CHAPTER 25

FRUIT JUICE CONCENTRATES AND CHILLED JUICE PRODUCTS

CITRUS products, especially orange juice, comprise the largest percentage of the total volume of juices sold in the United States. Much of the technology used in processing noncitrus juices was developed from citrus processing.

ORANGE JUICE

ORANGE CONCENTRATE

Processed orange juice is sold in four principal forms:

1. Frozen concentrate (3-plus-1 concentration, in which three volumes of water are added to one volume of concentrate for reconstitution) in a variety of package sizes. These are the familiar retail products.
2. Concentrate in bulk at 65° Brix. This is an intermediate product that is bought and sold daily as futures on the Commodity Exchange. Most of this product will ultimately be sold in one of the other forms.
3. Chilled orange juice, which is ready to drink when poured from the carton. It is either reconstituted concentrate or nonconcentrated juice. By law, these two products must be labeled “from concentrate” or “not from concentrate.”
4. Institutional or restaurant concentrates in special packaging at 4-plus-1 or higher concentrations.

After processing, frozen citrus concentrates in retail (3-plus-1) packages must be stored at 0°F. Highly concentrated bulk juice (65° Brix) may be satisfactorily stored at about 15°F. Chilled single-strength juices are stored at about 30 to 32°F.

Figure 1 shows a schematic flow diagram of citrus processing. The **Brix scale** is a hydrometer scale that indicates the percentage by weight of sugar in a solution at a specified temperature.

Selecting, Handling, and Processing Fresh Fruit

Selection. Fruit is selected for proper quality and maturity. Some fruit that is blemished but sound in quality, referred to as packinghouse eliminations, is used. A major portion of the crop is taken directly from the grove to the processing plant. To be mature, the fruit must have the proper Brix-acid ratio and the juice content and Brix must be above specified values. Fruit should be handled without delay because no real maturing occurs after harvesting; instead, the temperature and condition of the fruit determine the rate of deterioration. Citrus fruit is sufficiently rugged to withstand mechanical handling on conveyors, elevators, and belts, provided that the fruit is processed within a day or two after picking. Samples are taken mechanically as fruit enters the bins, and records of chemical analyses are maintained. Usually fruit from two or more bins is used simultaneously to improve uniformity. The fruit passes over inspection tables both before and after temporary storage in bins, and damaged or deteriorated fruit is removed.

Washing. Before juice extraction, the fruit is wetted by sprays. The wetting agent is dispensed onto the fruit as it travels over rotating brushes. Water sprays near the end of the washer unit rinse the fruit. A sanitizing solution may be used to sanitize conveyors and elevators.

Juice Extraction. Individual high-speed mechanical juice extractors handle from 300 to 700 pieces of fruit per minute. Some machines halve the fruit and ream or squeeze the juice from the half. Other machines insert a tube through the middle of the fruit and squeeze the juice through fine holes into the tube, at the same time sieving away the seeds and large pieces of membrane. After the juice has been extracted, it passes to finishers that remove the remaining seeds, pieces of peel, and excess cell or fruit membrane. In the past, this was a comparatively simple process involving one or two stages, but it has become complicated in recent years and varies extensively from plant to plant. Usually, one or two stages of screw-type finishers separate most of the pulp from the juice.

Pulp washing, in which soluble solids in separated segment and cell walls are recovered by countercurrent extraction with water, is permitted in Florida, provided that the resultant extract is not used in frozen orange concentrates. It may be used in other formulated products permitted by the Federal Standard of Identity for frozen concentrated orange juice.

The juice or pulp wash liquor from the finishers may require treatment in high-speed desludging centrifuges that remove suspended matter before transferring the juice to the evaporator. These centrifuges have peripheral discharges that open and close at intervals to discharge a thick suspension of pulp cells. This operation decreases the viscosity of juice in the evaporator, improves the efficiency of evaporation, and improves the appearance of the final product. Special means are used to classify orange pulp for inclusion in products with a high pulp content.

Heat Treatment. When frozen concentrated orange juice was first developed, minimal heat treatment was used to maintain optimum flavor. Such concentrate, if prepared from good, sound fruit, remains stable for a considerable time at 0°F and for nearly a year at 5°F. However, with large-scale production, it is not possible to ensure storage below 5°F. Concentrates originally of good quality tend to gel or clarify rapidly during storage. Heat treatment inactivates enzymes responsible for the development of these defects during improper storage. Earlier methods used steam-heated plate pasteurizers, but heat treatment is now almost universally included as an integral part of heat conservation in the evaporation process.

The preparation of this chapter is assigned to TC 10.9, Refrigeration Application for Foods and Beverages.

