CHAPTER 12

GRAPE JUICE

12.1 Importance

The United States of America is the largest user of grape juice and grape juice concentrate. About 25 percent of the 1999 crush was channelled into juice concentrate. From 1998 to 1999 the quantity of imported grape juice rose a whopping 50 percent and greatly exceeded exported juice. Imported grape juice and concentrate is on the rise. Thirteen nations combined to import grape juice and concentrate into the United States of America, Argentina having 70.3 percent share in 1999. Grape juice and concentrate accounted for 9.5 percent of the value of all 1999 imports of fruit juices and concentrates and is increasing. For comparison, orange juice market makes up 37 percent, apple 28 percent followed by pineapple and grape (Larsen, 2000).

The volume of grapes processed for beverage use worldwide (including wine and beverage alcohol) exceeds any other individual fruit. Indeed, many of the grape selection and juice preparation steps are common to both even to the extent that fruit not meeting juice standards can be used for wine and ultimately beverage alcohol. In contrast, grapes not meeting wine quality standards would rarely end up as juice. (Curiously, premium “world class” wine grapes make mediocre juice.) An appreciable amount of the fresh market seedless grapes, especially ‘Thompson seedless’, end up as concentrate juice, primarily for blending purposes. However, for juice and juice beverages where grape character is important, other species and cultivars are most prominent.

The first grape juice processed in the United States of America was used as the sacrament on the communion table of the Vineland, New Jersey, Methodist Church. Dr. Thomas B. Welch, a dentist, processed the juice, derived from Concord grapes (*Vitis labruscana* L.). Concord juice and Concord blends have become the standard for quality red grape juice around the world. For white juice, Niagara along with Delaware and Catawba and various labrusca blends are gaining in popularity.

Nevertheless, any grape cultivar with acceptable fresh eating quality can be used for juice. With creative blending (Chapter 9) even those of marginal juice quality can be utilized, providing the grapes are not spoiled or otherwise contaminated.

12.2 Grape juice composition

The composition of grape juice is similar to that of whole grapes except that crude fibre and oils, which are primarily present in the seed, are removed. Sugars, acids, methyl anthranilate (*in Vitis labruscana*), volatile esters, alcohols and aldehydes are major flavour constituents. Glucose and fructose are the major sugars present in grape juice. The quality of grape juice largely depends upon sugar level, acid content and flavour constituents such as methyl anthranilate and other volatiles, tannins and colour substances. Changes that occur in grapes during growth and maturation determine quality of the juice.
The principal acids of grape juice are tartaric, malic and citric, but small quantities of other acids are present. Flavour and aroma develop during the ripening process. Colour in grape juice is largely the result of anthocyanin pigments located in and near the skin. Moreover, the types and quantities of anthocyanin pigments are different among grape species. The differences in the types of anthocyanin help to explain why some grapes have better colour stability and are more suitable for juice processing than others.

The specific composition of juice from any grape species can never be assumed since composition varies from year to year and changes continually during ripening (De Golier, 1978). Likewise, the composition of a given species and cultivar will vary from area to area depending upon soil, location and climatic conditions. In general, as fruit matures, the sugar and colour increase and the pH and titratable acidity decrease.

The Concord grape juice industry has determined that the best objective index to determine optimum maturity is percent soluble solids. It has been reported, for instance, that around Lake Erie ideal flavour, acid and colour levels occur in grapes when the soluble solids value is between 16 and 17 percent (Morris and Striegler, Somogyi, et al., 1996b). The juice industry determined that as the percent soluble solids of Concord grapes increased above 18 percent, flavour and acid decreased; consequently, quality decreased. Concord grapes that are harvested in the range of 14 to 15 percent soluble solids have excess acidity and inadequate flavour-aroma components and may have insufficient colour. The Concord juice industry usually uses 15 percent soluble solids as the lower level of acceptable quality and pays a premium for grapes based on each increase in percentage soluble solids up to 18 percent. However, most cultivars of Vitis vinifera, the major wine grape throughout the world, produce grapes that are much higher in percent soluble solids, but lower in acid at harvest. It is not uncommon for these grapes to produce juice that is 22 to 25 percent soluble solids.

Because of the industry emphasis on the importance of the value of percentage soluble solids to quality, most of the literature dealing with the effects of pre-harvest variables on fruit and juice quality has used percentage soluble solids as the major index for quality. However, this is not the best method of predicting quality. To properly evaluate juice quality, it is important to consider all major quality attributes such as flavour, pH, acidity, colour along with percentage of soluble solids.

12.3 Pre-harvest factors influencing grape juice quality

Among major pre-harvest conditions that influence quality of grape juice are climate, soil, cultivar, vineyard management and maturity. Each of these factors exerts its own influence, but complex interactions among these factors must be kept in mind.

12.3.1 Climate

The maximum, minimum and average temperatures as well as the daily pattern of heat accumulation and solar energy level have to be considered in looking at the overall site (Somogyi, et al., 1996b). Rainfall, clouds and fog and their distribution through the season are important along with other water and solar factors.
12.3.2 Soil

Loose soils with moderate fertility and excellent drainage characteristics are best. This ideal situation and all conditions that vary from the ideal require different vineyard management systems to obtain maximum juice quality.

12.3.3 Cultivar

Concord is the grape cultivar most widely used for juice production and the United States accounts for the vast majority of the world’s Concord production. It is a rare grape cultivar that can produce juice with a balance of sugars, acids, flavouring substances, astringent characteristics and aroma as palatable and as well recognized by the consumer as Concord juice (Morris, 1985). Also, the highly flavoured Concord grape juice imparts a rich flavour after dilution and sweetening.

Other cultivars for dark juice are Fredonia, Van Buren, Sheridan, Ives and Clintonnes. Sunbelt is a new cultivar released from the Arkansas Agricultural Experiment Station. It has proven to be an outstanding juice grape cultivar in southern or warm production regions. Among white grapes, Niagara has become the standard for juice because of its unique aroma and flavour. Commercially, Niagara is usually blended with the less expensive and neutral Thompson Seedless juice from California. Cold-pressed Catawba, Isabella, Ontario and Seneca have been used for white juices, usually blended. California has greatly increased their production of grape juice concentrate, a great deal of it being the Vitis vinifera type. Vitis vinifera grapes are the most widely planted grape cultivars in the world.

The juice of muscadine grapes (Muscadinia rotundifolia) has a unique bouquet. It is appreciated by people in the Southern part of the United States of America, where it is native and its flavour is well known by the consumer. Cultivars vary in colour from almost white to pink, red, blue, purple and nearly black. Blends have a beautiful colour and a refreshing taste (Bates and Sims, 2001; Morris and Blevins, 2001).

12.3.4 Vineyard management

Pruning and training systems, fertilization, irrigation, application of growth regulators and pest control measures are vineyard management operations that can influence juice quality. Maintaining an adequate and balanced mineral nutrition program is a major factor in producing high fruit yields and quality grapes. It is not uncommon to create fruit quality problems with excessive nitrogen fertilization that results in excessive vigour and subsequent fruit shading. Also, excessive potassium (K) can result in quality problems. Excessive K levels in the juice were detrimental to fresh juice colour quality and stored juice colour stability, making a balanced K fertilization program highly important in vineyard management of grapes.
12.4 Harvest and postharvest factors influencing grape juice quality

Morris (1985) found that in harvest maturity, the flavour and sugar/acid ratio of Concord juice was directly related to maturity, making harvest dates crucial determiners of juice quality. Most grapes used for juice are mechanically harvested. It was shown that mechanically harvested grapes are of better quality than hand-harvested grapes. Effects on the quality of machine-harvested grapes can be altered or influenced by six major factors:

- Type of machine
- Cultivar
- Production system
- Harvest temperature
- Interval between harvesting and processing
- Postharvest handling system.

Muscadine grapes present a major problem for once-over machine harvesting, since, unlike other commercial Vitis species, many cultivars of muscadine do not ripen uniformly. The presence of immature fruit in an once-over harvest is undesirable, since it lowers the quality of the processed product. Lanier and Morris (1979) developed a system for sorting machine-harvested muscadine grapes into maturity classes using a density sorting system. It provided a rapid and inexpensive way of removing fruit of undesirable maturity. The ease of berry detachment from clusters, spherical shape of the muscadine berry and relatively small variation in fruit size characterizes it as ideal for mass density sorting.

12.5 Juice production

Figure 12.1 illustrates a generalized flowchart for grape juice production. There are several options for juice extraction and subsequent treatment. Methods for commercial preparation of grape juice have undergone continuous change. In most commercial operations, the continuous pressing method is used. Hot pressing is appropriate for deeply pigmented grapes where maximum colour extraction is desired. Whereas, the immediate or cold press procedure is necessary to maintain the initial colour of light coloured grapes.
Figure 12.1: Grape juice manufacture flowchart.

