but rapidly growing demand for fruit (and juices) certified as organic. To assist in juice authentication an independent organization has been set up in Europe to inspect, validate, and register processing factories worldwide (8).

3. Composition

Typical composition of a number of fruit juices and juice drinks is given in Table 1 (9), although because of widespread problems of adulteration in the 1990s it is now recognized that composition varies widely from country to country, with fruit variety and season. Much work has now been carried out, mostly in Europe, to develop sophisticated methods for authenticating fruit juices (10). Such methods often involve measurements and comparisons of the stable isotopes of carbon, hydrogen and oxygen in juice carbohydrate or acidic components or other minor mineral components. Commercial data bases can now be used to authenticate the principal fruit juice types from almost anywhere in the world. Fruit juice standards, particularly relating to juices reconstituted from concentrates are now published by the German Industry (The RSK system) (11), AIJN (originally known as "The European Association of Fruit Juice and Nectar Producers" and currently as "The European Fruit Juice Association") (12) and Codex Alimentarius (13).

4. Fruit Juice Authenticity

Adulteration of major fruit juices, and particularly orange and apple, became a significant issue in the 1980s and 1990s because of relative commodity price differentials between juice solids and sucrose. Since sugars are a major constituent of many juices the substitution of juice solids by sucrose or other bulk sugars from a variety of different sources became an attractive proposition. The addition of excessive amounts of pulpwash to citrus juices also became commonplace despite being prohibited in some countries. The addition of malic acid to low acidity apple juice concentrates to produce the more valuable high acid juice was another form of juice adulteration and in the case of more expensive red fruit juices, adulteration took many forms including dilution with less expensive juices, as well as carbohydrate additions. In the United States there were prosecutions for selling adulterated orange juice, and in the United Kingdom a government investigation in 1990 found 16 of 21 major orange juice brands to be adulterated (10). A wide range of analytical techniques were developed to detect various forms of adulteration. In Germany, an existing mulitfactorial RSK system (11), which required a fruit juice to meet a number of analytical characteristics, was used but in other countries new methods were developed. For detection of carbohydrate addition, measurements of stable isotopes of carbon hydrogen and oxygen and comparison against a wide database have proved to be a powerful tool as has the detection of small amounts of oligosaccharides that are characteristic of the added carbohydrate. Other techniques that have proved valuable for specific applications include examination of the amino acid and anthocyanin profiles of juices, and detection of added malic acid to apple juice. Many countries now use an industry based voluntary screening of consumer products supported by producer factory inspection and an audit trail of product.The net result has been a major reduction in instances of adulteration although isolated occurrences still arise.

5. Manufacturing

Figure 1 describes many of the steps in the generalized production of fruit juices although equipment and processes are varied significantly for the type of fruit to be handled. The processing of citrus and soft fruit into juice is discussed separately. Citrus have a thick, relatively tough peel that must be kept separate from the juice during extraction and also processed to extract the essential oils. Soft fruit are generally crushed whole and the juice is then separated from the pulp, peel, seeds, and pits (stones).

5.1. Citrus Processing. In major producing countries, citrus fruit generally are transported from growing areas by truck for processing. The truck is unloaded by gravity feed to a conveyor belt that transfers the fruit to a storage bin. In the United States, an official government inspector checks an 18-kg sample of the fruit for minimum standards of °Brix and acidity before it is certified as meeting maturity requirements for processing. The fruit is washed, sometimes with a detergent, as it passes over roller brushes, then rinsed and dried. Washing removes debris and dirt, and reduces the number of microorganisms on the fruit thereby making subsequent juice pasteurization processes more effective. Graders remove unwholesome fruit as the fruit passes over roller conveyors and is segregated automatically into several sizes prior to juice extraction by one of several types of extractors (14). Use of computer controlled sizing and grading of each load of fruit, based on fruit color, size, shape, and weight, is increasing. There is potential for total electronic grading and thus total automated quality control.

In one extractor (FMC Inc.), the fruit is located between two cups having sharp-edged metal tubes at their base and metal fingers that intermesh. The upper cup descends and the many fingers on each cup mesh to express the juice as the tubes cut holes in the top and bottom of the fruit. On further compression, the rag, seeds, and juice sacs are compressed into the bottom tube between the two plugs of peel. A piston moves up inside the bottom tube forcing the juice through perforations in the tube wall. A simultaneous water spray washes the peel oil expressed during extraction away from the peel as an oil–water emulsion; the peel oil is recovered separately from the emulsion, usually by a centrifugal process. Each extractor unit has several cups of a single size and in a typical factory installation banks of extractors process different fruit sizes.

In another extractor [Automatic Machinery and Electronics Inc. (AMC)] the individual fruits are cut in half as they pass a stationary knife. The halves are oriented in a vertical plane, picked up by synthetic rubber cups, and positioned across plastic serrated reamers revolving in a synchronized carrier in a vertical plane. As the fruit halves progress around the extractor turntable, the rotating reamers exert increasing pressure and express the juice. The oil and pulp contents in the juice increase with greater reaming pressure. The recoverable oil is removed in a separate step prior to juice extraction. Needle-sharp spikes prick the peel of the whole fruit, releasing oil that is washed away with water and recovered from the oil–water emulsion. Most citrus juice extraction equipment is based on these two types of extractor although plant similar to that originating in the United States is now made in Europe.

In the extraction of citrus juices, it is desirable to have as gentle an extraction pressure as possible. There should be minimal contact time between juice and pulp to reduce the amount of bitter substances expressed from the peel into the juice. The amount of suspended solids and pulp in citrus juice is controlled in a subsequent separation in a finisher. A screw action is used to force juice through a rotating perforated screen and separate the larger pulp particles from the juice. The oil level in the juice may, if required, be adjusted by vaporizing under a vacuum (15). Separated pulp is washed and finished several times to produce a solution that is then either added back to the juice to increase juice yield, or concentrated to produce pulp wash solids, also called water extract of orange solids, which can be used as a base for cloudy beverages. The use of so-called pulp wash has been the subject of much debate in the juice authentication issue although it is now generally regarded as acceptable if added back in an in-line process in small (<5%) quantities. Its use off-line is now generally not acceptable for authentic juice. Empirical methods for measuring pulp wash content have been developed using ultraviolet (uv) spectrophotometry (10).