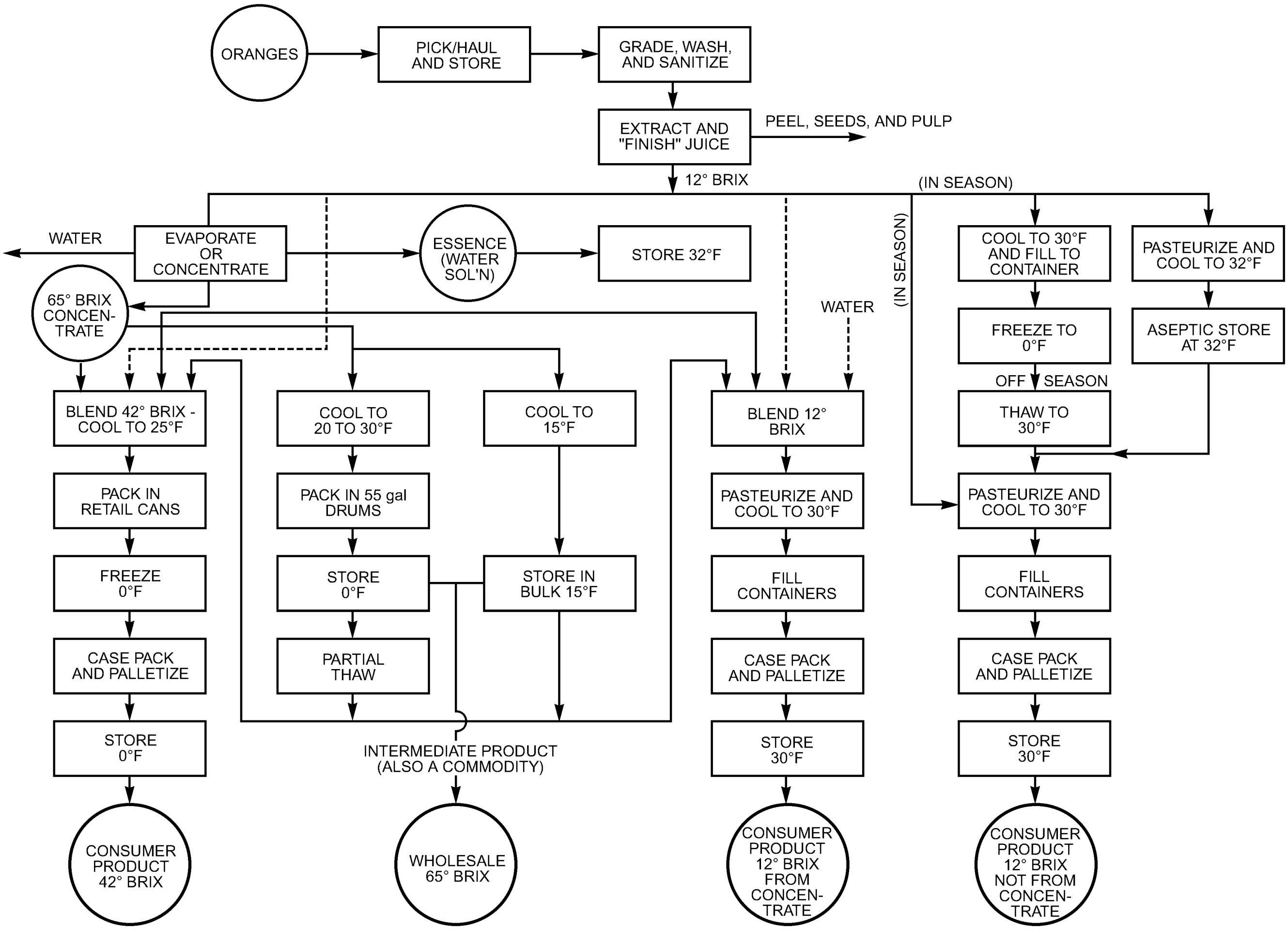

Fig. 1 Citrus Processing Schematic

Evaporation-Water Removal. Removal of water follows juice extraction and preparation. See the section on Concentration Methods for details.

Flavor Fortification. Originally, frozen concentrated orange juice was overconcentrated, and fresh juice (**cutback juice**) was added to reduce the concentration to the desired level and provide fresh flavor in the final product. This process is used extensively in frozen concentrates, but flavor levels cannot be standardized by this method alone.

Essential oil from orange peel does not by itself supply completely balanced fresh flavor, but it is now used extensively to control flavor intensity. Some **peel oil** is found in the cutback juice, but little remains in juice from the evaporator. Adding peel oil to the finished concentrate, at approximately 0.014% by volume in the reconstituted juice, has become standard practice.

Several variations have been introduced to supplement the use of peel oil and cutback fresh juice for flavor fortification. In most cases, vapor from the first stage of concentration is used to produce an **essence** that is restored to the final concentrate to enhance flavor. Although cutback fresh juice and cold-pressed peel oil are commonly added, most operations depend heavily on essence recovery and its incorporation into the final product.

Blending, Packaging, and Freezing. The final step in processing is the blending of concentrate with flavor-enhancing components such as cold-pressed orange oil and liquid essence. The 65° Brix concentrate is then reduced to about 42° Brix, the requirement for 3-plus-1 product, which reconstitutes to about 12° Brix when used by the consumer. The availability of cold-pressed oil and essence when no fresh fruit is available makes blending and packaging possible year-round.

Most retail product is packaged in fiber-foil cans, although aluminum and tinned steel cans may be used. Sizes range from 6 to 64 fluid ounces. Gable-top milk cartons and specialized large disposable plastic reservoirs for dispensers are also used.

Before filling, the product is cooled to about 25 to 35°F. This is usually done in the swept-surface cold-wall tank in which the concentrate is blended, but it may also be done in a bladed heat exchanger or, preferably, in a plate-type unit. Alternatively, the 65° Brix concentrate from the evaporator may be precooled (unblended) and packed in 55 gal open-top drums or delivered to large bulk storage tanks.

The filled cans pass through blast freezers, where their temperature is reduced to 0°F or below in 45 to 90 min. Cans are transported on link belts, and air handlers are arranged so that air at about –25°F is forced down through the loaded belt.