Figure 12.2: Hot press enzyme treatment.
Prior to rice hull addition (bucket on left)
12.5.1 Hot press

Hot-press juice production involves the addition of a pectolytic enzyme to break down naturally occurring pectins and it uses paper pulp or rice hulls as press aids to facilitate extraction of juice (Figure 12.2). A hot-press method yields more juice that contains higher total solids, more non-sugar solids, tannins, pigments and other substances than a cold-press juice operation. When hot pressing, the temperature and time in processing can be varied within a range to produce juice with uniform colour from grapes harvested throughout the season. Excessive extraction temperatures (exceeding 65°C or 150°F) must be avoided to preserve juice quality.

Following the schematic in Figure 12.3, harvested grapes are dumped into a hopper and transported by augers or pumps to a rotary stemmer-crusher that separates the fruit from the stem. The crushed berries are pumped through a steam-jacketed, vacuum preheater in which the pulp is heated to 60 to 63°C and passed into holding tanks. At this point, slow-moving agitators mix pectolytic enzyme and ~7 Kg of purified paper pulp (as a press aid) into each 1 000 Kg (metric tonnes, MT) of grapes. It takes between 30 and 60 minutes for the enzyme to break down the pectin to make the grape pulp ready for pressing. This part of the process helps to extract colour from the skins into the juice (Tressler and Joslyn, 1971).

Next, a dejuicer removes 30 to 35 percent of the free-run juice through a 40-mesh screen. The remaining pulp empties into a continuous screw press. The free-run juice may have as much as 20 to 40 percent suspended solids and is combined with the pressed juice that may have only 5 to 6 percent. The combined juices have most of the soluble solids removed by rotary vacuum filtration, pressure leaf filtration or centrifugation (Figures 6.14, 6.15 and 6.16). This process yields approximately 820 L of juice per MT of grapes. An additional 40 L of juice (after the juice and water have been concentrated) may be obtained
by breaking up the press cake, spraying it with hot water and re-pressing. (This operation involving the addition of water to extract additional soluble solids is not permitted in table wine manufacture).

Grapes are unique from other fruits in that after juice extraction, the argols (potassium bitartrate, tartar in crude form) and tartrates must be precipitated. Otherwise, the argols will settle out upon cooling or even when filtered juice is refrigerated. These crystals, although harmless, are aesthetically unpleasant and can be mistaken for glass fragments. Thus to accomplish detartration (cold stabilization), the filtered juice is flash-heated at 80 to 85°C in a tubular or plate-type heat exchanger, rapidly cooled in another heat exchanger to -2.2°C and placed in tanks for rapid settling of argols. Seeding with bitartrate crystals and ion exchange methods exist to accelerate the cold stabilization step. The final processing into a single-strength juice or concentrate can occur once the argols have settled and the juice is racked off. The sediment can be filtered, resterilized and stored to allow the argols to settle again for optimal recovery of juice. The juice is now passed through a heat exchanger (heating it to 77°C) into an automatic filler and then into preheated bottles. The bottles are capped, pasteurized at 85°C for 3 minutes, cooled and labelled. In newer operations hot fill into plastic or aseptic packing are increasingly the methods of choice in grape juice processing (Chapter 8), although glass bottles still present a quality image.

12.5.2 Cold-press

The major difference between this method of juice production and the hot-press methods are the steps that allow for heating of the crushed berries to 60 to 63°C and holding in tanks with pectolytic enzymes. Without these steps, the dark colour from the dark-skinned grapes is not adequately extracted and the juice is a lighter colour. However, light coloured grape cultivars, lacking skin pigment and yielding a light green to yellow juice, cannot be hot pressed. Enzymes may be added to the cold-press juice to facilitate the clarification and filtration process following cold stabilization. However, extended contact time or high temperatures must be avoided to minimize enzymatic browning and undesirable colour extraction. Also, about 100 ppm of SO2 should be added to minimize browning. Juice yields from this method of processing may be only 710 L/MT, depending on the cultivar and pressing efficiency. In view of the tough skin and pulp, bronze muscadine grapes may only yield about 560 L/MT when processed using the cold press method.

12.6 Processing factors that influence quality

Colour is one of the most important qualities of grape products. A typical purple-red is associated with high quality ‘Concord’ grape juice or other red grape juice, but changes in colour from purple-red to brown during processing and storage cause a drastic decline in quality. This is true of all cultivars and species of grapes. The red muscadine grape anthocyanin pigments are extremely unstable under conventional warehouse storage temperatures (Bates and Sims, 2001).

The increase in soluble solids of ‘Concord’ grapes from 14 to 18ºBrix during maturity usually corresponds to an increase in colour. After grapes reach 18ºBrix, colour quality may decrease. With Vitis vinifera cultivars, the colour will continue to increase up to 22 to 26 ºBrix. This condition is cultivar-dependent. The development of the typical purple-red colour in ‘Concord’ grapes begins at veraison (time at which berries commence to ripen) and
However, as the pH of ‘Concord’ grapes gets to 3.7 to 3.8 or higher, a change in the pigment occurs which results in a colour shift from purple-red to blue. Therefore, it is important to harvest at a low pH (3.3 to 3.4) to maintain stable colour in processed juice.

Extraction temperature influences juice colour by affecting the activity of polyphenoloxidase (PPO), which accelerates the rate of degradation of anthocyanins (colour ingredient) in crushed grapes. Inactivation of PPO by heat prior to depectination prevents loss of anthocyanins during extraction and subsequent storage. Storage temperature and time are primary factors for stability of colour in long-term storage. Research studies have shown that maturity, total acidity and juice storage time affect the amount of tartrates or argols in grape juice. The percentage of total phenols was increased in less-mature grapes and at high extraction temperatures (King, et al., 1988).

Increased storage time is detrimental to juice quality. Studies showed similar results for ‘Concord’ and muscadine grape juice (Morris, 1985). Juice from mature grapes had better quality initially than juice from less mature grapes but declined in quality more rapidly during storage. Storage at 35°C resulted in a more rapid loss of quality than storage at 24°C.

Many studies and trials have been conducted to develop and determine the acceptance of grape juices and grape juice blends from new cultivars. King, et al., (1988) studied the effect of maturity and carbonation on muscadine grape juice. A sensory panel preferred the late maturing juices with high muscadine character and low phenolic and acid levels. Carbonated juices were lighter in colour but preferred equally to non-carbonated juices. Muscadine juices have been mixed with other popular grape juices, cranberry juice and apple juice for unique blends (Sistrunk and Morris, 1985). The dark juices were highly acceptable and retained their colour and flavour quality during a 12-month storage period. The lightest combinations (lighter muscadine with apple and ‘Niagara’ grape juice) were rated highest and remained stable during storage.

One study investigated the effects of amelioration and carbonation on five wine grape cultivars processed for juice (Rathburn and Morris, 1989). The juices with adjusted sugar and/or acid rated higher in flavour than those without the adjustment. Carbonation improved the ratings of the unadjusted juices but generally had no effect on adjusted ones. Two wine grape cultivars, Aurore and Verdelet, produced juices that rated comparable in flavour to ‘Niagara’, the white juice industry standard.

Later studies evaluated consumer preference tests on blueberry juice blended with water and with three different grape juices. On the hedonic scale used, a majority of the panel members ranked the flavour and colour of all four blends in one of the “like” rankings. The Blueberry-Concord blend had the highest ranking for flavour. Blueberry juice blends have been formulated and marketed as a result of this study. There is an excellent market for juice blends that use grape juice as a major ingredient.

### 12.7 Grape juice concentrate

Grape juice concentrated to 55, 65 or 68°Brix minimizes transportation and storage costs. This concentrate is diluted for use in single strength grape juice or multi-fruit and sparkling juice. Fruit concentrate is used full strength to sweeten jams, jellies, yoghurt,
frozen fruit deserts, cereals, cookies and other bakery products. Many consumers perceive fruit concentrates to be a healthy replacement to table sugar and corn sweetener.

Concentration of juice is a vital operation of the juice processing industry. Juice may be concentrated by evaporation or freeze concentration. Historically, evaporation has been the most widely used concentration process for grape juice (Figure 12.4). Although many types of evaporators are available, all have essentially the same components (Hartel, 1992). Evaporators generally include a heat transfer surface, a feed distribution device, a liquid-vapour separator and a condenser. It is best to heat grape juice for as short a time as possible and to rapidly cool the product. Reduced exposure to heat minimizes the effect on flavour, aroma and sugar components. The following sections describe juice processing systems that are often coupled with essence recovery systems. The recovery systems are generally activated carbon columns that adsorb flavour and aroma compounds. Steam stripping can then be used to selectively remove these compounds for later addition to the concentrate or for other uses.

![Figure 12.4: Grape juice concentrate plant, California.](image)

12.7.1 Rising film evaporator

Rising film or long-tube vertical evaporators are sometimes used for juice processing. These evaporators have the advantage of short evaporation times due to high heat transfer rates through thin films at high temperature differentials. The evaporator consists of bundled tubes inside a steam chest. The feed stream is heated and introduced into the bottom of the tubes where some of the product is vaporized. The concentrated fluid rises under vacuum in a thin film along the tubes. The tubes empty into a vapour/liquid separator. The vapour is diverted into a condenser to be liquified or is passed through a carbon column

12.7.2 Falling film evaporator

A falling film is almost identical to a rising film evaporator except that fluid is pumped over the top of the tube bundle. This evaporator is the most popular type because it can handle more viscous fluids than the rising film evaporator is and can be operated at lower temperature differentials.
12.7.3 **Plate evaporators**

Plate evaporators operate similarly to plate heat exchangers. The fluid to be condensed passes on one side of a plate and steam flows on the other side. The superheated fluid then passes into a flash chamber. The vapour flashes off and the product and vapour are separated. High viscosity fluids can be efficiently concentrated in these evaporators possibly to concentrations above 60°Brix.