Navel orange juice containing Limonin, grapefruit juice, and pulp wash solids can be excessively bitter. A commercial process developed in ∼1992 for debittering these liquids, involves separating the pulp by centrifugation or ultrafiltration passing the resulting juice through a column packed with a neutral resin to selectively remove the bitter juice components, and recombining the pulp with the debittered juice prior to concentration in an evaporator. The debittered juice or pulp wash solids are often used in blended orange or grapefruit juice products.

5.2. Concentration and Aroma Recovery. Most of the orange and grapefruit juice sold and transported internationally is as frozen concentrate, usually 60–65 °Brix. Because single-strength citrus juices generally are 8–15 °Brix solutions, a fivefold or greater concentration has occurred, making the concentrate a more economical product to freeze, store, and transport.

Citrus juices are almost exclusively concentrated in a thermally accelerated short-time evaporator (TASTE), which has optimized efficiency for the amount of water removed per kilogram of steam used; eg, in a seven-effect evaporator, 2.77 kg (6.1 lb) of water are removed for each kilogram of steam used. Each effect consists of a bundle of tubes, with falling films of juice flowing inside, mounted inside a cylinder so that steam flowing into the first-effect cylinder can condense on the outside walls of the tube bundle as it transfers heat to vaporize a portion of the water contained in the juice. The hot water vapor thus produced is used to heat juice in the next effect, and so on. This results in successively lower temperatures with each consecutive effect, starting at 98°C (208.4°F) in the hottest effect and reaching 45°C (113°F) in the last effect. Concentrated juice is discharged from the last effect to a vacuum flash cooler producing a product temperature of ∼13°C (55.4°F). The system is under vacuum with a progressively higher vacuum in each successive effect sufficient to cause water evaporation.

During water removal, much of the desirable flavor characteristic of the citrus juice is carried off with the vapor, especially in the early effects. Essence recovery units are used routinely to condense the volatile flavor substances as a water-phase essence, industrially termed aroma, and an oil-phase essence oil. These are valuable commercial flavor fractions saved separately to be added back later to concentrated juice. The concentrate is cooled quickly and stored at −10°C (50°F) in bulk vessels up to 500,000 L or greater, refrigerated stainless steel tanks, ie, bulk storage or tank farms. At the time a processor is ready to prepare a commercial juice pack for retail sale, concentrate from several batches in bulk storage is blended to achieve the desired sugar/acid ratio and color. Water-phase essence and oil fractions are added to restore flavor lost during concentration. Most of the single-strength orange juice marketed worldwide is prepared by reconstitution of such blended concentrates to between 11.2 and 11.8 °Brix juice, followed by pasteurization and chilling prior to retail packaging, usually in aseptic packs of 1.0 L. In European markets, there is a code of practice requirement to reconstitute orange juice to a minimum of 11.2 °Brix while in countries that follow the Codex guideline, orange juice must be reconstituted within the range of 11.2–11.8 °Brix in accordance with National Legislation.

A newer juice concentration process, requiring minimal heat treatment, has been applied commercially in Japan to citrus juice concentration. The pulp is separated from the juice by ultrafiltration and pasteurized. The separated juice containing the volatile flavorings is concentrated at 10°C (50 °F) by reverse osmosis and the concentrate and pulp are recombined to produce a 42–51 °Brix citrus juice concentrate. The flavor of this concentrate has been judged superior to that of commercially available concentrate, and close to that of fresh juice (16). Clarified citrus juices (other than lemon or lime) are not regarded as acceptable to most consumers in Europe or the United States.

A further process using freeze concentration has also been developed and has been used on a very limited commercial scale. Fresh juice is cooled to $<$ 0°C (32 °F), and the water crystals that form are removed and washed by more juice. This process is repeated four or five times until the residual juice has a concentration of $\sim$ 45 °Brix. The juice is said to have flavor characteristics that resemble those of the fresh juice. The economics of the process are said not to be favorable for most markets and applications.

Pasteurized single-strength orange juice, NFC, often called premium orange juice in the United States, is increasing in sales worldwide with a corresponding reduction in the retail market share of frozen concentrated orange juice in the United States (17). The NFC juice requires special extraction and storage conditions to ensure high quality. Juices are expressed with extractors designed to produce juice having low oil content ($<$0.035%). Juice must be chilled and stored aseptically or in frozen blocks to provide a year-round supply to packers.

Unpasteurized orange and grapefruit juices are increasingly popular products in the United States and Europe. Fruit must be extracted under strict conditions of hygiene and the juice kept just $>$ 0°C (32 °F) during its $\sim$ 17-day shelf-life. Year-round juice supply relies on the importation of fresh fruit from different growing countries according to the harvest season and it is often difficult to maintain consistency of flavor and °Brix/acid ratio. In the United States, however, deaths have been recorded following consumption of unpasteurized fruit juices contaminated with *Escherichia coli* O-157, and as a consequence, the FDA ruled that all juices that are pressed, packaged, and sold elsewhere must be subject to a process, such as pasteurization or uv irradiation, which ensures at least a 5 log reduction in viable organisms in the product. The ruling is said not to apply to juice obtained from fruit pressed at the point where the juice is consumed.

5.3. Lemon and Lime Juice. Lemons and Persian or Key limes can be extracted using the same FMC and AMC extractors described above. The juice can be concentrated in a TASTE evaporator, an APV Crepaco, Inc. evaporator, or other types of evaporators (18). An alternative method of manufacture for clarified lime juice to supply the United Kingdom demand for Lime Juice Cordial has been to crush whole limes in a screw press, and then allowing the juice and pulp to stand for several days to permit natural pectolytic enzyme activity to clarify the juice. Peel and pulp residues are then processed to recover lime oil. Separated juice can then be concentrated in a suitable evaporator or by subjecting it to ultrafiltration. This latter technique produces a six to seven times concentrate with an outstanding pale color. Lemon juice is widely produced in Argentina and several European countries, notably Italy, Spain, and Greece, where it is available as either a clear or cloudy product. Lemon and lime juice concentrates are still available in Europe preserved with $\sim$ 1500 mg/kg sulfur dioxide (SO_2) and are typically used in making concentrated (dilute to taste) soft drinks. Clarified lime juice, made by mixing juice with filter aid prior to passing through a filter press, is the one clarified citrus juice that is a significant article of commerce in the United States. The pasteurized bottled juice is popular for drink mixes, punch bases, and fountain drinks (18). Major producers of lime juice have developed techniques that use commercial pectolytic enzymes to speed the clarification process followed by concentration using ultrafiltration (UF).

