3 Fruit and juice processing
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3.1 Introduction

It could be said that freshly pressed fruit juice provides the truly natural answer to all the requirements of a soft drink: thirst quenching, fresh, healthy, flavourful, nutritional and, of course, natural. So why should it have been necessary to look any further towards the creation of different flavour types and the myriad of drink varieties that has appeared over the years in beverage markets around the world? Necessity, being the mother of invention, has been the driving force in all this. In the early years of the industry there was a real necessity for soft drinks manufacturers, in order to stay in business, to control a major threat to their trade, that of microbial fermentation and spoilage of the bottled product.

A freshly squeezed orange or fresh pulped and strained apple would supply a fruit juice drink for immediate consumption, but to expect it to maintain its quality for even a day or two was tempting providence. Nowadays, with the benefit of ultra-high temperature (UHT) pasteurisation, aseptic packaging techniques and systems, pressed juices can be stored for extended periods with very little deterioration in quality. Previously, reliance had to be placed upon the use of preservatives and ‘classical’ pasteurisation at lower temperatures (70ºC+) and longer holding times. As businesses grew and production and filling lines enlarged and developed, so did understanding of the need for correct sanitisation of the plant items. The progressive nature of the soft drinks industry has meant that throughout its history there have been many innovative developments, and in the early years these centred on the filling and packaging, or containerising, of beverages. During the second half of the twentieth century, apart from the continuous move towards more efficient means of production and marketing of bottled or canned soft drink products, there was much progress in our knowledge of the constituents responsible for perceived flavour notes. Advances in instrumental analytical techniques have made it possible to identify those chemicals in natural extracts (whether of fruit or botanical origin) that provide the characteristic flavour profile.

The advent of gas chromatography in the 1950s, its coupling with the diagnostic strength of mass spectroscopy (GC–MS) and the remarkable improvements in column sensitivity have no doubt been critical factors in the generation of the large numbers of beverage flavours and drink types available on today’s market. This analytical knowledge, apart from leading the way to ‘designer drinks’, has also served to maintain and standardise the quality of a range of beverage types that still base their success upon traditional fruit juice systems. The majority of the active flavour components of most fruit types have been
identified (TNO-CIVO) and provide the beverage technologist with a basis for the addition of certain characters in the development of a new product.

It is the emphasis placed upon certain flavour characters that can provide the drink with its identity in the marketplace. This can be achieved by the use of both natural and synthetic or nature-identical flavourings to create the desired top-note effects. A fruit-based drink will always declare as part of its list of ingredients the juice or juices (if mixed) used, at natural or ‘single-strength’ status. Usually appearing fairly high in order of concentration, the fruit juices will provide the generic character of the drink, with its specific identity being given by the flavouring materials chosen for a particular formulation (preferably in synergy with the flavour contribution of the juice ingredient).

The beverage technologist has a wide range of fruit types to choose from, and this chapter will investigate some of the procedures associated with the processing of these to produce fruit juices commercially.

### 3.2 Fruit types

#### 3.2.1 Botanical aspects, classification of fruit types

The term ‘fruit’ is applied to a critical stage in the reproduction of botanical species throughout the plant kingdom: it is the structure that encloses, protects or harbours the seeds until they are ripe, and it often assists in their dispersal. Broadly speaking, fruits can be categorised into two groups according to their physical condition when ripe: dry fruits and succulent or fleshy fruits.

The widest diversity in the manner of seed dispersal is exhibited by the dry fruits. These include the windborne types such as dandelion ‘parachutes’ or sycamore ‘keys’. Mechanical scattering is exhibited by many of the legumes, whose seed pods, when fully ripened and dried out, can split with explosive force to scatter their contents in readiness for a follow-on crop. Another type is made up of those fruits, such as ‘cleavers’ or ‘dock-burrs’, that possess small hooks whereby the fruit is caught up in the fur of animals for transportation.