12.7.4 **Centrifugal or conical evaporators**

These relatively new evaporators produce a thin film using centrifugal force in single or nested cones. The cones have steam on the alternate side to provide a heat transfer surface. The systems operate under vacuum and allow the total time on the juice transfer surface to be as little as 0.5 seconds with only a small increase in product temperature. They are good for use with extremely heat sensitive and/or high viscosity products. Two major drawbacks are low capacity and high capital cost. However, these evaporators can also be used to distill, degas and deodorize liquids that have high heat sensitivity.

12.7.5 **Freeze concentration**

This process is based on the physical phenomenon of freezing point depression. Pure water freezes at a temperature of 0°C, but if a solid is dissolved in the water the freezing point temperature is lower. At a specific critical temperature, pure ice water crystals will form leaving a more concentrated liquid in solution. In freeze concentration, three fundamental elements are employed: 1) a freezer or crystallizer produces a slurry of ice crystals, 2) a centrifuge, wash column, or filter press separates the ice crystals from the slurry and 3) a refrigeration unit reduces the heat from fusion and the heat generated by friction from hydraulic flow, wall scraping and agitation of the slurry. Freeze concentration avoids the difficulties associated with heat-based evaporation methods. It is capable of concentrating most fruit juices to 50°Brix without appreciable loss of taste, aroma, colour, or nutritive value. Even so, freeze concentration has not achieved widespread commercial acceptance due to relatively high capital costs and low throughput.

12.8 **Grape spreads**

The process of making grape jelly, jam, preserves, butter or marmalade consists mainly of cooking the grapes and/or their juice in combination with sweeteners and pectins. United States federal standards dictate the ingredients, their proportions and the final concentration of soluble solids level. The ratio of minimum total soluble solids to fruit sweetener as required by the FDA is shown in Table 12.1.

**Table 12.1: FDA minima for grape jelly, jam preserves and fruit butter.**

<table>
<thead>
<tr>
<th>Finished Product</th>
<th>Soluble Solids</th>
<th>Parts by weight Fruit</th>
<th>Parts by weight Sweetener</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grape Butter</td>
<td>43% minimum</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Grape Jelly</td>
<td>65% minimum</td>
<td>45</td>
<td>55</td>
</tr>
<tr>
<td>Grape preserves/Jam</td>
<td>68% minimum</td>
<td>45</td>
<td>55</td>
</tr>
</tbody>
</table>
Jam, preserves and grape butter are made from whole or crushed grapes. The fruit pieces in preserves are usually larger than in jams. Grape butter is made from screened grapes and differs from jam in the final solids concentration and in the ratio of fruit to sweetener.

12.8.1 Sweeteners

The recognition by the jam and jelly industry that liquid sweeteners or syrups offer ease of handling and blending has greatly increased the popularity of corn sweeteners. Syrup from cornstarch may be produced in virtually any combination of viscosity and sweetness with other functional specifications.

Corn syrups are widely used by manufacturers of quality jellies, jams, preserves and butters. United States federal standards have authorized the replacement of up to 25 percent of total sweeteners with corn syrups for these products and up to 50 percent in marmalades. The use of corn syrups is economical and offers these quality improvements:

- Prevents sugar crystallization,
- Provides a pleasing level of sweetness,
- Improves texture and smoothness,
- Allows better colour retention.

It is not difficult to substitute corn syrup in any preserve recipe or formula: 0.57 kg of corn syrup is used for every 0.45 kg of sugar replaced. Therefore, 0.57 kg of corn syrup provides 0.454 kg of solids and replaces the sugar on a solids basis.

A satisfactory gel must be formed to produce a spreadable product. Gel formation requires that the concentration of the water-sweetener-acid-pectin mixture be in the proper proportions. If the grape juice or fruit does not provide sufficient quantities of acid and/or pectin to form a good gel, then it is permissible under Federal standards to add pectin and/or acid in a quantity that “reasonably compensates for any deficiency.” Since Federal regulations fix the proportions of the grape juice or fruit, the relative amounts of sweetener, acids and pectins are the only variables.

12.8.2 Acids

A specific acidity (pH) is necessary for pectin to form a perfect gel. The optimum pH range for forming a pectin gel is 3.0 to 3.35. Within this pH range the consistency of the product will be primarily determined by the amount of pectin present. When whole grapes are present in the product, the fruit itself provides some spreadability and decreases the need for pectin.

US Federal Regulations allow the addition of vinegar, lemon juice, lime juice, citric acid, lactic acid, malic acid, tartaric acid, or any combination of two or more of these. The quantity of added acid must reasonably compensate for any deficiency in the natural acidity of the fruit ingredient without requiring a label declaration of added acid. The following standard acid solutions will produce the same general gel firmness under comparable conditions. Each acid may impart a slightly different tartness to the final product.
• Citric Acid. 0.454 kg of citric acid (crystals or powder) dissolved in 0.47 L of hot water will produce a solution with 17.6 gm of citric acid to 28.4 gm of solution.

• Tartaric Acid. 0.23 kg of tartaric acid (crystals or powder) in 0.47 L of hot water yields 11.1 gm of tartaric acid per 28.4 gm of solution.

• Lactic Acid is available as 50 percent food processing grade lactic acid and has a mildly acid taste that doesn’t overpower delicate fruit flavours. It sets pectin approximately seven times slower than citric acid at the same pH and therefore can be used when a slower set is required. Its liquid form simplifies its use in most applications.

12.8.3 Buffer salts

If grape juice has a reduced pH in the natural state, the end product will have a pH lower than the optimum 3.0 to 3.35 and will cause premature setting of the pectin. Buffer salts (sodium citrate, sodium potassium tartrate or any combination of these) may be added to adjust the pH in this situation. The buffer salts may be added in solution or dry when mixed with the pectin. No label declaration is required.

12.9 Pectins

Pectin is a carbohydrate present in all plants, which, along with cellulose, is responsible for structural properties of the plant. Commercial pectins are normally produced from either citrus fruits or apples in accordance with internationally accepted specifications for identity and purity (Chapter 11).

The following discussion on pectins modified and adapted from the Handbook for the Fruit Processing Industry by Hercules Incorporated, Food Gums Group, 1313 N. Market, Wilmington, DE 19894-0001, now out of print.

High methoxyl pectins (HM-pectins) have a degree of methylation above 50 percent. HM-pectins require soluble solids above approximately 55 percent and a pH around 3.0 to form gels. Once formed, additional heating cannot melt the HM-pectin gel. The degree of esterification of HM-pectin determines the gelling rate and gelling temperature of the pectin, as reflected by the designations “rapid set” and “slow set” HM-pectins. At an elevated pH of 4.5, HM-pectin is stable only at room temperature or below. Elevated temperatures cause the pectin molecule to rapidly depolymerize and the gelling properties are completely lost.

Low methoxyl pectins (LM-pectins) are pectins with a degree of methylation below 50 percent. The gelling mechanism of LM-pectin differs substantially from that of HM-pectin. To obtain gel formation in a system containing LM-pectin, the presence of calcium ions is crucial. On the other hand, LM-pectins form gels at much lower percent soluble solids than HM-pectins and greater variations in pH are tolerated without a major effect on the gel formation. LM-pectin gels may melt when heated but show excellent stability at all temperatures in the pH-range 2.5 to 4.5. The right combination of two varieties of LM-pectins can very closely duplicate the texture and taste of a HM-gel at any Brix level from 20° to 70°.
Jellies are normally produced with slow set pectins because there is ample time for any air bubbles to escape from the product before gel formation starts. In jams and preserves, a uniform distribution of fruit particles throughout the container is desired. To avoid fruit flotation, gel formation must begin immediately prior to filling the container.

Choice of the type of HM-pectin for jams and preserves consequently depends on the filling temperature. Higher filling temperatures, used with small containers, normally require rapid set pectin. Medium-sized and large containers, where lower filling temperatures are necessary, require use of medium set and slow set pectins, respectively. In markets where jam standards state a minimum soluble solids of 68 percent, slow set pectin is normally preferred. At these high percent soluble solids, rapid set pectin gels at too high a temperature when pH is in the usual range. In jams with a relatively mild acidulous taste and high pH, rapid set pectin must be used, especially if soluble solids are at the lower end of a 60 to 68 percent range.

12.9.1 Addition of pectin

Pectin must be completely dissolved to ensure full utilization and avoid unhomogeneous gel formation. Complete dissolution requires dispersion without lumping and can be achieved by means of a high-speed mixer. The pectin is completely dissolved in a few minutes thus pre-blending with sucrose is not necessary.