Lime juice, and especially lemon juice, are widely used as condiments on food, but the bulk of concentrated juice used in the United States is to make frozen concentrated lemonade and limeade. The process of UF is also employed. Frozen concentrated limeade, first sold in 1951, is made by the addition of lime oil to lime juice and then the addition of sugar until the Brix reading reaches 50°. The product is frozen and stored at $-18°C$ (-0.4 °F) or lower (18).

Lemon and lime peel oils are the most valuable essential oils recovered from citrus. They are widely used in the soft drink industry in lemon–lime flavored beverages, and lime oil is an ingredient in cola flavor as well (19). Lemon oil is usually obtained by a process where the oil glands in peel are punctured by passing them across an abrasive surface. The oil is washed off by a water spray and oil is collected by centrifugation. Lemon oil is also used extensively in household products for its pleasant clean aroma. The principal lime oil of commerce is collected from the Key, or Mexican, lime that is too small to be extracted in conventional juice extractors. The whole fruit is crushed in a screw press and the oil is obtained by vacuum deoiling, ie, partial distillation. Because the acidic juice and peel oil are in contact prior to distillation for oil recovery, chemical changes to the lime oil occur that give the oil a strong aroma and flavor not normally present (18). This stronger flavored oil has become the accepted oil of commerce for most lime flavoring uses. The more expensive cold-pressed lime oil (ie, where there is no distillation or heat treatment) is also used in some applications.

5.4. Citrus Comminutes. In the United Kingdom in particular, there is a demand for comminuted citrus products, especially from oranges and lemons, for use in the manufacture of whole fruit drinks for consumption after dilution. Such products rely on the combination of juice, peel, and oil constituents to provide a much stronger flavor than can be obtained from juice alone. Early comminutes were produced by simply pulping the whole citrus fruit. Later developments take the various components from citrus processing including concentrated juices, blending them in required proportions, colloid milling, and pasteurizing the resulting mixture. Citrus comminutes are often stored with chemical preservatives for later use in the manufacture of soft drinks. United Kingdom regulations permit the carry over of preservatives from comminutes into appropriate end products.

5.5. Soft Fruit Processing. Fruit used for juicing must be sound, free from gross damage or contamination, especially mould or rot that can lead to tainted juices or, especially in apples, the presence of toxic mould metabolites, eg, Patulin. Mechanical harvesting can cause bruising and skin penetration that may cause off-flavors or the growth of pathogenic organisms (20). Mechanical harvesting is used extensively on apples and black currants, whereas berries are mainly picked by hand. Most temperate deciduous fruits, including apples, pears, grapes, berries, black currants, and red currants, are processed by milling, ie, comminuting the whole fruit and then pressing the juice from the resulting mash. Processing equipment for stone fruits, eg, peaches or apricots, requires an additional stage to remove the stones prior to pressing. Many tropical soft fruits require specialized processing stages.

5.6. Milling. All fruit used for juicing must be thoroughly washed. A variety of methods are used to break the fruit to release juice. These methods depend on the structure of raw material, the clarity desired in the final juice, enzymatic discoloration, and destruction of pectin. The most common disintegrator used in North America is the hammermill, or a variation of it, where fixed or free-swinging hammers force the fruit particles through a screen. The degree of disintegration is varied by type of hammer used, ie, blunt hammers for impact disintegration or sharp hammers for chopping; diameters of the screen holes beneath the hammers; and hammer speed. Some processors believe this type of breakdown gives higher juice yields than other methods (20).

Another common system is the fixed knife mill. This consists of a chamber containing fixed knives and a rotating three-armed spider that shreds the fruit by forcing them against the fixed knives. Fruit are gravity fed into the chamber from an opening in the top. Small holes under the knives permit the mash to fall through to a conveyor.

Milling is essential for relatively hard fruit, eg, apples, whereas grapes and berries need only light crushing. Some soft fruit, eg, raspberries and strawberries, are received frozen and must be defrosted prior to processing. Grapes and other fruit harvested in clusters are mechanically destemmed prior to crushing. For crushing, a series of intermeshed arms mounted on two cylinders shred the grapes as they pass through to produce a mash.

The pulp from stone fruit, eg, apricots and peaches, must be removed in a way that prevents damage to the stone; the stone often contains components that can affect juice flavor and storage stability. A mill for stoned fruit contains hard rubber-lobed wheels that rotate together to force the fruit down and strip most of the pulp from the intact stone. An alternative process for peaches involves halving and pitting the fruit in a Filper twist pitter, pulping the fruit halves, and heating the pulp to 82°C (179.6 °F) in a steam cooler. A fruit disintegrator is then used to produce a puree that is put through a finisher. Such pulpy fruit purees can be treated with sugar syrup to produce nectar drinks containing 25–50% juice (21).

5.7. Enzyme Treatment of Pulp. Because of their cell structure, some fruits are not easily juiced by milling and pressing. Commercial pectolytic enzymes are widely used to break down cell structure and degrade pectins in the juice to improve extraction efficiency. The principal disadvantage to enzyme use is the cost relative to the additional juice yield obtained. For fresh apples and pears, efficient juicing can occur without the use of enzymes, but after a period of storage of the fruit, the cell structure changes and enzyme treatment is of greater benefit. Many other fruits benefit from enzyme treatment prior to juicing as well, including strawberries, cherries, plums, black currants, and raspberries (19). Fruit for processing is received either frozen or at ambient temperature. It usually must be mixed with the pectolytic enzyme and heated for 1–2 h for optimum pressing efficiency, eg, 1 h at 15–30°C (59–86 °F) for apples. By use of an appropriate cocktail of enzymes it is now possible to obtain almost complete liquefaction of fruit, eg, apples although the legal status of juice so obtained must be in question. Enzymes may also be used to treat juice following pressing when clear products are required.