Thermal Properties. In calculating cooling and freezing requirements, concentrates may be considered to approximate sucrose solutions of the same concentration. In the range of 60 to 65° Brix, the specific heat is about 0.68 Btu/lb·°F; for 42° Brix, the value is about 0.74 Btu/lb·°F. Thermal conductivity in the liquid state is in the range of 0.17 to 0.18 Btu·ft/h·ft^2·°F. Regarding the heat of fusion for freezing tunnel design, the value should be 70 Btu/lb in the range of 30 to 0°F; however, experience has shown that a value of about 100 Btu/lb should be used. This allows for extraneous heat gains, coil defrosting, and so forth.

COLD STORAGE

Cold storage facilities for citrus processing can be divided into three categories according to temperature requirements of 0, 15, and 30°F.

Finished goods for retail and institutional markets are stored at 0°F in insulated, refrigerated buildings. Bulk 65° Brix product packed in drums is also stored at 0°F. The refrigerated buildings range from a few thousand square feet to a few acres. Other than the usual insulation requirements, two factors are critical to the design: (1) the vapor retarder outside the insulation must be as close to hermetic as possible, and (2) irrespective of the insulation in the floor, a heat supply must be installed beneath the insulation to maintain the temperature below the floor at about 32°F. Otherwise, the floor will ultimately heave from ice formation below the floor.

The 15°F buildings are used for bulk storage of 65° Brix concentrate. In a typical installation, a 15°F building would house several large stainless steel tanks, ranging from a few thousand to 200,000 gal each. At the stated temperature, the product is barely pumpable, requiring sanitary positive-displacement pumps. Because the temperature is virtually impossible to change after the product is in the tank, the product must be cooled to storage temperature before it is introduced to the tanks. Cooling usually occurs in a plate heat exchanger.

Finally, 30°F storage rooms are used largely for chilled single-strength juice in retail packages or for not-from-concentrate bulk tank systems. This product is discussed in the sections on Chilled Juice and Refrigeration.

CONCENTRATION METHODS

The three major methods for producing concentrates are (1) high-temperature, single pass, multiple-effect evaporators; (2) freeze concentration with mechanical separation; and (3) low-temperature, recirculatory, high-vacuum evaporators.

Thermally Accelerated Short-Time Evaporator (TASTE)

At present, TASTE is the standard evaporator of the citrus industry. This unit has also been successfully applied to grape, apple, and other juices. TASTEs produce at least 90% of all juice concentrate in the western hemisphere. The first cost of this unit is among the lowest of all alternatives, and it has excellent thermal efficiency. Flavor quality and storage stability of juice processed in this unit compare favorably with those of juice from alternative methods of concentration.

The TASTE includes all standard methods of heat conservation. It is multiple-effect, uses concurrent vapor for staged preheating, and flashes condensate to discharge condensed vapors at the lowest possible temperature. Residence time is minimal because all stages are single-pass. Total residence time is 2 to 8 min, varying directly with evaporator capacity.

Figure 2 shows a schematic diagram of a typical TASTE. A triple-effect unit illustrates the basic design. Typical units are offered in four to seven effects (five to nine stages), and capacity ranges from about 10,000 to 90,000 lb/h water removal. The vapor-to-steam ratio is approximately the number of effects times 0.85. In Figure 2, note that juice enters the spray nozzles atop each stage at a temperature well above the saturation temperature at which that body operates. The resultant flashing of vapor, combined with the spray effect of the nozzle, distributes the juice on the vertical tube walls. Thus, the juice film and the water vapor flow concurrently down the tube; the juice flows down the wall as the vapor flows in the central area of the tube. The centrifugal pumps that transfer the juice to the succeeding stage operate continuously in a cavitating, or almost cavitating, condition.

As juice is transferred from stage 3 to stage 4, it must be reheated to a higher temperature (140°F) to effect sufficient flashing. Reheating is typical for any effect that has more than one stage. These stage divisions are necessary when water removal renders the remaining juice insufficient to wet the total required surface for that effect. Then flash cooling quickly reduces the concentrate from 117°F to the pump-out temperature of 60°F.

On a TASTE, vapor flow is fixed and virtually unalterable. Although the juice flow shown in Figure 2 is concurrent with the vapor, in many cases it is mixed flow, in which the juice may first be introduced to an intermediate effect before being delivered to the first effect. In all cases, however, the essence-bearing material must be recovered from the vapor stream that is produced where the juice first enters the evaporator.

Figure 2 also shows an essence recovery method. Several different systems for essence recovery are used, some of which are proprietary. The refrigeration load for essence recovery is relatively small, usually 3 to 5 tons, according to evaporator capacity.