12.9.2 Syneresis

The use of pectin in jams, jellies and preserves has two major purposes: creation of a desired texture and binding of water. If the water binding effect is not achieved completely, the final gel will show a tendency to contract and exude juice, known as syneresis.

Products based on HM-pectin must have greater than 60 percent soluble solids. High solids counteract the contraction of the gel structure and correctly produced HM-pectin-based products seldom show any syneresis. HM-pectin jellies do not reform their gel texture when mechanically ruptured and once initiated, the syneresis will remain constant or even increase over time. A small amount of syneresis will occur during normal consumption (when the gel is broken), especially if the product is stirred or pumped.

LM-pectins are usually used in jam, jellies and preserves with soluble solids below 60 percent for reduced calorie applications. The tendency for syneresis to occur increases with lower solids, but this phenomenon is partially counteracted by the ability of LM-pectin to reform the gel texture after mechanical rupture, especially if the calcium content of the system is relatively low.

Only a small amount of syneresis should occur after breaking the gel structure in the soluble solids range of 40 to 60 percent. At soluble solids lower than this range, syneresis becomes pronounced and it may be necessary to combine LM-pectin with other water binding hydrocolloids, such as locust bean gum, if a completely syneresis-free product is required.
The basic formula for making grape jelly is given in Table 12.2 and conforms to the Federal standards of identity. This formula has been tested on a commercial scale still, manufacturing processes and conditions may vary. Several test batches should be prepared and evaluated before a formula is used in commercial production.

### 12.9.3 Procedure

1. Begin heating the standardized unsweetened fruit juice in the cooker.
2. Blend the pectin with 6 to 10 times its weight of dry sugar and add this mixture to the juice in the cooker.
3. Add the balance of the sugar and/or corn syrup. Heat until the desired finishing temperature or solids content is reached. This finishing point is determined in one of the following ways, listed in order of preference
   (a) Heat to a refractometer reading of 65 percent soluble solids (ºBrix).
   (b) Heat to about 6°C above the boiling point of water, about 106°C at sea levels.
   (c) Heat to a ºBrix of 65 to 68.
4. The acid solution is not added until just before the filling operation. In some cases it may be desirable to add the acid directly to the container and pour the jelly solution into it while stirring.

#### Table 12.2: Basic jelly formula.

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Pounds</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard grape juice¹</td>
<td>82</td>
<td>45</td>
</tr>
<tr>
<td>Sucrose</td>
<td>75</td>
<td>55</td>
</tr>
<tr>
<td>Corn syrup (43°Baume) acid</td>
<td>31</td>
<td>²</td>
</tr>
<tr>
<td>Pectin, slow set</td>
<td>¹⁄₂ to 1%</td>
<td>³</td>
</tr>
</tbody>
</table>

¹ any juice containing the specified amount of soluble fruit solids (86.5 percent)
² Quantity may be varied to obtain a pH of 3.0 to 3.35 in the finished product
³ Quantity will be varied, depending upon type of juice and the pectin manufacturer’s recommendation.


The United States Federal Regulations stipulate that the juice portion of the basic jelly formula contains a minimum percentage of soluble fruit solids. In mixed juice products, the percentage is the average percent soluble solids of each respective juice as determined by the FDA. The average required soluble solids content of grape juice used to prepare jelly and the corresponding factor (reciprocal of each percentage times 100) are 14.1 and 7.0, respectively.
This factor is used in a short-cut formula to calculate the amount of juice that must be used to equal the soluble fruit solids of a standard juice in the basic formula. For example, the average soluble solids of grape juice is 14.1 percent. Therefore, the 37.3 kg (82 lbs) of standard grape juice in the formula must contain 5.3 kg (11.66 lbs) of soluble fruit solids. An adjustment is necessary in most cases, since the grape juice used by the jelly maker will not contain exactly 14.1 percent soluble solids. If the grape juice on hand contains 10 percent soluble solids, for example:

37.3 kg (82 lbs) of standard grape juice
0.10 (soluble fruit solids) x 7 (factor) = 53 kg (117 lbs) of juice would be required for each 45.4 kg (100 lbs) of sweetener solids (Clintonnes Corn Processing Company).
CHAPTER 13

TREE FRUIT : APPLE, PEAR, PEACH, PLUM, APRICOT AND PLUMS

13.1 Raw material

Apples are more widely grown than any other fruit; apple trees of one kind or another are grown all around the world. (Root, Somogyi, et al., 1996b). Apple production can vary from one year to the next by as much as 20 percent, depending on the climate of any given year. There are hundreds of apple cultivars, but only about 20 cultivars are commercially important. More than 90 percent of this production is represented by 14 cultivars and only five of these account for most of the world’s apple production: Delicious, Golden Delicious, McIntosh, Rome Beauty and Granny Smith.

Newer cultivars are becoming increasingly common in the marketplace. Some newly popular cultivars are Gala, Fuji, Jonagold, Braeburn and Lady Williams. Many new commercial cultivars are red strains of the primary cultivars. There is a wide variety in their characteristics. For instance, Gala matures in 100 days or less while the Western Australian cultivar Lady Williams needs more than 200 frost-free days to mature. Some need long cold winters to break dormancy while others can be grown in very mild climates such as Israel.

While some cultivars are grown exclusively for use in processing, at least some of the harvest of all commercial apple cultivars is used in processed products. Only sound, ripe fruit should be used for further processing because decay, damage, maturity, firmness, colour, soluble solids, acids and tannins of the fruit impact the quality of the product. Perfectly good fruit from the commercial fresh market cultivars (an average of 20 percent) are used for processing. Some fresh market cultivars produce excellent juice and still others produce superior sauce. Some apples are grown specifically for processing, but most of the apples that are sold to the processor are salvaged fruit grown for the fresh market. Premium price is paid for large, bruise-, disease- and insect-free apples delivered to the processor. This requires apple producers to pay full attention to their cultural details whether growing for fresh or the processing markets. Production practices for apples will vary not only with the apples’ destination, but also with the climate and soils in which they are grown.

13.2 Harvest

The majority of the apple crop is hand harvested because only a very small percentage of that crop is intentionally harvested for further processing. To use mechanical harvesting, a grower or cooperative of growers must be producing at least 40 000 bushels (~ 700 MT), in order to justify the cost. Since apple processing is mainly thought of as a salvage operation, the amount of apples available to process is largely dependent on the size of the fresh market harvest and its quality. Consequently, processing apples are harvested and stored in the same manner as premium, fresh market apples.
Salvage operation or not, it is absolutely essential that fruit for juice (or any other application, for that matter) not be “drops”, i.e. apples that have fallen from the tree and are collected off the ground. There have been numerous incidences of food poisoning associated with the use of drops for fresh, unpasteurized apple juice (Table 4.1). Even with improved sanitation and a microbial kill step between processor and consumer, drops will invariably contain many damaged or partially rotten fruit, impossible to grade out. In addition, it doesn’t take many mouldy juice apples to exceed the 50 parts per billion limit in juice of the fungal metabolite, patulin, a human carcinogen (Ashurst, 1995). While most aflatoxin analyses have been done on major crops such as apple, grape and orange, it is likely that tropical fruits contain levels worth establishing (and probably reducing).

One advantage that apples have over other more perishable fruit crops is that the fruit may be successfully kept in storage for a few weeks to several months. However, to maintain their high quality for processing over storage time periods, it is extremely important that they are picked at the proper stage of maturity and storage conditions are optimized for specific apple cultivars. The processor must determine when the apples for processing are to be harvested.

Figure 13.1: Apple maturity, Northern Hemisphere.
(Childers, et al., 1995)

Generally speaking, there is a window of about five to 20 days, depending upon cultivar and climatic and cultural conditions, during which the fruit can be picked with reasonable assurance that the apples can be stored until they can be processed. Figure 13.1 illustrates these conditions (Childers, et al., 1995). Apples continue to increase in size to

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maturity, when the apple drops from the tree. Harvest must begin as late as possible and yet while the fruit still adheres to the tree. Fruit mature enough to drop will not store well or make the best product. Of course, sound Good Agricultural Practices (GAPs) logically prohibit the use of drops for juice manufacture (FDA, 1998a).

While no one method is entirely dependable under all circumstances, there are several methods available to determine the proper time to pick. These indices may serve one cultivar differently from another. The intended use of the cultivar is also a consideration. It may be best to combine several of these indices with plain good judgement and experience to determine the proper harvest date. Some cultivars have such a body of research attached to them that these indices can be more specific to these cultivars.

13.2.1 **Time elapsed from full bloom to maturity**

It is important for the processor to predict when the apples will be arriving at the processing plant. Full bloom is considered to be that time when 80 percent of the blossoms on the north side of the tree are open. The time from bloom to maturity can be predicted for each cultivar for each growing region. Seasonal mean temperature seems to have little effect on this time interval, but other conditions may affect its accuracy. High temperatures just before harvest may cause excessive fruit drop before harvest time. Trees heavily fertilized with nitrogen may delay skin colour in the apples, or fruit drop may be more pronounced. A light crop tends to mature sooner than a heavy crop. These variables may be very disconcerting.