5.8. Press Aids. Fibrous materials are sometimes added to the fruit pulp to facilitate juice liberation, or to provide a stable structure to withstand the application of pressure (19). Several types of press aid are used, eg, diatomaceous earth, coarse wood flour, rice hulls, and bleached or unbleached wood pulp. Diatomaceous earth and wood flour may be sprinkled over press cloths, or added to the pulp before the cloths are filled for hydraulic pressing, thereby making discharge of the spent cakes easier and also increasing the amount of juice. When continuous presses are used, more fibrous press aids are required to develop a cake structure that permits compression without slippage against a revolving screw. The most common materials for this are bleached and unbleached wood pulp that liberates a minimum of soluble materials that may affect the flavor or color of the juice adversely. Unbleached wood pulp is available in bale form and must be shredded, whereas the sheet form of bleached pulp is frequently defibrated in a hammermill.

The press aid must be thoroughly dispersed throughout the fruit pulp before it enters the press. For this purpose, a mixing trough equipped with open-loop paddles made from square barstock has been used. The composition of the fruit entering the press by gravity is controlled by feeding the pulp to the mixer with a variable speed screw pump. The addition of unbleached pulp, when it is used, is controlled by the rate of feed to the shredder; when bleached pulp is used, by the rate of feeding to the hammermill. The amount of bleached or unbleached pulp added to the fruit may vary 0.5–5 wt%, depending on type, variety, and maturity of the fruit, degree of defibration of the press aid, and thoroughness of dispersion in the fruit pulp. If too little fiber is added, the juice yield is low and there is an exceptional amount of suspended solids in the juice. Too much press aid gives a decreased juice yield owing to absorption by the press aid; the cake may be so dry that it cannot be discharged from the press. Rice hulls are frequently added at the rate of 0.25–1% to prevent blinding of the screen holes in the press cage by fruit particles. Press aids are little used in countries supplying European markets.

5.9. Pressing. There are a variety of fruit presses. Some presses are more suitable for one type of fruit than for others, but most can be used for any fruit with varying degrees of success. Some presses require the use of a press aid, eg, diatomaceous earth or wood chips. Total juice yield from the original fruit defines press efficiency. Additional yield can be obtained by adding a small amount of water to the press cake and pressing again. The legal definition as juice of such products is not permitted in many countries.

A simple rack and frame press uses heavy nylon cloth positioned in a wooden frame inside a rack. A measured amount of apple or other fruit mash is added from a hopper above the frame. The mash is leveled with a hand trowel and the edges of the nylon cloth are folded over the mash to encase it and create a cheese. The frame is removed, and a second rack is placed on top of the first cheese; the process is repeated until a stack of cheeses is prepared. A hydraulic ram then applies gradually increasing pressure on the stack and expresses the juice. A high yield of juice (80%) is obtained and no press aid is required. Because this process is labor intensive (22), it is mostly used for small farm and pilot-plant operations.

The Bucher-Guyer horizontal rotary press is a highly automated batch process machine that requires no press aid. The press consists of a horizontal hydraulic ram inside a rotating cylinder containing many flexible rods covered with a knitted synthetic fabric. The rods have serrated surfaces to allow juice that passes through the fabric to flow to the discharge ends. Hydraulic pressure is applied for a preset time, the ram is retracted, and the cylinder is rotated to break up the press cake. This cycle is repeated several times before the press cake is removed from the cylinder and the press is cleaned (21). Juice yield for this horizontal rotary press can reach 84%; with secondary water addition it may be increased to 92% (20).

The Stoll press uses a horizontal hydraulic ram and a chamber with screens on the sides that holds the mixture of fruit mash and press aid. Hydraulic pressure is applied to the mash first at 2750–3440 kPa (400–500 psi), and then at 17,200–20,600 kPa (2500–3000 psi) for preset times; the pomace is removed after each cycle. One person can operate several presses at once, each with a 4–5-t/h throughput.

A belt press commonly uses two belts of woven material. Fruit mash is deposited on, and spread out evenly between, the two belts that converge and press the mash between them. The belts wrap around a series of successively smaller cylinders or pass between rollers (less efficient) for the pressing action. Juice yield for the wraparound belt press is typically 72%, and increases up to 92% with secondary water addition (20).

Screw presses have been used extensively in North America, but are not popular in Europe. The mash is added at the top of a vertical rotating screw. As the mash moves down it is compressed in the taper and juice flows out through slatted conical walls. Compression of the pomace blocks channels for juice flow and inhibits juice extraction. Extensive use of press aids is necessary for efficient operation.

5.10. Concentration and Aroma Recovery. Concentration of juice from soft fruit is best carried out using an evaporator that causes as little thermal degradation as possible and also permits recovery of volatile materials important to the aroma of the fresh fruit, ie, essence. Evaporators that use a high temperature for a short time and operate under a vacuum, eg, the APV Crepaco falling film plate evaporator or the Alfa Laval centrifugal evaporator, are most commonly used. The TASTE evaporator, almost universally used for citrus, is rarely if ever used to concentrate soft fruit juices.

Multiple effect falling film vacuum plate evaporators use a plate-and-frame heat exchanger to heat the juice to the required temperature for boiling under partial vacuum. The plate evaporator consists of multiple gasketed plates arranged in series within a compact frame. As feed juice flows in a single pass as a falling film, the water is vaporized on contact with steam heated plates and is discharged as a liquid–vapor mixture to a large volume separator. The concentrated juice flows out the bottom and the water vapors are used to heat the next effect or are condensed. For maximum energy efficiency the warm concentrate stream is used to preheat feed juice (23). Falling film plate evaporators are especially useful for heat-sensitive fruit juice because of short heat contact time, rapid start-up and shutdown times, and minimum juice loss from a small liquid hold up volume (20). They also can be used by a single processor for multiple fruit crops during the year.

Centrifugal evaporators are also suitable for concentrating fruit juices because they have very low heat contact times. The expanding flow centrifugal evaporator contains a stack of rotating, steam-filled hollow cones. As juice is sprayed onto the inside of the cones near the apex, centrifugal force spreads juice across the inner surfaces of the cones. The resulting concentrate is forced to the stationary walls of the evaporator and collected. Steam condensate on the outer surface of each cone is similarly forced out by centrifugal force so that the heating surface in contact with the product is constantly heated with hot dry steam. Thus juice concentrate and steam condensate are continuously removed. Juice can be concentrated in one pass with a few seconds contact time (20).