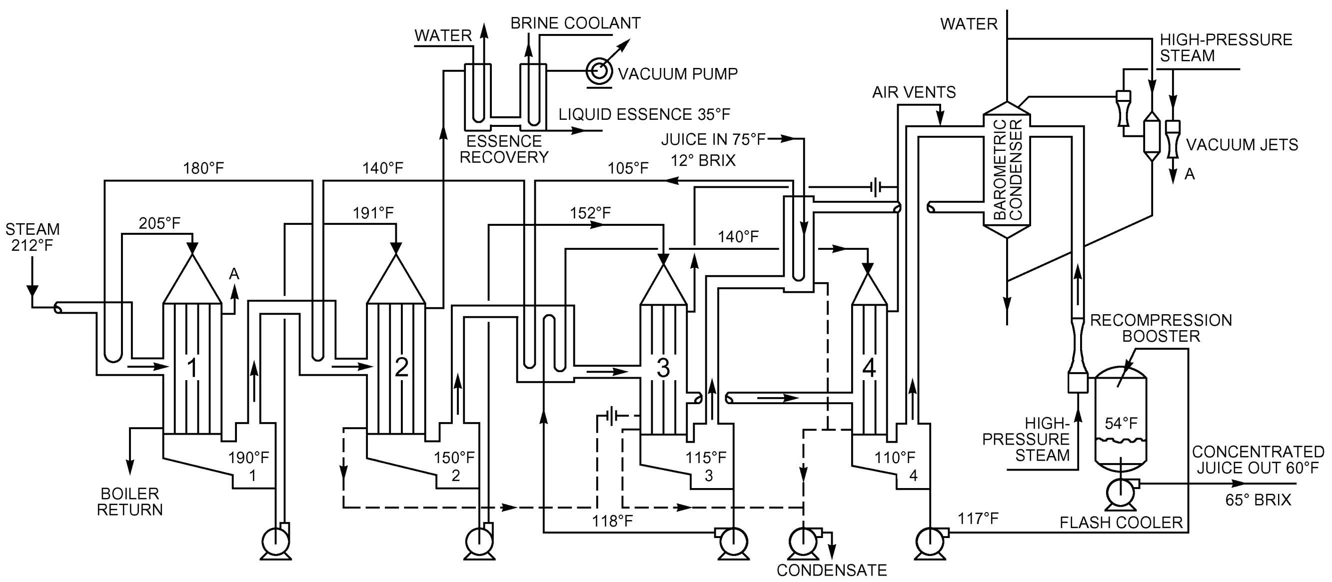

Fig. 2 Thermally Accelerated Short-Time Evaporator (TASTE) Schematic

Freeze Concentration

In the freeze concentration system, juice is introduced and pumped rapidly through a swept-surface heat exchanger in which ice nuclei are formed at about 28°F. This slurry is delivered to a recrystallizer, in which small crystals are melted to form larger crystals. The slurry of larger crystals, together with the resultant concentrate, is delivered to the wash column, where the ice rises. As it does, chilled water (melted ice) is introduced at the top to wash the ice crystals; these continue to rise and melt as they reach the top of the column. The concentrate (now ice-free) is drawn off the bottom of the wash column.

At first, centrifuges were used to separate ice crystals from concentrate, but because of poor separation and attendant problems with crystal washing, the losses of orange soluble solids were unacceptable. The proprietary wash-column process drastically reduces these losses. The output concentration of commercial freeze concentration equipment is presently limited to under 50° Brix.

When first-quality oranges are used to prepare the juice, freeze concentration makes a concentrate that is indistinguishable from fresh juice. However, first costs for equipment and installation are relatively high, and operating costs at best are the same as for modern evaporators. The cost is high despite the 144 Btu/lb required to freeze water, as opposed to about 1000 Btu/lb for evaporation. A contributing factor is the relative cost of electricity (compressors) versus steam from fossil fuel. Another factor is that, by using multiple-effect evaporators, the 1000 Btu/lb can be divided by the number of effects in the evaporator, thus reducing the energy requirement to the range of 150 to 250 Btu/lb, depending on the number of effects.

QUALITY CONTROL

The most important factor in quality control is using good, sound fruit, but quality must also be checked during processing and again in the final product. Standards for the various concentrates describe the quality and serve as a basis for grading. Concentrates are checked for Brix value, Brix-acid ratio, peel oil content, and other factors. Additionally, tests may be run to ensure that other requirements of a particular brand are met. At periodic intervals, bacteriological samples are taken during various stages in the plant, plated on orange serum agar, and examined after incubation. Although the necessary sanitation measures are known, bacteriological samples serve as a check and indicate whether the procedures have been effective.

In warm weather, cleanup must be more stringent and more frequent than during cold weather. TASTEs can run for only 6 to 12 h before substantial loss of evaporation or the release of hesperidin crystals forces a cleanup cycle. These cycles are normally spaced to coincide with other required cleaning in the juice extraction system and often take no more than 30 min of production time. Thermal conditions in a properly operated TASTE are so adverse to microorganisms and enzymes that these do not influence the cleaning cycle. Normally, low-temperature evaporators are cleaned at least every 24 h; however, in some instances when arrangements are favorable, they may run as long as 7 days between cleanups. Total plate counts in final product are generally maintained well below 10^6 organisms per millilitre of reconstituted juice. Counts of a few thousand per millilitre are common and indicate a high degree of plant cleanliness. Sanitation is based on asepsis rather than antisepsis. The natural acidity and high sugar content of citrus juice concentrate normally inhibit rapid growth of organisms. Generally, counts tend to decrease in storage.

CHILLED JUICE

Chilled juice is usually packed either in fiber cartons or in plastic bottles or jugs. The ideal storage temperature is about 30°F, but it is frequently handled in the retail trade at 40 to 45°F and is typically stored in household refrigerators. Normal shelf life is 3 to 4 weeks.

Chilled juice is marketed in two basic forms: “from-concentrate” and “not-from-concentrate.” Because of higher overall costs, the not-from-concentrate product is higher-priced. Figure 1 shows the processing steps for each of the two products. The sole difference in the two products is the source of the juice.

From-Concentrate Juice. Bulk concentrate, taken either from partially thawed drums or from bulk storage, is mixed in a blending tank with water, essence, and cold-pressed oil so that it is reconstituted to about 12° Brix. This juice is then processed in a three-stage pasteurizer. First, the juice is preheated in a regenerative section that recovers heat from juice leaving the pasteurizing section. It then flows to the pasteurizer, where it is steam-heated to 180 to 190°F. Then it flows back through the regenerative section, where it is partially cooled by incoming juice. Finally, it passes through the cooling section, where it is cooled to about 30°F. A refrigerated glycol/water solution usually serves as the chilled brine for this purpose. These pasteurizer units are usually plate units, but tubular equipment is also used. From this point, every effort is made to maintain the juice at 30°F as it is packaged and placed in 30°F storage.