13.2.2 **Starch/iodine test**

This quick, widely used method uses a standardized iodine solution applied to a cut apple cross-section. A darkened pattern develops which indicates the level of starch remaining in the apple. The pattern is compared to established charts that are available commercially. If the starch level indicates that the starch is about half cleared from the fruit, then the apple is ready for harvest and storage. When it is almost all cleared, it is ready for consumption. Samples should be taken twice a week near to harvest of 10 apples/block from tagged, typical trees. Select two typical apples/tree.

13.2.3 **Pressure test**

One of the best methods of determining the proper harvest date is a firmness test. Firmness of flesh can be determined by a pressure gauge (Figure 13.4) designed for this purpose and available commercially. The determination is based on the fact that firmness gradually decreases as fruit matures. Several readings are averaged to get the result. Season, cultivar, sampling and testing techniques can influence firmness. Instructions on the proper use of the instrument are available from the manufacturer.
13.2.4 Soluble solids

Since starch in apples gradually changes to sugar as the fruit matures, a few drops of apple juice may be tested for sugar development right in the field with a hand-held refractometer (Figure 13.5). However, soluble solids values can be more variable than firmness readings. It is wise to blend the juice of several typical apples before testing for sugar. Cultivar, crop size, cultural practices and growing season can influence the readings.
13.2.5 Ground colour change

The green “ground” colour of the unexposed side of the apple changing to yellow can be an index of maturity. However, even this can be influenced by the nutritional condition of the tree and vary from cultivar to cultivar. Too much nitrogen may delay the change. Growers must know their cultivar. The colour change of Golden Delicious at 135 to 150 days from full bloom can give a good index of maturity. However, other cultivars may drop from the tree before colour change.

13.2.6 Flesh colour change

Flesh colour change from light green to white in Delicious, Golden Delicious and some other cultivars is useful. Harvest before the change may result in storage scald for susceptible cultivars. In contrast, seed colour change from white to brown is a poor index of maturity.
13.2.7 Water core

Water soaked areas in flesh for McIntosh and Jonathon can be an indication they are past good storage life. Water core early in Red Delicious can indicate prime condition for storage, but if water core areas are coalescing, storage will be shortened and apples should be moved early.

13.2.8 Easy removal of fruit from spur

When some cultivars are ready to pick, they can be separated from the spur without breaking the stem by lifting, with or without slight twisting. Some cultivars (McIntosh and Delicious) may drop before maturity because of early frost or other factors, while there are cultivars like Jonathan and Stayman that may retain fruit until over mature. Thus this index may only indicate when picking is necessary to save the crop. With the use of “Stop-Drop” chemical sprays to “stick” the apples on, this index is of little value.

13.3 Storage

Since most processors cannot use the whole harvest they receive as they receive it, some fruit is stored, short term, as they come in, not refrigerated. Other fruit is stored refrigerated in a temperature range of 1 to 4°C, depending on the cultivar. The next level of storage is controlled atmosphere (CA). CA storage usually consists of a modified atmosphere, 2 to 3 percent oxygen and 1 to 4 percent carbon dioxide, at a reduced temperature. The exact specifications are adjusted to the cultivar being stored. Apples can maintain quality under these conditions for 4 to 6 months. Only the highest quality apples destined for the fresh market are placed in CA storage. However, many times the fresh market price will drop to the point that CA apples will be dumped to a processing market. Apples from CA storage should be allowed to “normalize” for a few days before processing. These apples and apples from refrigerated storage are capable of producing good quality processed product. Processors take into consideration that different qualities of juice or applesauce can be manufactured from the same cultivar, depending on the type of storage, time of storage and stage of maturity when processed.

Advances in controlled atmosphere technology have had a dramatic effect on apple storage logistics and opened up markets hitherto unavailable for fresh and processed apple products. This is an advantage not fully shared by other fruit crops whose shelf life extension by CA is much less.

13.4 Storage facilities

There are essentially three types of storage buildings for apples: air cooled storage, mechanically refrigerated storage and refrigerated and controlled-atmosphere (CA) storage.

13.4.1 Air-cooled storage

These storage houses cool by admitting cold night air (applicable climates) at inlets near the floor of an insulated building and forcing upper accumulated warm air out at outlets.
near the ceiling. Both openings are closed during the day. These storages are economical and effective in areas where the night air becomes cooler than the accumulated air in the storage house.

13.4.2 Mechanically refrigerated storage

For longer periods of storage than is afforded by the air-cooled storages, mechanical refrigeration is needed. This would become necessary to extend the season on fresh-market apples or to extend the cooling of processing apples because the volume is so large they cannot be completed in the period of time afforded by the air-cooled storage situation. Specifications of room size, room construction, capacity, compressors, condensers, expansion coils, etc. for both mechanically refrigerated storage and CA storage can be found in Childers, et al., 1995.

13.5 Processing

Apples are processed into a variety of products, but by far the largest volume of processed apple products is in the form of juice. Apple juice is processed from apples that are unsuitable for peeling, such as “eliminator” apples, smaller than ~57mm diameter, too small to peel, etc.

Apple juice can be produced and sold in several forms. Fresh apple juice or sweet cider is juice of ripe apples, bottled or packaged with no form of preservation. This form needs to be sold at the orchard or at outlets close by. Even under these conditions it is important to pasteurize the juice to eliminate \textit{E. coli} or other dangerous organisms. This recommendation has been established after several incidents of serious \textit{E. coli} problems associated with unpasteurized apple juice in the United States of America.

Apple cider is considered around the world as the fermented juice of the apple, but in the United States apple cider refers to sweet cider, the simple juice of early season, tart apples. Shelf-stable apple juice is sweet cider that has been treated for preservation. This could include clarified juice (pectinized, filtered, pasteurized and bottled), crushed apple juice (pasteurized and with a high pulp content), natural unfiltered juice or juice concentrate; frozen (natural or clarified and concentrated to 42°Brix) or high Brix (clarified and concentrated to 70°Brix)
Table 13.1: Nutrients in the edible portion of 454 g of apples.

<table>
<thead>
<tr>
<th>Products</th>
<th>Energy (Calories)</th>
<th>Protein (g)</th>
<th>Fat (g)</th>
<th>Carbohydrate (g)</th>
<th>Calcium (mg)</th>
<th>Phosphorus (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw fresh</td>
<td>242</td>
<td>0.8</td>
<td>2.5</td>
<td>60.5</td>
<td>29</td>
<td>42</td>
</tr>
<tr>
<td>Applesauce</td>
<td>413</td>
<td>0.9</td>
<td>0.5</td>
<td>108.0</td>
<td>18</td>
<td>23</td>
</tr>
<tr>
<td>Unsweetened</td>
<td>186</td>
<td>0.9</td>
<td>0.9</td>
<td>49.0</td>
<td>18</td>
<td>23</td>
</tr>
<tr>
<td>Apple juice</td>
<td>213</td>
<td>0.5</td>
<td>0.1</td>
<td>54.0</td>
<td>27</td>
<td>41</td>
</tr>
<tr>
<td>Frozen slices</td>
<td>422</td>
<td>0.9</td>
<td>0.5</td>
<td>110.2</td>
<td>23</td>
<td>27</td>
</tr>
<tr>
<td>Apple butter</td>
<td>844</td>
<td>1.8</td>
<td>3.6</td>
<td>212.3</td>
<td>64</td>
<td>163</td>
</tr>
<tr>
<td>Dried, 24%</td>
<td>1 247</td>
<td>4.5</td>
<td>7.3</td>
<td>325.7</td>
<td>141</td>
<td>236</td>
</tr>
<tr>
<td>Dried, 2%</td>
<td>1 601</td>
<td>6.4</td>
<td>9.1</td>
<td>417.8</td>
<td>181</td>
<td>299</td>
</tr>
</tbody>
</table>

13.6 Apple juice manufacture

There are a number of procedures employed in apple juice production, depending upon the end product desired. Figure 13.6 is a generalized flow scheme for producing some of these products.

Figure 13.4: Apple juice flowchart.
13.6.1 Prejuicing

Apples are brought to the processing building and dumped by the truckload or out of pallet bins, into a water-filled tank (Figure 13.7). (Such practices should be discouraged for fresh juice manufacture, due to the potential for contamination, particularly when dump water temperature is lower than the fruit temperature. In this case water-borne pathogens may be sucked into the fruit and hence protected from subsequent fruit surface sanitary measures). Fruit are then spray washed and sorted (removing damaged and diseased fruit). Depending on process logistics, clean, sorted fruit may be stored as described in Sections 13.3 and 13.4 (and inspected again before juicing) or juiced immediately. To prepare them for juicing, a disintegrator, hammer mill or grating mill may be used to grind the apples. The mashed apples need to be free of large pieces yet not so fine that pressing becomes difficult. The type of extraction equipment may dictate the chopping method to achieve highest efficiency. The hammer mill adjusts more easily to different pulp consistencies.