It is the second group, however, that will be the focus of this chapter, the succulent or fleshy fruits, where the seeds are ripened or supported within a soft or fleshy mass containing food materials that may tempt animals to eat the fruit. After being eaten by animals the fruit is digested, but the seeds, protected by a hard shell-like coating, will progress through the alimentary canal of the animal to be passed out in the faeces. This rather primitive method of propagation has been Nature’s way almost since the dawn of time, having the advantage of a ‘built-in’ seedbed growing system rich in nitrogenous compounds and often essential trace elements. The *Prunus aves* or bird cherry gained its name in recognition of this manner of propagation.

The process of evolution and natural selection ensured that the more successful fruit forms survived in harmony with their surrounding environment.
The appearance of humans on the planet and their own evolution to the status of hunter–gatherer brought a new meaning to the term ‘selection’, and our ancestors would have taken the first steps in categorising the available fruits according to flavour character.

Many of the commercial fruit varieties popular in the Western world have been developed from specimens whose origins can be traced back to regions east of the Mediterranean, where stone fruits (such as peach, apricot and cherry) and pome fruits (such as apple and pear) grew in fertile surroundings and became part of the staple diet of the inhabitants.

Figures 3.1–3.3 show the structures of various succulent or fleshy fruits.

**Figure 3.1** The structure of the soft fruits. (a) Currants, e.g. blackcurrant (*Ribes*); (b) raspberry (*Rubus*); (c) achenes, e.g. strawberry (*Fragaria*).
3.2.1.1 The basics of plant reproduction and fruit formation

The flower is the reproductive centre of a plant, and the series of changes resulting in the formation of a fruit starts here with the process of pollination, whereby pollen is transferred from anthers to stigma by a series of mechanisms dependent upon the plant species. In essence, these mechanisms can be initiated by an insect visiting a flower and becoming dusted with pollen from the ripe stamens (carrying the pollen-bearing anther) and then visiting another flower where the pollen on its body will adhere to the stigma of the second flower. At this stage the pollen grain, containing the male nucleus, fuses with the stigma, absorbing nutrient and sending out a growing tube that eventually reaches an ovule contained in the plant ovary. The male nucleus passes down the tube during this period and is ideally positioned to fuse with the female nucleus.

Figure 3.2 (a) A typical stone fruit or drupe, e.g. the damson (Prunus) and (b) structure of a ripe apple (Malus).
contained in the ovule. From here on rapid changes occur, resulting in the fruit, or receptacle, and seed formation.

3.2.1.2 Respiration climacteric
During their ripening or maturation stages some, but not all, fruit varieties undergo a phase of upsurge in metabolic activity known as the climacteric, a term coined by Kidd and West (1922) to describe the increase in respiration rate and heat evolution as the fruit softens and develops flavour and aroma. Fruits such as apples, pears, bananas and most stone fruit have stored reserves of starch, and during the climacteric these are converted to sugars by starch-degrading enzymes. The carboxylic acid content of the fruit also takes part in the conversion, so that acidity levels are consequently reduced as the maturation takes place.

3.2.2 Harvesting considerations for berry, citrus, pome, stone and exotic fruits

The harvesting of fruit purely for juicing purposes is a relatively minor issue compared with the size of the world market for fresh fruit for direct consumption. Ease
of transportation and distribution enables an almost continuous supply of fruit from around the world as harvest time limits are compensated for in the growing areas of both the Northern and Southern hemispheres.

In the Western world, where marketing has become a major influencing factor, fresh fruit for direct consumption is produced to meet very exacting standards. We will have all seen, on the supermarket shelves, high-class displays of, for example, regulation sized Granny Smiths or Red Delicious apples, uniform in shape and appearance, presented at optimum ripeness. The main criteria for juice processing, on the other hand, are more straightforwardly that the fruit should be sound, of good quality, and of correct maturity. In order to achieve these objectives, a highly efficient international quality management system is required to operate throughout the whole procedure of growing, harvesting, ripening, storing and handling of the fruit. Apples and pears can be stored under prescribed temperature and environmental conditions in order to ripen gradually. When they are graded to meet requirements for direct sale, those fruits falling outside size limits may be sent for juicing purposes. Careful handling of the fruit during harvesting is an essential requirement, as also is the post-harvest management. If the fruit is already destined for juicing then it is more usual for mechanically harvested fruit to be transferred direct from the orchard to the processing plant to meet the demands of a tight production programme during the season. (In Europe the season usually runs from the end of June to mid-December).