Not-from-Concentrate Juice. When fruit is mature and in season, fresh juice may be taken directly from extraction to pasteurizing and packaging. No blending is required, and the remaining process duplicates that for the from-concentrate product. However, unless special means are used during extraction, the peel-oil content of the juice may be excessive. A low-oil extraction method or heating and flashing the juice in a special deoiler before pasteurizing can remove excess oil.

Because not-from-concentrate chilled juice is in demand year-round and mature fruit is only available a maximum of 8 months per year, two storage methods are commonly used to ensure year-round supply: (1) store the juice in large bulk tanks in an aseptic environment at a temperature just above the freezing point or (2) freeze the fresh juice and store in a solid form at about 0°F.

The aseptic system usually involves a number of large storage tanks in a cold room. These tanks are commonly built to hold one million gallons or more of juice. Most of these tanks are constructed of carbon steel with a special interior lining; however, some are constructed entirely of stainless steel. The entire system must be carefully sanitized before use and must be so maintained during use. Juice is pasteurized and cooled before introduction to the tanks.

Freezing fresh juice predates the aseptic liquid method, and involves cooling the juice to about 30°F before placing it in a container for freezing. The choice of container is related to (1) the rate at which the juice will be frozen and (2) the method used to thaw the product and remove it from the container for later processing. In some instances, the advantage for freezing may be counterbalanced by disadvantages for thawing and removal.

For example, juice may be cooled, placed in an open-top drum, and immediately transferred to –10°F storage, where it will slowly freeze. The product quality will be satisfactory, but thawing and dumping the product from the large drum is difficult. In another method, the juice is frozen and stored in a specially constructed container. Later, it is fully thawed and pumped from the container. In still another method, the juice is encased in a plastic bag and then quick-frozen in a blast freezer room. Thawing and removal methods are similar to those for drums. Some juice is also stored in open ice blocks, which make recovery easier but make the juice more susceptible to contamination or losses.

A third distinct method of providing fresh juice in the off-season is to store fresh oranges under refrigeration for extraction of juice as required. This method requires large cold rooms held at about 30 to 32°F. In many cold storages, moisture must be added to keep the air at saturation. Added moisture, however, increases the refrigeration load because all condensate from the cooling coils must be recycled to the conditioned space. Because of cost and other limitations, fresh fruit is seldom stored for juice.

REFRIGERATION

Refrigeration Equipment

The choice of refrigerant for juice processing is almost universally R-717 (ammonia), although a few small systems use R-22. R-22 is sometimes used in freeze concentration systems, although ammonia has also been used for this purpose.

High-stage compressors have been of the reciprocating type, but to meet greater demands, there is a trend toward rotary screw compressors.

Most condensers are evaporatively cooled. Exposure to subtropical climatic conditions makes construction materials an important consideration. In Florida, water conditioning is critical because the available makeup water has a high mineral content.

The most common refrigerant evaporators in cold rooms and blast freezing tunnels are finned or plain coils. In larger installations, a single, low-pressure receiver serves a multitude of coils. Liquid refrigerant is pumped through the coils at two to three times the evaporation rate, and the liquid/gas mixture is returned to the low-pressure receiver, from which the compressors take their suction. At refrigerant temperatures below 32°F, coils must be defrosted on a regular basis, generally by hot gas from the compressor discharge manifold. Some smaller ammonia installations use air units, each with its own surge drum and controls for flooded operation. Small installations using R-22 are usually direct-expansion, and some use electric or water defrost.

To solve coil defrosting problems, some cold rooms and freezing tunnels operate with continuous defrost, in which a strong solution of propylene glycol is sprayed continuously over the coils. The weaker glycol solution is removed, and acquired water is driven off in an external concentrator. Unless extreme care is used in designing the eliminators, the glycol solution may be entrained and deposited on the containers. The resultant appearance of the containers is unacceptable. More information on coil defrost can be found in Chapter 3.

Another common evaporator is a shell-and-tube unit that chills a secondary coolant, typically propylene glycol. Ethylene glycol should not be used for food processing because it is toxic. Plate juice processors require large volumes of chilled polypropylene glycol. Although the refrigerant can be supplied directly to a gasketed plate heat exchanger, most heat exchangers do not satisfy the pressure requirements of the refrigerant.

Freezing tunnels using an alcohol-water solution chilled in shell-and-tube equipment have been constructed. The chilled solution was sprayed over the containers for quick freezing. These tunnels are now largely obsolete and have been replaced with blast units.

Swept-surface heat exchangers for concentrate precooling preparatory to can filling were also used. These units operated as flooded refrigerant systems, but most have been replaced by plate units, which also require glycol coolant. Today, application of swept-surface units is generally limited to freeze concentration systems.

A typical installation has a number of small loads, including

- Essence recovery (condensing of water vapor laden with essence). This load is typically handled with shell-and-tube equipment either by direct expansion or with a secondary coolant (glycol).
- Winterizing of cold-pressed oil in order to form precipitates of undesired materials in a quiescent storage vessel. The process goes forward at about 0 to –40°F and requires months of storage. Winterizing may be done in 55 gal drums in a cold room or, preferably, in a jacketed tank using direct refrigerant expansion or very cold glycol.
- Storage of essence. Tanks of essence may be stored in a 30 to 33°F cold room or in an outdoor insulated storage tank in which heat gain is removed by continuous recirculation of the essence through an external plate heat exchanger cooled by glycol brine.