Although apples contain potent browning enzymes, pectin enzymes are in low concentrations. Thus, commercial macerating enzymes are usually added. There are a number of enzyme products prepared just for apple mash pretreatment that break down cell walls to free the juice, lower the viscosity and reduce pulp slipperiness.
13.6.2 Extraction

Extraction may be accomplished through pressing chopped apple continuously or in batches. There are a number of pressing systems:

- The hydraulic cider press is one of the older methods of pressing ground apples but is still widely used in commercial setups around the world (Figures 6.9 and 6.10). Since the ground apple pulp passes directly from the chopper to the press cloth, this method usually does not involve using enzymes in the mash. The press racks are now made of food grade plastic. (They were previously square lattices of wood cut to fit each press.) They are slats about 1.9 cm wide and .6 cm thick, spaced about .6 cm apart. The top part of each slat is rounded for easy cleaning. Elm or poplar were the woods of choice for these slats, but oak has also worked well. All slats should be well coated with a chemical resistant varnish to make them nonabsorbent and easy to clean. Nails should be brass or, better still, stainless steel. For loading, a rack is placed in the press truck; a form or bottomless box is placed on the rack; a press cloth is placed on the rack so that the corners hang over the sides. The press cloths are coarsely woven cloths cut to fit a given press. They are made of cottons, wool, or nylon, with nylon being preferred because it is light, strong, easy to clean, nonabsorbent and resistant to stains and mildew. However, they need to be “heat set” so that they will not harden when washed in hot water during cleaning. Apple pulp is placed in the form until it is evenly filled. The apple pulp is then wrapped up in the cloth. Another rack is placed on the filled cloth and the process repeated until there is a stack of “cheeses” that fit the capacity of the press. Ripe apples allow thinner layers of mash than harder apples. The layers should be uniform for highest efficiency of pressing. Some plants have devices that measure the “cheeses (using either a volumetric or weight principle) to eliminate the chance of uneven loading. The average pressing cycle for a cider press is 20 to 30 minutes,

- The bladder press is an effective batch system. The Willmes Pressor is a horizontal, cylindrical screen lined with press cloth material, with a large inflatable tube in the centre that inflates and presses pulp up against the cloth-covered wall (Figure 6.11). The whole assemblage is rotated after it is filled and closed and as the tube is being inflated. Juice is expressed into a catch trough below and collected from a drain. Pressure on the tube reaches a maximum of 6 atmospheres or approximately 600 kPa. Usually a press aid is needed to keep the pulp from adhering to the press cloth and stopping the free flowing of the juice. Cleaned rice hulls work very well and a good grade of disintegrated wood pulp (sheets of paper manufactured for this purpose) works well also, but is more absorbent,

- Continuous screw presses can be used successfully with slippery apple pulp with the addition of press aids. Ground apples and a press aid are fed into the top of the press and are gradually pressed down by a tapered screw revolving at 3 to 5 rpm. Stationary paddles or interrupter bars in the path of the screw prevent the mass from slipping on the screw. The cylinder around the screw is a reinforced screen through which the juice travels to a drainage
pan at the bottom. At the bottom, the pomace is forced through an annulus that is partially closed by a sliding cone. The cone is mounted on the pistons of an air cylinder. Varying the air pressure to the cylinder varies the amount of compression on the pomace. Usually, a pressure of 500 to 600 kPa is required. Screw presses that operate in the horizontal plane, but otherwise in the same manner, are equally effective. A common press aid is a purified wood pulp that has been fluffed in a hammer or attrition mill to give a low bulk density of ~0.16g/ml. This press aid is added to the ground pulp at a rate of 1½ to 4 percent as the pulp enters a horizontal-mixing trough equipped with open loop paddles. The paddles form a helix that mixes the pulp and aid in about 45 seconds at a speed of 50 to 60 rpm. Frequently a mixture of 0.5 percent to 1 percent rice hulls is used with 2 percent fluffed wood pulp. There is some danger in adding off flavours to the apple juice through the misuse of press aids or by excessive pressure and shear action that crush seeds and grind cores. Juice yields of 690 to 770L per MT of apples may be obtained. The suspended solids in the juice usually range between 2 to 6 percent.

- Continuous plate or belt press is a press in which a layer of apple pulp is squeezed between moving vertical plates. Apple pulp with press aid added is spread on a horizontal nylon belt having a weave similar to that in press cloths used in the hydraulic press. As the belt is moved forward converging chains to bring its outer edges together form a continuous U-shaped pocket before it passes between vertical panels attached to heavy roller type chains. Increasing pressure is exerted on the pulp causing the juice to be forced out between the plates and into the collection pan. At the end of the press, the cloth belt diverges until it passes over horizontal rollers for discharge of the pomace and cleaning. It then returns to the point of feed. A juice yield of 730L/MT of apples may be obtained.

- Screening type centrifuge is a revolving, cone-shaped, self-cleaning screen through which juice is squeezed by centrifugal force. The pulp that is discharged from this system is then pressed again by one of the first two methods listed. It has been determined that this method is rapid and gentle, but less efficient than the aforementioned methods.

Apple juice from any of the presses described is invariably cloudy and contains particles (bits of apple and press aid particles) that can be removed by screening. A cylindrical “cider” screen, which is made of stainless steel screening of approximately 100 to 150 mesh, revolves on a system of rollers. The revolving action keeps the screen clean by causing the pomace to gather into small balls and finally into a continuous roll which falls off the end of the slightly sloping screen. A stainless, dewatering shaker screen can also be used (Figure 6.14). Screened juice reduces the load on the filter.

13.6.3 Unclarified juice

For the “natural” look associated with fresh apple cider, the ground apple pulp is treated with ascorbic acid before pressing to minimize browning. The juice is screened or settled, but not otherwise filtered. The ascorbic acid is best added directly to the mill, to be mixed with the pulp as soon as possible after the apples are crushed and pulp exposed to air.
About 30 grams of ascorbic acid added to 100 kg of apples seems to be effective, if all processing is done without delay. (This amount may be cultivar dependent since a cultivar may have a very active oxidative enzyme system requiring an increase in ascorbic acid.) In view of recent fresh cider food poisoning outbreaks, the majority of unclarified juice is flash pasteurized.

13.6.4 Enzyme treatment

An enzyme step is not employed if the end product desired is a cloudy or “natural” looking apple juice. Otherwise, after juice extraction, the raw apple juice must be treated with enzymes to remove suspended solid materials. If not removed, this colloidal material can clog filters, slowing production and can cause the juice to form a haze later on. Enzymes work by hydrolyzing soluble pectinaceous materials, hemicellulose and other polymers and colloids that increase juice viscosity, thereby leaving the juice more easily filtered. Many enzyme preparations are available both in liquid and powder forms. They are all subject to conditions that can influence enzyme performance such as pH, temperature, enzyme concentration and length of reaction time. Considering these variables, it is recommended that test trials be conducted with specific enzymes under typical operating circumstances to determine the proper concentrations and conditions.

There is a hot and a cold method for enzyme treatment. In the hot method, the enzyme is mixed into juice at 54°C and held for 1 to 2 hours. In the cold treatment, the enzyme is mixed into the juice at room temperature, 20°C and held 6 to 8 hours. The enzyme activity can be monitored by adding five millilitres of juice to 15 ml of HCL-acidified ethyl alcohol, observing the mixture for 5 minutes for gel formation. No gel formation means that the depectinization has been completed.

13.6.5 Tannin and gelatin treatment

For highly astringent apples, tannin removal is beneficial. Many of these tannins can be precipitated with addition of gelatin. However, in order not to remove all tannins and therefore some of the flavour and colour of the juice, it is often the practice to first add more tannins and then precipitate a certain amount with gelatin. A classic, older procedure of possible value with overly astringent juices is described (Walsh, 1934):

Solution 1. Dissolve 9.45 g of tannin (tannin acid) in 176 ml of 95 percent ethyl alcohol. Then add 704 ml of water and mix thoroughly.

Solution 2. Dissolve 21.2 g of gelatin in 704 ml of water and add 176 ml of 95 percent ethyl alcohol.

Heat a portion of the water and add the gelatin slowly, stirring continuously. Then add the rest of the water and dissolve the gelatin by heating in a pan of hot water or double boiler and stirring. Add the alcohol and mix well.

These solutions should be kept in stoppered bottles and may be used as needed, the alcohol acting as a preservative in both cases. In some cases the gelatin will gel when cold, but can be liquefied when needed by putting the container in hot water.
Four clear glass quart bottles should then be filled to the neck with apple juice and numbered 1, 2, 3 and 4. Then add to each bottle the following amounts of Solution 1 (tannin) and Solution 2 (gelatin).

<table>
<thead>
<tr>
<th></th>
<th>Bottle No. 1</th>
<th>Bottle No. 2</th>
<th>Bottle No. 3</th>
<th>Bottle No. 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution 1. (ml)</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Solution 2. (ml)</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>20</td>
</tr>
</tbody>
</table>

Measure and add the amounts of solutions shown to each bottle, adding the tannin first in all cases and shaking well after the addition of each solution. Let the bottles stand for 10 minutes. The bottle showing the clearest juice is the one to which the proper proportions of tannin and gelatin were added.