There are two methods available for aroma recovery. In one method, a portion of the water is stripped from the juice prior to concentration and fractionally distilled to recover a concentrated aqueous essence solution. Apple juice requires 10% water removal, peach 40%, and Concord grape 25–30% to remove volatile flavor as an essence. Fractional distillation affords an aqueous essence flavor solution of 100–200-fold strength, which means the essence is 100–200 times more concentrated in flavor than the starting juice. A second method of essence recovery is to condense the volatiles from the last effect of the evaporator; they are enriched in volatile flavor components (23).

Essences generally are stored separately from the bulk concentrates for stability, and their addition prior to retail packaging is essential to restoring much of the natural fresh flavor of the starting juice otherwise lost during processing. Unlike citrus, which affords both an aqueous and an oil-phase essence, only an aqueous-phase essence is obtained for deciduous fruit. Virtually no essential oil is present in the peel or juice in the latter. European Union juice regulations make the addition of the aroma volatiles to reconstitued juices obligatory (24).

5.11. Clarification. The appearance of fruit juices varies widely. Citrus and pineapple juices have high contents of insoluble solids and are almost always sold as cloudy juices, whereas cranberry, grape, and many apple juices have little or no suspended solids and are translucent. In some juices, eg, citrus, many of the flavoring constituents adhere to the cloud, and the clarified juices lack flavor (25). For this reason, and the unsightly appearance of sediment in bottled juice, considerable research has been devoted in the citrus industry to the causes of solids flocculation. Preservation of the natural pectin content by rapid heating and cooling of juice as soon after pressing as possible to inactivate the natural enzymes has been found to be particularly important. Size of the suspended particles is another factor influencing flocculation; this may be adjusted by screening, homogenization, colloid milling, or selective filtration.

In the production of opalescent or natural-type apple juice, ascorbic acid is added to the fruit pulp before pressing, or to the juice as it comes from the press, to retain more of the apple flavor (4). Ascorbic acid addition and pasteurization of the juice as soon as possible after pressing prevent polyphenol oxidation, which causes browning and contributes to pulp flocculation.

In the production of clear juices, the natural pectin is degraded with pectolytic enzymes to facilitate filtration and prevent the subsequent precipitation of the pectin. Other sources of colloidal haze in filtered juices are polymerized tannins, or compounds formed by the combination of tannins and proteins. The haze also may result from the denaturation of proteins. To overcome tannin precipitates, gelatin is sometimes added to the juice during enzyme digestion. The amount and type of gelatin added to form a floc must be carefully controlled because an excess of gelatin causes a haze. Laboratory tests are frequently conducted by adding graduated amounts of gelatin and tannin to samples of juice and noting the amounts required for greatest clarity after standing them overnight. Such tests are frequently necessary because of the variation in the natural tannin and protein contents of the juice. The use of kieselsol. a synthetic silica sol, in combination with gelatin (4), or honey and pectinase enzyme mixtures (26), increase the speed of the clarification process so that in-line clarification is possible.

Digestion of juice with commercial pectolytic enzyme preparations may be carried out at 13°C (55.4 °F) for 15–18 h or at 49°C (120.2 °F) for 1 or 2 h. Intermediate digestion temperatures are not used because of the possibility of alcoholic fermentation. If a higher digestion temperature is used, the juice may be clarified by rotary vacuum precoat filtration followed by a small-cartridge or leaf-type filter to remove any filter aid. If juices are digested at low temperatures, sufficient time usually elapses for flocculation of the solids, and the clear juice is decanted and passed through a pressure-leaf filter. The filter aids used are diatomaceous earth of fine-to-medium grades depending on the clarity desired and the nature of the solids. Completeness of pectin destruction is of importance in maintaining good filtration rates and filtrate clarity.

Use of UF membranes is becoming increasingly popular for clarification of apple juice and is also used for lime juice. All particulate matter and cloud is removed, but enzymes pass through the membrane as part of the clarified juice. Thus pasteurization before UF treatment to inactivate enzymes prevents haze formation from enzymatic activity. Retention of flavor volatiles is lower than that using a rack-and-frame press, but higher than that using rotary vacuum precoat filtration (27).

Natural-style juices that contain the cloud are increasing in popularity, especially apple juices, because these retain more fresh flavor if processed carefully. Optimum processing conditions chill the fruit to 4°C (39.2 °F) before milling, add 500 ppm ascorbic acid to retard browning, press under nitrogen, and flash pasteurize the juice as quickly as possible (4).

To avoid formation of tartrate crystals in bottled grape juice, the filtered juice is stored at −2°C (28.4 °F), or just above the freezing point, for several weeks to permit the deposition of potassium acid tartrate crystals (6). Prior to storage, the juice is pasteurized at 88°C (190.4 °F), and then cooled in storage at −2°C (28.4 °F) before it is pumped into clean storage tanks. Unless care is taken in the sanitation of the pasteurization and cooling equipment, piping, and tanks, yeast growth may cause alcohol production or generation of off-flavors.

5.12. Pasteurization. Fruit juices generally have a pH of 4 or less and spoilage is usually limited to bacteria and yeast and mold growth (19). Flash pasteurization minimizes flavor changes owing to heat treatment and is recommended for premium quality and natural-style juices. For flash pasteurization several pasteurization methods are used, eg, a plate heat exchanger with a separate holding tube. Typical flash pasteurization conditions for microbial stability are 85°C (185 °F) for 15–30 s although a higher temperature, typically 95°C (203 °F), is usually regarded as necessary for complete pectic enzyme inactivation. The NFC juices are typically subjected to a temperature of between 90 and 95°C (203 °F) for a few seconds.

The plate heat exchanger is a bank of stainless steel plates separated from each other so that heating medium and juice can transfer heat through the plates without direct contact with the product.

Regeneration-type plate pasteurizers consist of a preheating section in which hot pasteurized juice is used as the heating medium to preheat incoming juice and simultaneously cool the pasteurized juice, thus saving energy (14). The preheated juice is further heated with steam or hot water to pasteurization temperature. A holding section within the plate pasteurizer maintains the temperature long enough to assure adequate pasteurization. A cooling section using chilled water may be needed, but the initial preheating section using pasteurized juice may be so efficient that the exit temperature for pasteurized juice approaches ambient temperature and no further cooling is needed (20).