Refrigeration Loads

Refrigeration loads vary not only with plant throughput but also according to the relative rates at which different products are processed. For a given amount of consumable product, the volumes of chilled juice are higher than those for concentrates by a factor of 4:1 to 6:1. Thus, the refrigeration load depends largely on the proportions of concentrates and chilled juices being processed.

To illustrate the magnitude of the refrigeration loads, the following fixed set of processing conditions is assumed. All percentages are percentage of total throughput of **soluble solids**.

- The plant has an operating evaporator capacity of 100,000 lb/h of water removal.
- 10% is packed as not-from-concentrate chilled juice. Of this, half is packaged directly for immediate sale; the remainder is frozen for storage and use during the off-season.
- 90% is processed into concentrate, which is made up of 85.5% fed to the evaporator and 4.5% reserved for use as cutback to make 42° Brix retail packs.
- Of the concentrate from the evaporator, 30% is packed in bulk for later use as from-concentrate chilled juice; an additional 24% is similarly packed for later use as retail frozen concentrate.
- The remaining 31.5% from the evaporator is blended with the 4.5% cutback (to total 36%). This is packed into retail containers at 42° Brix and immediately frozen.
- The chilled juice line processes 30% of the concentrate (i.e., same as quantity from the evaporator stored for this purpose).

Given these conditions, plant refrigeration loads would be approximately as follows:

	Refrigeration, Tons	
	Low-Stage	**High-Stage**
Process	250	640
Cold storage	150	280
Miscellaneous loads	—	100
Total	400	1020

Compressor Manifolding

In most cases, low-stage compressors have their own isolated high-stage machines, with an intermediate pressure of 30 to 35 psig. The remaining high-stage compressors are usually paralleled to handle all other high-stage loads at a somewhat lower suction pressure (15 to 20 psig) to optimize power requirements.

Frequently, these systems operate as central systems, with all condensers manifolded using a common receiver.

PURE FRUIT JUICE POWDERS

One manufacturer successfully produced a vacuum-dried orange juice powder. In this **puff-drying** process, concentrate of about 58° Brix is introduced into a vacuum chamber, where it is dried on a moving stainless steel belt. The dried powder is flavored with a locked-in orange oil prepared by dispersing orange oil in a mixture of molten sugars, extruding, and cooling rapidly. The oil is thus kept out of contact with the powdered orange juice until water is added to reconstitute the juice.

Another process, known as **foam-mat drying**, has been under investigation for citrus juices. In this process, a small amount of foam stabilizer is added (0.5% of dry solids content), and the chilled concentrate of about 50° Brix is beaten into a foam. This foam is laid out in a sheet about 1/8 in. thick on perforated trays. An air blast clears the foam from the holes, and the stacked trays are conveyed up a column while hot air passes up through them and reduces the moisture to about 1.25% in 12 min. The product is then chilled until it hardens and is scraped from the trays. In a variation, a thin layer of foam is placed on a polished stainless steel belt, dried in a stream of hot air, and finally stripped from the belt in dried form with a doctor blade.

Both puff-drying and foam-mat drying were developed through U.S. Department of Agriculture (USDA) research.

OTHER CITRUS JUICES

Grapefruit Juice

Production of frozen concentrated grapefruit juice uses essentially the same equipment as production of frozen concentrated orange juice does. Some adjustments at the extractors are necessary to accommodate grapefruit. Because bittering is considered a defect, debittering systems may also be used to improve the flavor.

Both sweetened and unsweetened frozen concentrate grapefruit juices are prepared (the sweetened product in greater quantities). The final unsweetened product may vary from 38 to 42° Brix. The sweetened product must contain at least 3.47 lb of soluble grapefruit solids per gallon exclusive of added sweetening ingredients. The final Brix may vary from 38 to 48°. In Grade A unsweetened concentrate, the Brix-acid ratio may vary from 9:1 to 14:1; in the sweetened product, the ratio may vary from 10:1 to 13:1. All the types mentioned are 3-plus-1 concentrate. Either seedless or seeded grapefruit can be used, but seeded varieties, such as Duncan, are generally preferred.

Blended Grapefruit and Orange Juice

The same procedures are used in producing a grapefruit and orange juice blend as are used in preparing the separate products. USDA grade standards recommend no less than 50% orange juice in the mixture and as much as 75% orange juice when it is light in color. Military specifications require 60 to 75% orange juice. USDA grades require 40 to 44° Brix in unsweetened concentrates. In sweetened concentrates, the Brix must be at least 38° before sweetening and 40 to 48° after sweetening. For Grade A, the Brix-acid ratios in the packed concentrate may vary from 10:1 to 16:1 if unsweetened, and from 11:1 to 13:1 if sweetened.

Tangerine Juice

Tangerines require different methods of handling during picking, hauling, and storage at the plant. Whereas the grapefruit and orange are generally round, quite firm, and able to withstand considerable rough handling, the tangerine is somewhat flat and irregular in shape and has a loose, tender skin that is easily broken. If the skin is broken and the fruit bruised, bacteria and yeasts readily attack the fruit, and undesirable enzyme actions occur. Thus, tangerines cannot be handled in orange bins but must be handled in boxes or loose in trucks to a depth of no more than 2 ft.