The quantities of tannin and gelatin to use for 380L-batches of apple juice are then found by referring to the table below. For smaller amounts of cider, proportionate amounts of tannin and gelatin are used. For example, if bottle 3 showed the clearest juice at the end of 10 minutes, 35 gm of tannin and 126 gm of gelatin should be added to each 380L of juice; for 190L, one-half these amounts should be added.

### AMOUNTS OF GELATIN AND TANNIN TO BE USED FOR 100 GALLONS APPLE JUICE

<table>
<thead>
<tr>
<th></th>
<th>Bottle No. 1</th>
<th>Bottle No. 2</th>
<th>Bottle No. 3</th>
<th>Bottle No. 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tannin (grams)</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>Gelatin (grams)</td>
<td>42</td>
<td>84</td>
<td>126</td>
<td>252</td>
</tr>
</tbody>
</table>

The actual clarification of apple juice according to this procedure is carried out by first stirring into the apple juice a solution containing the proper amount of tannin. A few minutes later the correct quantity of gelatin, dissolved in hot water, is added, stirring constantly. It is most essential that the juice be very thoroughly stirred after the addition of the treating chemicals. After standing overnight, the clear supernatant liquids are drawn off and filtered. In some plants, the liquid is not separated from the sludge since the filter retains the sludge. This speeds up the operation and eliminates the waste due to discarding juice with the sludge.”

The success of the tannin-gelatin method of clarification is due to some extent on the experience of the operator. Too much gelatin in the juice can slow filtering and cause the finished juice to cause a cloud or precipitate upon storage.

### 13.6.6 Heat clarification

Flash heating the apple juice between 82 and 85°C will coagulate the particles that interfere with juice filtration. The juice is then rapidly cooled and filtered or centrifuged. There are some difficulties with this method.
• An additional heating step prior to final pasteurization may have a detrimental effect on flavour,
• Rapid cooling is necessary to minimize flavour changes,
• The method efficiency is cultivar dependent and not applicable to all apples,
• If the pasteurization temperature is higher than that used for flash heating, additional heat-induced coagulation may occur after filling.

13.6.7 Centrifuged apple juice

Centrifuged juice is slightly clearer than unclarified juice but quite cloudy and viscous compared to the filtered juice although free of visible suspended particles. The pressed, screened juice is fed to either a tubular bowl or continuous centrifuge (Figure 6.15). Both types work well, but the continuous type is self-cleaning and therefore does not have its operation interrupted for cleaning.

13.6.8 Bentonnesite fining

A means of reducing both haze and juice astringency uses the adsorbptive properties of bentonnesite. The finely divided bentonnesite clay particles have an enormous surface area to which tannins and protein-tannin complexes adsorb. Since this may be at the expense of colour and flavour, treatment amounts must be carefully chosen. Fining is also effective in reducing harshness and astringency in some wines (Amerine, et al., 1980; Vine, et al., 1997). As such, it has an unexploited juice flavour cleanup potential.

13.6.9 Filtration

To obtain a brilliantly clear apple juice polish filtration is necessary. Filtering freshly pressed juice is a difficult operation due to the pectinaceous nature of apple juice and the potential for post filtration haze formation. Untreated juice can be rough filtered in large capacity filters with large filter areas that can be easily cleaned. The juice from this method has superior flavour and excellent body. It may have a slight haze that increases with time as proteins and tannins react. Filtering juice that has not been depectinized reduces the filtration rate to about 1/3 of enzyme treated juices.

There are many types, styles and capacities of filters available. Plate and frame filters with disposable pads or sheets are easy to clean, but readily clog after extended use (Figure 6.16). Continuous filters with back flush capability are preferred. The juice contact surface should be stainless steel or food grade plastic. In a pre-coated filter, the liquid, containing suspended filter aid, is forced by pressure of vacuum through a coated membrane (Figure 6.16). In the case of apple juice, the medium is usually diatomaceous earth. This medium is available in many grades. It takes skill and experience to operate a filter in an apple juice plant. There is a great deal to know about pre-coating, filter aids, special pumps, etc. Either a new filter must arrive with complete directions, or an experienced operator needs to be on hand for consultation (Tressler and Joslyn, 1971).
13.7 Pasteurization

The most important method of preserving apple juice is pasteurization, which involves heating the juice to a given temperature for a length of time that will destroy all organisms that can develop, if juice is put hot into containers that are filled and hermetically sealed. Flash pasteurization is, true to its name, the rapid heating of juice to near the boiling point (greater than 88°C) for 25 to 30 seconds. Steam or hot water passes the juice between plates (Figure 8.5) or through narrow tubes that are heated. Design of the heat exchanger provides juice flow turbulence and even heating to prevent scorching and burn-on in the unit. There are numerous flash pasteurization heat exchangers available. They are all adaptable to a continuous operation set-up.

Juice can be canned or bottled in cans, glass or plastic. Cans used are enamel or lacquer lined to resist corrosion from the juice. As the cans travel the canning line, they must pass through a can washer, be filled from filling machines and immediately sealed on a can-closing machine. After closure cans should be positioned or inverted so that the hot fill will be in contact with the lid and thus, pasteurize it. From here, the cans must be removed to a cooling room where they will be cooled to near 38°C to stop the effect of high heat on the contents. If cooled to a temperature lower than 35°C, the labels will tend to detach, the can will not dry and will be susceptible to surface rusting. This necessitates that the cans travel continuously from washing, to filling to cooling to labelling and packing.

Bottling juice requires specialized equipment. Cans can be roughly handled, but bottles are fragile ("bruising" not visible to the eye can cause breakage later) and susceptible to thermal shock. Temperature changes of greater than 7°C should be avoided. Bottles must be cleaned before filling then heated (steam jets) within 7°C of the fill temperature. The best filler draws the liquid into the bottle by evacuating the bottle, thus reducing oxidation. Bottle closures can be screw caps, crown caps or vacuum caps. The vacuum caps have the advantage of allowing less headspace; if the contents ferment only the cap will blow off rather than the bottle exploding. Bottles also must be cooled. This can be accomplished in a special cooler that sprays hot water on them and decreases the temperature as the bottles move along. At the end, they emerge close to 38°C, still warm enough to dry.

Newer packaging and processing systems use plastic containers that can be hot filled and rapidly cooled without the danger of thermal shock. In addition, aseptic processing greatly reduces heat-induced flavour changes. Still, glass bottles are the traditional standard and carry a quality image not implicit in cans, plastic bottles or aseptic packs. Recent concerns about contaminated fresh cider have resulted in United States Federal Regulations that strongly discourage unpasteurized juice and advise pasteurization of all apple juice products, even at small roadside stands and country markets that prepare juice on site. The alternative is a not very appealing warning label on fresh apple juice (FDA, 1998b).
13.8 Concentration

Apple juice may also be concentrated as a form of preservation, for use as reconstituted juice and in further processing. Evaporating systems such as rising film evaporators, falling film evaporators and multiple effect tubular and plate evaporators can be used (Chapters 8, 11 and 12). Because apple juice is so sensitive to heat the multiple effect of evaporation with essence recovery is the one most commonly used. This method heats the juice in stages. The juice is evaporated to 20 to 25°Brix at 90°C and the aroma captured by fractional distillation. This concentrate is brought to about 40 to 45°Brix at about 100°C. In the third stage it is heated to about 45°C and concentrated to about 50 to 60°Brix. The final heating at 45°C will bring it to 71°Brix. The concentrate is cooled to 4 to 5°C and standardized to 70°Brix and then bottled, barrelled or stored.

13.9 Applesauce

Although not strictly a beverage, applesauce merits mention as a co-product of apple processing operations. For making applesauce, clean, sorted, peeled apples, plus all the apple sauce recipe ingredients, are chopped and cooked in a cooker heated by live steam or jacketed steam. Liquid sugar is the preferred sweetener because it imparts a desirable “sheen” to the finished product appearance. The chopped apples are cooked at 93 to 98°C for 4 to 5 minutes to soften the apples and inactivate the enzymes responsible for browning. The cooked apples are passed through a pulper with a screen for the purpose of removing undesirables and for sizing the sauce. Baby food goes through a ~0.8 mm screen for the finest of textures. The sauce is next inspected by being poured over a backlit flat plastic sheet. Inspectors remove all dark pieces with a flexible vacuum tube.

The applesauce is now ready to be canned or bottled. It is heated to 90°C and piston-filled into cans or bottles. Applesauce must be filled and sealed at 88°C in the seamer or capper. To insure a vacuum in the container, a jet of steam may be passed over the top of the container just prior to sealing. As the steam condenses, a vacuum is created in the container. This step is important in cans to prevent headspace detinning. The containers are held for 1 to 2 minutes prior to cooling to insure sterilization of the lids or caps. Water-cooling takes place in a draper belt, walking beam or reel cooler to an average of 35 to 40°C to prevent “stack cooking” in the warehouse.