However, the decision to be taken on exactly what degree of maturity should be reached by the fruit before harvesting is not an easy one, and it is here that the whole operation can encounter success or failure. The soluble solids content of the fruit is a reliable indicator in the case of non-climacteric fruit, whose composition will show little change following harvest and storage under suitable conditions. The suitability for harvesting of citrus fruit and grapes, both non-climacteric fruits, can be assessed successfully, and the ratio of soluble solids to titratable acidity is frequently used in establishing maturity criteria for these fruit. Citrus fruits are harvested direct for commercial sale or juice processing, undergoing washing, grading, and thereafter packaging or juicing. Fruits that undergo climacteric change are more difficult to deal with because the full potential of the fruits will not be known until they are fully ripened, but the important commercial decisions on harvesting cannot be left until then.

Unlike pome and citrus fruits, soft fruits are subject to rapid deterioration when even the slightest ‘bruising’ takes place, and unless they are harvested for direct use in the press it is best to subject them to rapid freezing and hold them in the temperature range of $-18$ to $-26^\circ C$. Two forms of grading are employed for soft fruit. Selected top-quality berries will be individually quick-frozen (IQF) to be used as later whole fruit pieces in jams, yoghurts and culinary uses, whereas fruit for conversion and use as fruit pulp may be cleaned by washing it free from leaves and twigs and ‘block-frozen’. Berry fruit intended for juice production will be block-frozen as harvested, complete with any incidental stray
foliage. In the case of blackcurrants, redcurrants and the like, this comprises the stalks to which the individual berries are attached; it is known as ‘strig’ and serves a useful function as a natural filter-aid during the pressing stage to release juice from the fruit.

Although freezing will disrupt the cell structure of soft fruit and render it ‘pulpy’ upon thawing out, any adverse changes to juice quality will be minimal and flavour and colour can be easily preserved by this treatment.

### 3.3 Fruit types for processing

#### 3.3.1 Pome fruits

Pome fruits include the apple, pear, medlar and quince. The latter two fruits are of little commercial importance in an age in which ease of harvesting and crop yields rule supreme in terms of cost considerations, but they are occasionally seen in speciality outlets. Medlar fruits are brown-skinned and apple-shaped and are best eaten after ‘bletting’, a process whereby the flesh softens and sweetens during storage. This can take up to 2–3 months from harvest and explains why in the Middle Ages, in Europe, the medlar was a useful fruit to store for winter consumption. Likewise the quince, similar to the pear in shape, although at one time a very popular fruit is now something of a speciality. It is ripe when the fruit turns a bright yellow. It is high in natural pectin and finds its main use in jams and jellies.

The apple and pear are of major commercial importance and are grown in most temperate regions of the world. Argentina, Australia, Bulgaria, Canada, China, France, Germany, Hungary, Italy, Japan, the Netherlands, New Zealand, Poland, South Africa, Spain, the United Kingdom and the United States are among the foremost countries growing pome fruit on a considerable scale for both home and export use. Although local varieties are found to have a following in their own regions, the world markets are dominated by perhaps no more than 20 dessert and culinary varieties, which have been selectively bred for such characteristics as disease resistance, winter hardiness, appearance (colour and shape) and texture together with high average yield. Among these are Bramley’s Seedling, Brayburn, Cox’s Orange Pippin, Red Delicious, Golden Delicious, Discovery, Granny Smith, Jonathon and Newtown Pippin. The main varieties of pear to be found in the market are the Bartlett or Williams Bon Chrétien, the Comice (Doyenné du Comice) and the Conference.