The processes and equipment used in manufacturing concentrated tangerine juice are practically the same as those used with oranges. Because the fruit is smaller, the yield of juice from a given number of extractors is smaller, and about twice the extracting equipment is required to furnish enough juice to keep the evaporators operating at full capacity. Generally, values for Brix-acid ratio, peel oil content, and concentration have followed those prescribed for the orange product. Recently, more of the pack has been sweetened, and there has been a trend toward packing at a higher concentration. A Brix of 44° is common for a 3-plus-1 concentrate.

NONCITRUS JUICES

PINEAPPLE JUICE

Pineapple juice is prepared from small fruit and the parts of larger pineapples that are unsuitable for packing as fruit pieces. The main sources are the cores, the layer of flesh between the shell and cylinder that is cut for the preparation of pineapple slices, and the juice that drains from crushed pineapple: altogether, about one-third of the weight of the fresh fruit. Pieces of shell and spoiled flesh are removed during inspection. Juice is extracted by passing through disintegrators and screw presses. It is then centrifuged to remove heavy foreign material and excessive insoluble solids. Processing up to this point is the same for both single-strength and concentrate.

Pineapple concentrate is produced from single-strength juice in equipment similar to that used to produce orange and other fruit juice concentrates. The first step in the concentrating operation is to strip out the volatile flavoring materials. These are separated as about a 100-fold concentrate and added back to the final concentrate. Concentration occurs in multiple-effect evaporators.

Pineapple concentrate is produced either as a 3:1 product with a Brix of about 46.5° or as a 4 1/2:1 product with a Brix of about 61°. The 3:1 concentrate is produced in both a sterile form and a frozen form. However, even the sterile product is stored and sold under refrigeration in order to preserve quality. The 4 1/2:1 concentrate is also produced in both a sterile form and a frozen form. It may be held for short periods without refrigeration, but it should be stored at 40°F or lower. The frozen 61° Brix concentrate is packaged in polyethylene bags and held in 7 gal fiber containers. This product is stored under refrigeration.

Bulk pineapple concentrate is used principally for mixing with citrus concentrate to produce frozen juice blends. Pineapple concentrate is also used as an ingredient in many types of canned fruit drinks.

The composition of pineapple juice varies greatly. Brix varies between 12 and 18°, with an average of about 13.5 to 14°. Brix-acid ratio ranges from 12:1 to over 20:1 and usually averages between 16:1 and 17:1. Because pineapple concentrate is produced at a standard Brix, variation in composition shows up only in the acidity and the Brix-acid ratio.

APPLE JUICE

Evaporative procedures include some method of essence (ester) recovery for incorporating the volatile components of apple flavor into the final concentrate. These procedures are designed to take advantage of the fact that in the distillation of apple juice, most of the volatile flavors are found in the first 10% of the distillate. This portion of distillate is passed through a fractionating column to obtain the volatile flavors in concentrated form, usually about 100-fold compared to the fresh juice. The remaining 90% of the original juice, now stripped of its volatile flavors, is then concentrated under vacuum to somewhat more than the concentration desired for the final product.

For example, 100 gal of apple juice prepared in a conventional manner may be treated to yield 1 gal of 100-fold essence and 24 gal of concentrated stripped juice. The combination of these two fractions yields full-flavored fourfold concentrate. If a higher concentrate is desired, the stripped juice is concentrated to a greater extent. In such instances, however, the juice must be depectinized to avoid excessive viscosity and gelation of the highly concentrated juice.

One report shows that fourfold apple juice (depectinized) concentrate was essentially unchanged after one year of storage at 0°F. Similar information on concentrate prepared without depectinization is not available.

GRAPE JUICE

Concord Grapes

Most of the concentrated grape juice marketed in North America is prepared from Concord grapes (*Vitis labrusca*) grown in New York, Michigan, Washington, Pennsylvania, Ohio, Arkansas, and Ontario. The grapes are harvested when the soluble solids reach a concentration of 15 to 16%. This varies with maturity and is influenced by cultural and climatic factors.

After washing, Concord grapes are conveyed to the stemmer, which consists of a perforated, slowly revolving (20 rpm) horizontal drum with several beaters inside, revolving at a much faster speed (200 rpm), to knock the berries off the cluster and partially crush them before they are discharged through the drum perforations. Cluster stems are expelled from the open end of the drum. The crushed fruit is then pumped through a tubular heat exchanger, where it is heated to 140 to 145°F for good extraction of pigments and juice. The hot pulp then goes to hydraulic presses, where juice is removed in the same manner as apple juice. Expressed juice may be clarified in a centrifuge or filter press; the latter uses 1 to 2% diatomaceous earth to maintain a high filtering rate and remove a substantial amount of suspended matter. Under normal operating conditions, 190 to 195 gal of juice are obtained from a ton of grapes. In some plants, screw presses are used to remove juice from all or part of the crushed grapes, but this increases the amount of suspended matter to be removed later.

Clarified juice is pasteurized in tubular or plate heat exchangers to a temperature of 180 to 190°F and cooled immediately to 30°F before storage in tanks in refrigerated rooms maintained at 28°F. The juice is usually cooled in two or more steps. Some heat exchange systems begin with a regeneration cycle, in which hot juice leaving the pasteurizer preheats entering juice. Cooling water discharged from the heat exchangers may be piped to the washers to heat the water applied to the incoming grapes.