13.10 Pears

Pears are processed very similarly to apples. They should be ripened to a pressure test of 0.9-2.2 kg before processing. Pears may be harvested while they are still firm 7.6 to 9 kg pressure test and safe to handle without damage. If they are stored at 1°C for one week they can then be ripened uniformly for four to five days at 10°C and 85 percent humidity. To produce nectar, pears are washed and mechanically peeled and cored, after which they are heated to 85°C for 3 minutes in a continuous steamer. This hot fruit is passed through a continuous extractor with a 0.084 cm screen and then a brush-type finisher with a 0.08 cm screen. After adjustment with sugar, citric acid and water to a values of about 13 to 15°Brix and 3.9 to 4.2 pH, the nectar is flash pasteurized at 96°C in a heat exchanger then hot-filled into cans, sealed at (at least) 88°C and held inverted for 3 minutes before being cooled. Can linings should be used that have no reaction with the nectar.
Clear pear juice is generally obtained through the help of enzymes. Heated, sliced ripe pears are put through the finisher and cooled to 38°C. A macerating enzyme treatment is used for several hours at this temperature to depectinize the puree. At room temperature, the time should be extended to over night. When a clear sparkling juice can be obtained from the puree, then the depectination has taken place (this can be tested in a centrifuge). The amount of press aid will vary for each operation, but about 1 to 2 percent is added to purees put through most rack-and-frame presses. This juice and about 0.25 percent filter aid can then be clarified in a pressure filter with pre-coated plates.

13.11 Peaches

In contrast to the fruits previously mentioned, peaches are not usually extracted as juice, but rather as a pulp or puree. The juice, employing pectic enzyme treatment, is light in colour, flavour and body compared to the pulp. When dealing with peaches, the whole pulp refers to the peach pulp after mashing and before fibre and other coarse material is removed. Pulp refers to the whole pulp after fibre and coarse material is removed. Pulp base is pulp with such additives as sugar, acid, colour and, stabilizer. This product can be stored and used in a variety of ways. Peach juice drink is a product prepared by dilution of peach pulp or peach pulp base. Cloudy concentrate is pulp base with some of the water evaporated. And clear juice concentrate is peach pulp or pulp base that has the insoluble material removed by pectic enzyme treatment and filtration, followed by evaporation.

Peach cultivars show a wide variation for ripening date, ºBrix, total acidity, flavour, colour and freedom from browning. Most of the cultivars grown for the fresh market are suitable for pulping. The ideal peach for processing will score high on these points: flavour; balanced soluble solids and acids; suitability for mechanical peeling, pitting and pulping without producing seed fragments; maximum of yellow colour and minimum of red colour; difficulty in turning brown; uniform ripening of whole peach; enough firmness and stability to withstand a reasonable amount of handling after ripening. This ideal peach is fully ripe and soft fleshed. The best peach is obtained from peaches graded for ripeness and free from rot, other spoilage and insect damage, rather than from orchard-run (second grade) fruit.

Peaches may be peeled by steam peeling or by lye peeling. In the lye peeling operation, whole peaches are either immersed in or sprayed with a lye solution (up to 5 percent in strength) at a temperature of at least 99°C for 15 to 20 seconds. They are held for another 60 seconds and then spray washed with cold water. Some operations disregard the peeling step and simply pulp the whole fruit with the skin intact. This yields 13 to 15 percent more whole pulp. The aroma and the colour of the pulp can be influenced by disregarding the peeling and is also a function of the cultivar and stage of maturity.

If peaches are heated before pulping, the pulping process can be made easier, oxidation reduced and cloudiness stabilized. This is best accomplished by heating in a continuous thermo-screw for 2 minutes at 93°C. The jacket around the thermo-screw should be kept at ~125°C during this blanching/softening step.

Pulping the fully ripe peaches removes the seed and reduces the peach pulp by passing it through a ~3 mm screen. The speed of the paddle is best at about 1 000 rpm. Faster speeds will whip air into the product. This pulp is then passed through a finisher with screens having 0.061 to 0.084 cm perforations, operating at about the same speed. Pulp is separated
from the fibre and unripe portions at this stage and is reduced to a liquid. A 1 MT load of peaches will produce about 494 L of puree. For peach nectar, 241 L of 30°Brix sucrose syrup should be added to each 380 L of puree. If the pH needs to be reduced to 3.7 to 3.9, then it may be necessary to add citric acid.

At this point, the puree may have air mixed in it, which can lead to deterioration of the nectar’s colour and flavour. It may be advisable at this point to pass the nectar through a deaerator. The nectar is now ready for flash pasteurization. Processors mix in 0.14 percent ascorbic acid at this juncture and then feed the nectar uniformly into the pasteurizer. Puree is pasteurized at 88 to 93°C and quickly cooled to 1.7°C if it is destined to be aseptically canned and refrigerated. Otherwise the puree may be filled hot directly into cans or bottles. These cans should be closed using vacuum and nitrogen or a vacuum produced with a steam jet. Cans should then be cooled with water spray, dried with warm air, labelled and stored in a cool dry place.

13.12 Apricot

Apricots for juice or concentrate are processed in the same manner as peaches, but are not peeled, although the skin and other fibrous material are eventually removed in the juicing process. Fruit, unsuitable for cutting, but without rot, are heated to 99ºC in a thermal screw, then run through a pulping unit to remove the stones. A series of finishers removes the skin and fibrous material. The juice can be made into nectar with the addition of sugar, water and acid. The juice made into concentrate is brought to 32ºBrix. Puree is sweetened with approximately 1.8 times its volume of 15 to 16ºBrix sugar syrup and acidified with citric acid. Apricot puree can be processed in cans or hot filled directly from the pasteurizer (Somogyi, 1996b; Tressler and Joslyn, 1971).

13.13 Plums and prunes

In areas of heavy plum production, harvest date is determined by skin colour changes that are described for each cultivar. There are colour chip guides available designed to determine maturity for each cultivar. Some cultivars have skin ground colour that is masked by full red or dark colour development during maturation. For these cultivars, flesh firmness is measured for an indicator of maturity. Plums are less susceptible to bruising than most peach and nectarine cultivars at comparable firmness.

Plums do not usually give up a juice upon crushing and pressing and must be treated with a macerating enzyme in order to yield an actual fruit juice. The method for obtaining this juice is similar to the following:

- The fruit are first sorted, washed and drained. The fruit is then steam heated for about 10 minutes to prepare it for pulping with a very coarse screen to remove the pits. It also helps inactivate the naturally occurring enzymes and prevent darkening. The resultant puree is put through a heat exchanger to cool to 50°C.

- At this point an appropriate enzyme is thoroughly mixed in (amount dependent on type and cultivar of fruit). This mixture is left to stand from six to 12 hours until juice drains readily through a sample of cheesecloth. Now a pressing aid is added, such as
infusorial earth. From this point on the juice is pressed similarly to apple pulp, except two layers of cloth are used. A normal heavy apple press cloth is covered with a light canvas or heavy white muslin to insure a clearer juice and keep the seams from bursting upon pressing. A “cheese” of pressed cloths and racks should be built up as with apple pulp pressing.

- The plum juice thus obtained must be filtered and have the Brix adjusted to ~23ºC. The juice is ready to be pasteurized. It may be flash pasteurized to 88ºC and filled into appropriate bottles or cans at 82 to 85ºC, sealed and placed on sides a few minutes to pasteurize the lids and then cooled. Alternatively, the juice may be filled cold into crown-capped bottles, placed in water and heated to 85ºC for 30 minutes for litre size and smaller bottles.

Prunes, which are dried plums, have long been used for juice. Prune juice is reported to have laxative properties. This effect plus the shrivelled appearance of prunes has resulted in a negative image for the product. Hence, the industry is attempting to replace the word prune with “dried plum”, hoping for a more positive image.

The plum changes appreciably during dehydration with both enzymatic and Maillard reactions contributing to the dark colour and typical heated fruit flavour of prunes. At ~18 percent moisture, it is impractical to extract juice, so prunes are subjected to an aqueous extraction (Figure 6.7) to produce the sweet brown juice with prune-like characteristics and similar physiological effects.

Two methods are used to produce prune juice from dried plums. Manual diffusion is seldom employed commercially anymore, although it is mentioned here because this method is simpler, less expensive and requires less equipment. This method calls for dried fruit to be steeped in large vats (holding 160 to 180 kg of prunes and 300 to 380 L of water) at 83ºC for 2 to 4 hours. This extracted juice is combined with the juice of a second extraction of the same fruit, done the same way, except only 63 L of water /100 kg of fruit is used. These combined juices are added to the juice of a third extraction; again performed the same way, only using 40L water/100 kg fruit. This combined extract is either used to extract a fresh vat of prunes (in which case the Brix is generally over the desired level) or is concentrated to the desired ºBrix of 18.5 to 21. The extracted residue pulp is discarded.

The second method is called the disintegration method. As much as 550 kg of prunes are washed and vigorously boiled and agitated for 60 to 80 minutes, until disintegrated. This mash is then pressed as described for apple pulp or put through a high-speed centrifuge (approximate 4 000 rpm). The resulting juice, about 10 ºBrix, is allowed to settle, siphoned off and then must be concentrated to the desired ºBrix of 18.5 to 21.

Curiously, other dried fruit extracts are not as popular as prune juice, although the dramatic effects of dehydration followed by extraction should yield some rather novel, high value beverages worth exploring.