#### 3.3.2 Citrus fruits

Citrus fruit varieties are grown for commercial use in many parts of the world. Originating in the southern and eastern regions of Asia, China and Cochin China,
and the Malay Archipelago, the citron (*Citrus medica*) is said to have first arrived in Europe during the third century BC, when Alexander the Great conquered western Asia. Later, the orange and lemon were introduced into the Mediterranean region in the days of the Roman Empire, when trade routes from the Red Sea to India became established. Cultivation of citrus fruits has since spread worldwide to all regions where the climate is not too severe during the winter months and suitable soil conditions are available. In the United States, the notable growing areas are in Florida and California and in South America, Brazil has taken over the largest share of the world market for oranges and orange juice products. Morocco, South Africa and parts of Australia have shown increased output during recent years, although within the latter two areas yields are frequently affected by variable weather conditions. China is the largest producer after the United States and Brazil, but over 90% of its output is for the home market.

In the area of citrus juice production, Brazil, California and Florida are the major players, with Spain and Israel being notable producers of specialised concentrates. Israel enjoyed a thriving citrus industry in the 1980s, but has since lost much ground due to strong competition from South America with the emergence of the Brazilian market. In recent years a spate of drought conditions, labour shortages and political instability has done nothing to improve the situation.

The main citrus varieties for juice processing are the orange, lemon, lime and grapefruit.

### 3.3.2.1 Orange

The most important of all citrus fruits is the sweet orange (*C. sinensis*), and this is widely grown in those regions of the world suited to citrus. Each region tends to have its own characteristic varieties. Common varieties to be found growing in various parts are Navel, Valencia, Shamouti, Hamlin and Parson Brown. The mandarin orange (*C. reticulate*) is representative of the ‘soft citrus’ loose-skinned oranges, ‘easy peelers’, hitherto of primary importance to the Far East and now popular in other parts, including the United States and Europe. The group includes satsumas, an important crop in Japan, and the clementine, an important cultivar to be found in Mediterranean areas. Other cultivars of note are the tangor, a hybrid of mandarin and orange, and the tangelo, a hybrid of mandarin and grapefruit. A third distinctive variety of orange is the bitter orange (*C. aurantium*), chiefly represented by the Seville orange, which is grown commercially in southern Europe mainly for such products as marmalade. Compared with other citrus crops its yield is small and of little use in the juice market.

### 3.3.2.2 Lemon (*C. limon*)

An important crop in Italy and some other Mediterranean countries, the lemon is also grown commercially in the United States. The characteristic oval-shaped,
yellow fruits, apart from their culinary use, are an important source of juice and flavouring for the soft drinks industry.

3.3.2.3 **Grapefruit (C. paradisi)**
A large round citrus fruit with a thick yellow skin and somewhat bitter pulp, the grapefruit is generally accepted to be a hybrid between the pummelo and the orange. The pummelo (C. grandis) originated in Asia and is grown in many eastern countries including China, Japan, India, Fiji and Malaysia. It was introduced to the West Indies during the seventeenth century by Captain Shaddock, and hence in that region it is sometimes referred to as a ‘Shaddock’. Today the commercially important grapefruit is grown in many parts of the world. Notable producing countries are Argentina, Cuba, Cyprus, the Dominican Republic, Egypt, Honduras, Israel, Mexico, Mozambique, Pakistan, South Africa, Spain, Turkey and the United States. The most predominant cultivar to be seen in the market is the Marsh Seedless, followed by a red, pigmented version, the Star Ruby.

3.3.2.4 **Lime (C. aurantifolia)**
Limes require warm and humid weather conditions in order to thrive on a commercial scale. India, Egypt, Africa, Mexico and the West Indies are therefore prime growing areas. Mexico and the West Indies together produce a large percentage of the world’s lime crop. Relative to the other citrus fruits, limes are a small round fruit; they are green or greenish yellow in colour, and not more than 8–10 cm in diameter, with a sharp, fresh and characteristic flavour.