The method of handling the cooled juice depends on its intended use. If it is to be used in jelly manufacture, the juice is stored at 28°F for 1 to 6 months to permit settling of the **argols**; these consist of potassium acid tartrate, tannins, and some colored materials that would give a gritty texture to the jelly or detract from its clarity. Clear juice is siphoned off the precipitate in the storage tanks and may be refiltered. If the concentrate is to be sold as a blend formed by mixing in sugar and ascorbic acid before canning and freezing, the cold storage tank merely serves as a surge tank, because juice is pumped out to the concentrator within a few hours. A polishing filter is used before the concentrator to minimize fouling of the evaporator tubes. Concentrates for both jelly manufacture and blended juice may be stored in tanks at 27°F before processing. Whenever single-strength juice is bulk-stored at 27°F before concentration, spoilage by fermentation is a danger. To minimize yeast growth during storage, all pipelines and equipment from the pasteurizer to the cold room should be designed for ready and frequent cleaning. Interior surfaces of storage tanks must be relatively smooth and free from crevices, and the tank should be thoroughly cleaned before use.

Concentration involves two steps. First, volatile flavoring materials are stripped from the juice, and the stripped juice is then concentrated to the desired density. Volatile components are removed by heating the single-strength juice to 220 to 230°F for a few seconds in a heat exchanger, flashing a percentage of the liquid into a vapor in a jacketed tube bundle, and discharging the liquid and vapor tangentially through an orifice into a separator. The separator should be large enough to reduce the vapor velocity to 10 fps or less for minimal entrainment. Twenty to 30% by mass of the original juice flashes off as vapor, which is led into the base of a fractionating column filled with ceramic saddles or rings. A reflux condenser on the vapor line from the column and a reboiler section at the base of the column provide the necessary reflux ratio. Vent gases from the reflux condenser are then chilled in a heat exchanger, and the condensate containing the essence is collected at a rate equivalent to 1/150 of the volume of entering flavoring material.

Methyl anthranilate, which has a boiling point of 512°F and is only slightly soluble in water, is an important flavor component of Concord grape juice. Its high boiling point and low solubility cause losses when the stripping column's efficiency is low. These losses may be reduced by increasing the vaporizing temperature.

In a typical formulation, grape juice is concentrated to a little over 34° Brix, and essence or fresh cutback juice is added to reduce it to 34° Brix. Sucrose is added to achieve 47° Brix, and citric acid is added until the total acidity is 1.8% calculated at tartaric acid. The concentrate may be cooled to 20 to 30°F in a heat exchanger or cold wall tank, filled into cans, sealed, cased, and allowed to freeze in subzero storage. When diluted with an equal quantity of water, this concentrate yields the equivalent of sweetened single-strength juice; however, for a more palatable beverage, three parts of water are added. The product is labeled as concentrated, sweetened grape juice.

Muscadines

Muscadines (*Vitis rotundifolia*), typical of the southeastern United States, differ from *V. labrusca* in that they grow not in clusters but as individual berries, so there is no need to destem them. These grapes are processed into juice as follows: grapes are harvested, transported in trucks to the receiving station, dumped into hoppers, and crushed with potassium persulfate ($K_2S_2O_8$) to give 50 ppm free sulfite.

After crushing, the grapes are conveyed into a pneumatic press (without heating), and pressure up to 75 psi is exerted. Once the juice is extracted, it is quickly pasteurized as it passes through a plate heat exchanger that heats it to about 185°F. The juice is partially cooled, and a mixture of pectinases and cellulases is added to clarify it. After 1 to 2 h, the juice is passed through an ultrafiltration (UF) tubular unit with 2.0 μm pores for filtering. The juice is then repasteurized and cooled to 45°F in plate heat exchangers and sent to large refrigerated storage tanks for removal of tartrate and sediment at 28°F. Some of the juice is concentrated to about 65° Brix in a triple-effect evaporator with an essence recovery system. This concentrate is field-frozen and used later for bottle juice. When ready to bottle, juice is pumped through the UF unit, bottled and capped, and passed through a pasteurizer/cooler in a conveyor belt.

STRAWBERRY AND OTHER BERRY JUICES

Frozen strawberry juice concentrate, a sevenfold concentrate with separately packed concentrated (100-fold) essence, is used for manufacturing, especially jellies. Availability of sevenfold frozen concentrate also allows marketing of high-quality strawberry juice solids. Concentrates of red raspberry, black raspberry, and blackberry juices are also available in limited quantities.

Preparation of strawberry and other berry juice concentrates involves essence recovery in which 12 to 20% of the juice is separated by a stripping process using a steam injection heater. Vapors containing volatile flavors are concentrated in a fractionating column to the desired degree. Juice remaining after the essence recovery step is concentrated under vacuum three- to sevenfold by volume. For strawberry juice, a maximum temperature of 100°F for 2.5 h should not be exceeded, whereas temperatures up to 130°F may be used in preparing batches of boysenberry.

Preparation of juice for concentration involves chopping or coarse milling of cold, sound berries and mixing with pectic enzymes and filter aid. After several hours (4 to 5 h at room temperature), juice is expressed with a bag press or rack and clothes press. The cloudy juice is clarified in a filter press. Recovered essences are concentrated and packaged separately so that the jelly manufacturer can incorporate the essence in the jelly just before filling. This procedure greatly reduces the amount of essence lost by volatilization. The essence can also be incorporated in the concentrate to make a full-flavored product for shipping as a single unit.

Concentrated juice without essence can be packed in enamel-lined containers that need only be liquid-tight. Concentrated essence should be kept in carefully sealed cans to avoid loss of the highly volatile flavor. Both juice concentrate and essence are kept frozen for proper quality retention.