Hot filling of the container with juice pasteurizes the package as well as the product, thus ensuring product sterility. In this process, bottles or cans are filled with juice preheated to a temperature sufficiently hot to pasteurize the container and closure (lid) without further heating. Immediate inversion of the sealed container is necessary to assure sterilization of the closure. After the pasteurization period, the containers are cooled as quickly as possible. An alternative, and widely used procedure, is to heat the pack with hot water sprays in a tunnel, usually in three stages. Initially, the spray preheats the pack in the first one-third of the tunnel; sprays heat the pack to pasteurization temperature in the next third; and the final third is a cooling section with progressively cooler sprays so that a cooled pack emerges. Typical conditions used in tunnel pasteurizers are an actual process time of 20 min at pasteurizing temperature of 70°C (158 °F) (20).

Aseptic packaging in flexible laminated multilayer plastic containers has become popular worldwide because the packaging materials are economical and the product can be stored at ambient temperature (28). In such packaging, the juice must be heat pasteurized, cooled to prevent heat damage to the package, and introduced into the package in a sterile atmosphere. The package is presterilized with hydrogen peroxide or other approved sterile solution prior to juice addition. These aseptically packaged juice drinks have a shelf-life of 12 months at room temperature.

Alternative methods of pasteurization that are under development include irradiation with high energy electrons or X-rays and the use of high pressure pasteurization. In the latter process, batches of product in flexible packages are placed in a pressure vessel and subjected to pressures of $\sim$ 600 MPa. Because current processes are labor intensive and limited by batch operation the process is limited to premium products where, for freshly squeezed product, shelf-life can be extended by two or three times that of unprocessed juice.

Some strains of the microorganism Alicyclobacillus can be a problem in long-life ambient stored fruit juices. It is a thermophilic organism and its spores are extremely heat resistant, not being destroyed by pasteurization at 95°C (203 °F). Storage of juices at elevated temperatures (>26°C) (28.8 °F) will result in growth of the organism if present and consequent spoilage noted as an off-taste. The organism occurs naturally in soil and contact of the fruit with the soil must be avoided. The AIJN are developing a best practice guide for processors.

5.13. Chemical Preservatives. Most governments require a listing of ingredients, including preservatives, on the labels of food and beverage containers, and only permit use of those materials considered to be noninjurious to health. The most common preservatives used in fruit juice beverages are the potassium and sodium salts of sorbic, benzoic, and sulfurous acids, as well as dimethyl dicarbonate. However, the use of any chemical preservative in pure fruit juices is no longer permitted in many countries although labeling the product as a "juice drink" can sometimes provide a loophole to facilitate the use of permitted chemical preservatives in non-aseptic packaging. A common rate of addition of sodium benzoate to a beverage at drinking strength is 0.015–0.020 wt% (28) when calculated as benzoic acid. Sorbic acid is typically used at ~0.025 wt%, but added as the potassium salt. Some countries permit higher levels in concentrated drinks provided the prescribed maxima are not exceeded on dilution. In an acidic juice drink, benzoic acid and sorbic acid may impart an objectionable flavor at higher concentrations. The storage life of juices treated with chemical preservatives is seriously curtailed if they are heavily contaminated during preparation, or not refrigerated as much as possible. The amount of SO_2 added as a gas or as a sulfite salt varies widely with pH and solids content of the juice or concentrate. At low pH, free SO_2 is the most effective form. At high pH, dissociated SO_2 is bound by sugars, aldehydes, etc, and is not available as an antimicrobial agent. Effective amounts of SO_2 cannot be used in canned beverages because of accelerated corrosion, with thiamin, or with certain natural coloring agents (28). Sulfur dioxide is particularly effective in providing some antimicrobial protection to the headspace of beverages and is also valued for its antioxidant properties. The use of SO_2 in beverages other than wine is now very restricted in many countries and, where used, its allergenic properties may have to be declared on the product label. Dimethyl dicarbonate (Velcorin or DMDC) is now used as a preservative in many countries but its toxicity requires the use of special dispensing equipment. Dimethyl dicarbonate decomposes to CH_3OH and CO_2 in a product and its maximum rate of addition is typically 0.025 wt%.

5.14. Freezing Preservation. Fruit juices can be preserved by freezing. The juice is filled into waxed paper or plastic containers approved for food use so that a 10 vol% headspace is left for expansion during freezing. The juice should be as cold as possible before filling and in some cases the juice or concentrate is chilled to a slush in a wiped-film heat exchanger. The containers are placed on refrigerated shelves with provision for forced-air circulation around them, or in the case of round containers, conveyed with rotation through a liquid refrigerant. The frozen juice should be held at a uniform temperature of −18°C (−0.4 °F) to reduce ice crystal growth and damage to the colloidal solids. The convenience of having a ready-to-serve single-strength juice is partly lost by the consumer having to thaw the product before use and frozen products for consumer use have largely been replaced by chilled "freshly squeezed" juices. The most important use of freezing technology is now in the transportation and storage of concentrated juices.

5.15. Dehydration. Drying pure fruit juices is difficult because of the low melting points of the solids and their hygroscopic nature owing to the presence of fructose (26). Under conditions of low water vapor pressure, as in freeze-drying, the juice must be frozen in such a manner that the ice crystals are thoroughly distributed throughout the mass, or a concentrated syrup results rather than dry solids. However, by the addition of various ingredients, eg, dextrose, sucrose, lactose, or maltodextrin, the hygroscopicity of the solids may be reduced. Such additions have a dilution effect so that there are less fruit solids in the final powdered form. Vitamin and flavor losses during drying can be restored when formulating the finished product (29). In general, the flavor and appearance of dried juice powders are poorer than the equivalent liquid concentrated fruit beverages, and so these have not become popular with the consumer. They are more widely sold in hot countries where distribution and storage times are long and weight is at a premium.

6. Tropical Fruit

Pineapple juice has been the most popular tropical fruit juice consumed in the United States and Europe for many years. It has long been a by-product of the pineapple canning industry although now whole fruit for processing is grown in many countries including Thailand and Kenya. Juice pressed from the core, and from trimmings of fruit cut into cylinders for canning, is combined with juice collected from the cutting table to provide much of the pineapple juice sold commercially (24). This juice contains up to 40% pulp. The pulp content is reduced, usually by finishing with a screw-type finisher followed by centrifugation, before pasteurization and concentration. Pineapple juice can be concentrated in a falling film plate-type evaporator with an essence recovery step prior to concentration (30,31). As with other fruit juices, concentrated pineapple juice of either 60 °Brix with high pulp content, or 72 °Brix with low pulp content, is the principal product traded internationally. While aqueous essences can be added, they tend to be poor and variable in flavor, and commercial users frequently avoid their addition. The higher quality pineapple juice made using whole ripe pineapples is sold mainly in the (EU) countries, where it accounts for much of the pineapple juice consumed.

Pineapple juice has been available commercially since 1932, but the production and sale of other tropical fruit juices including passion fruit, guava, and mango, has more recently received significant attention in Europe and, especially, in North America (30). Tropical fruit juices are often too pulpy or have harsh or exotic flavors that make 100% juice products unacceptable to many consumers. They are more acceptable as nectars containing 25–50% juice or as blended fruit drinks where their strong flavors are diluted or modified.

Because of high pulp content, most tropical fruit are difficult to pasteurize or concentrate in a conventional manner without severe flavor change from excess heat treatment. Some are stored and sold as frozen purees, but others, eg, yellow passion fruit, can be concentrated effectively and are sold as 50 °Brix concentrates. The APV Crepaco Paravap, similar to the falling film plate evaporator, has plates especially designed for high vapor velocities and turbulences that afford a high rate of heat transfer and are amenable to concentration of fruit purees (23). As with other fruit juices, recovery of aqueous essence is usually necessary for production of high quality concentrates.

Passion fruit, mango, and papaya are tropical fruits available as concentrated juices or purees. Available single-strength purees include guava, banana, kiwifruit, lulo, soursop, and umbu (30). The international market for tropical fruit drinks has expanded significantly in recent years, but still only accounts for a small percentage of fruit juices. Blends of tropical fruits with more traditional juices, eg, orange and apple, have become some of the more successful drinks marketed. Banana puree is also widely used as a base for various food products, as well as smoothies. These latter products can be juices, nectars, or juice drinks with a pulpy consistency and have become an important growth sector.

7. Fruit Juice Drinks

In most markets, fruit juice must be 100% juice and contain no additives. Fruit nectars consist of pulp, juice, sugar, and water, and contain from 25 to 50% juice, depending on the fruit used. In the EU, the minimum juice content is 50% for orange and apple, 40% for apricot, and 25% for passion fruit and guava (32). Other fruit juice drinks include cocktails that usually contain at least 25% juice; and a variety of juice drinks that can contain from 1.5 to 70% juice (Table 2).

Cranberry juice, too acidic to be consumed as a 100% juice drink, has been sold in the United States since 1929 as cranberry juice cocktail. Juice extraction usually involves pressing the juice from thawed cranberries in a tapered screw press, which affords a 60–64% juice yield. The juice is diluted with two volumes of water and sugar is added to raise the °Brix to 15 to produce a juice cocktail. Under the Federal Food, Drug and Cosmetic Act, cranberry juice cocktail must contain not $<$25% single-strength cranberry juice with soluble solids content of 14–16 °Brix, vitamin C content of 30–60 mg/177 mL (6 oz), and citric acid content not $<$0.55 g/100 mL (21). Cranberry juice drinks have only become popular in EU countries very recently.

Commonly, a juice drink contains 5–10% fruit juice, which usually is a blend of several fruits. The 1990 U.S. Federal Nutrition and Labeling Act requires declaration of juice content so that the consumer can make a more informed choice (3) and a similar regulation now exists in EU countries. With cocktails and juice drinks, added sugars, acids, flavorings, colorings, and nutrients can be used to provide a wide variety of stable products of uniform quality. Because drinks require less juice than 100% juice products, the drinks can be sold at a lower price although the differential is frequently small or even nonexistant.

8. World Supply and Consumption

No attempt is made in this article to evaluate supply and consumption of fruit juices by value, as prices show considerable volatility. As an extreme example, FCOJ can vary between $ 600/tonne and $ 2500/tonne from one season to the next with prices showing a rapid fall in a further season.

More reliable figures (33) relate to the consumption of Juices and nectars. For 2005, the major consuming countries were as follows (million-L):

United States	9100
Germany	3500
Russia	2100
China	1400
United Kingdom	1350
France	1300
Japan	1075
Canada	1075
Spain	1000
Mexico	900

The top 10 per capita consumption figures (L/head of population) for 2005 were as follows:

Cyprus	44
Germany	42
Australia	40
Austria	35
Canada	33
Switzerland	31
Norway	31
United States	31
Finland	30
Denmark	29

Overall market shares showing regional consumption of Juices and Nectars in 2005 were:

North America	27%
West Europe	27%
Asia–Australasia	16%
East Europe	12%
Latin America	10%
Africa	4%
Middle East	4%

9. Notes

Mention of a trademark, trade name, or proprietary product is for the purposes of example or identification only and does not imply a warranty or guarantee of the product by the author or publisher. Other products may also be suitable.

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Table 1. **Composition of Fruit Juices**[a,b]

Juice	Water, %	Food energy, kJ[c]	Protein, g	Fat, g	Carbo-hydrate, g	Fiber, g	Ash, g	Ca, mg	Fe, mg	P, mg	K, mg	Na, mg	Vitamin A, IU[d]	Thiamin, mg	Riboflavin, mg	Niacin, mg	Ascorbic acid, mg
acerola	94.3	88	0.4	0.3	4.8	0.3	0.2	10	0.5	9	97	3	509	0.02	0.06	0.4	1600
apple	87.9	196	0.1	0.1	11.7	0.2	0.2	7	0.4	7	119	3	1	0.02	0.02	0.1	1
apricot nectar	84.9	236	0.4	0.1	14.4	0.2	0.3	7	0.4	9	114	3	1316	0.01	0.01	0.3	1
cranberry, cocktail	85.0	243	0.1	0.1	14.9		0.1	3	0.2	1	24	4		0.01	0.02	0.1	43
grapefruit																	
white	90.1	158	0.5	0.1	9.0		0.3	7	0.2	11	153	1	7	0.04	0.02	0.2	29
sweetened	87.4	194	0.6	0.1	11.1		0.8	8	0.4	11	162	2	0	0.04	0.02	0.3	27
grape	84.1	256	0.6	0.1	15.0		0.3	9	0.2	11	132	3	8	0.03	0.04	0.3	*e*
lemon	92.5	89	0.4	0.3	6.5		0.4	11	0.1	9	102	21	15	0.04	0.01	0.2	25
lime	92.5	87	0.3	0.2	6.7		0.3	12	0.2	10	75	16	16	0.03	0.01	0.2	6
orange																	
chilled	88.4	186	0.8	0.3	10.1		0.5	10	0.2	11	190	1	78	0.11	0.02	0.3	33
conc, diluted	88.1	188	0.7	0.1	10.8	0.1	0.4	9	0.1	16	190	1	78	0.08	0.02	0.2	39
orange–grapefruit	88.6	180	0.6	0.1	10.3		0.4	8	0.5	14	158	3	119	0.06	0.03	0.3	29
papaya nectar	85.0	238	0.2	0.2	14.5		0.2	10	0.3	0	31	5	111	0.01	0.01	0.2	3
passion fruit																	
purple	85.6	213	0.4	0.1	13.6	0.1	0.3	4	0.2	13			717		0.13	1.5	30
yellow	84.2	253	0.7	0.2	14.5	0.2	0.5	4	0.4	25	278	6	2410		0.10	2.2	18
peach nectar	85.6	225	0.3	*e*	13.9	0.1	0.2	5	0.2	6	40	7	258	0.01	0.01	0.3	5
pear nectar	84.0	249	0.1	*e*	15.8	0.3	0.1	5	0.3	3	13	4	1	0.01	0.01	0.1	1
pineapple	85.5	233	0.3	0.1	13.8	0.1	0.3	17	0.3	8	134	1	5	0.05	0.02	0.3	11
prune	81.2	296	0.6	*e*	17.5	*e*	0.7	12	1.2	25	276	4	3	0.02	0.07	0.8	4
tangerine	88.9	180	0.5	0.2	10.1	0.1	0.3	18	0.2	14	178	1	420	0.06	0.02	0.1	31
sweetened	87.0	209	0.5	0.2	12.0	0.1	0.3	18	0.2	14	178	1	420	0.06	0.02	0.1	22

[a]Ref. 9.
[b]Per 100 g, edible portion.
[c]To convert kJ to kcal, divide by 4.184.
[d]IU = international units.
[e]Trace.

Table 2. **Comparison of Fruit Juice and Beverage**[a]

Characteristics	Unsweetened fruit juice	Fruit beverage, including nectars
composition, %	100 (fruit)	1.5–70 (fruit or juice)
total sugars, %	8–17	0.1–20
energy, kJ/100 mL[b]	146.4–271.9	2.1–313.8
acid,[c] %	0.6–1.5	0.1–0.8
pH	2.5–4.0	2.5–4.0
nutrients	vitamins, mainly C, some A; potassium	as added; vitamin C common, a minority is multivitamin
other ingredients	acid, vitamins, preservatives	sugar, acid, intense sweeteners, flavorings, colorings, vitamins, minerals, preservatives
flavor	distinctive full flavor and body, blends of flavors not common	juice enhanced by added extract or flavorings, range of mouthfeel, blended flavors common
nutrition	no low calorie juices	usually lower calorie; can be fortified as desired
health and safety	distinctive of fruit	sugar level and acidity selected by manufacturer

[a] To convert kJ to kcal, divide by 4.184.
[b] Ref. 29.
[c] As citric acid. High acid fruit juice may have up to 6% acid.

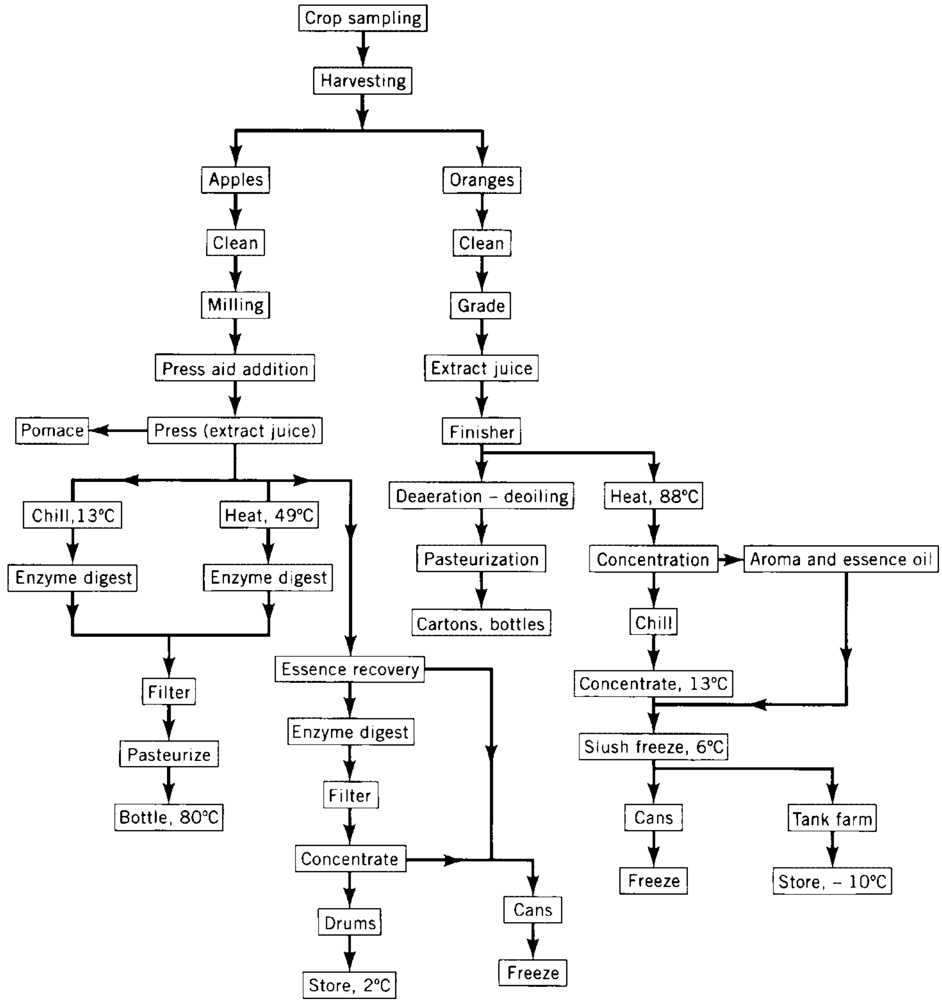

Fig. 1. Manufacturing process for citrus (orange) and deciduous (apple) juices.