3.4 **General comments on fruit juice processing**
The various types of fruit, because of their nature, shape, size, harvesting characteristics and so on, may require specialised treatment during processing. In all instances, however, the operation involves a number of stages: obtaining the fruit supply in a correct state of maturity, expressing the juice in the most efficient manner possible, and then, if required, treating the juice with enzymes (e.g. pectolases and cellulases) for clarification, followed by a suitable filtration stage before concentration and eventual packaging or storage.

In citrus fruits, where the outer skin or epicarp is a composite structure containing certain flavouring substances, it would be detrimental to juice quality if the fruit were subjected to direct pressure as is the case with the fleshy fruits, that is, soft fruits, pome fruits and stone fruits. Stone fruits, before being processed for juice separation, must first be separated from their stones, or pits, in order to facilitate ease of handling and to avoid unwanted notes in the finished
product. The pits can be further processed to yield both fixed oils for application in the cosmetics industry and glycosides from which may be sourced other natural flavouring ingredients, such as benzaldehyde, a characteristic of marzipan, almond flavourings and the like.

3.4.1 Processing of ‘fleshy’ fruits

In the separation of juice from its fruit, the traditional method has been to apply pressure to the mashed, or pulped, fruit in order to force the liquid portion through a cloth or some form of screen. There are several styles of separator available, for both batch and continuous production, and a few of these are referred to in the following.

3.4.1.1 Pack press

The pack press is based on the traditional ‘rustic’ press widely used in the cider industry. The press comprises a set of frames for containing the fruit. These are loaded, in stages, by placing a loose weave cloth over each rectangular frame and adding an appropriate quantity of the fruit mash from a hopper feed above the assembly. The mash is then smoothed, or trowelled, over the frame by the operator, who then folds the cloth across to cover it over. Another frame is then placed on top and the process repeated until several filled layers are formed. The stack is built up inside a rectangular tray, or bed, which serves as both a collecting device and a platform to be raised by the action of a vertical hydraulic ram in bringing the top of the stack into contact with a fixed frame. In this way pressure is created to express the juice, which runs down into the tray for collection.

Earlier versions of the pack press were made of hardwood. Some still are, but modern pack presses are usually constructed from stainless steel and are frequently designed to accommodate two stacks for improved efficiency. These are assembled in sequence in their respective collecting trays before moving across the hydraulic ram, so that while one pressing operation is under way the next stack is being prepared and charged in readiness to follow on. Thus an almost continuous, albeit labour-intensive, pressing operation can be carried out.

The pack press is ideally suited to a relatively small production output for specialised fruit varieties, but for large-scale production fully mechanised systems are necessary.

3.4.1.2 The horizontal rotary press

Perhaps the most successful of the mechanised systems, to date, has been the horizontal rotary press designed and developed by a Swiss
company – Bucher-Guyer AG, of Niederweningen/Zurich. This design carries a
horizontal hydraulic piston (HP) operating within the cylindrical hollow body of
the press. Between the specially designed endplate and the piston faceplate run
a large number of flexible drainage cores, with well defined ribbing along their
lengths to act as juice channels. Each line throughout its length is covered with
a coarsely woven filter sock. The press will work, self-optimised, to operate in
strict sequence with pressing periods appropriate to the fruit in process.

Mash is pumped into the press to partly fill the cylinder space. The piston then
moves forward under hydraulic pressure to express the juice by consequently
forcing it through the filter sleeves and along the channels in the drainage cores,
to be fed through outlets in the specially designed plates for collection in a juice
tank. The piston then withdraws whilst a second mash charge is received and the
process repeats. During the pressing operation the endplate of the unit rotates
with consequent meshing of the filter-lines, so that at the end of a pressing cycle
the lines are loosely meshed together within the press-cake, or fruit pomace.
As the piston moves back in conjunction with incoming mash, reverse rotation
occurs, disentangling the lines and redistributing the pomace amongst the fresh
charge of mash. Hence there is no build up of press-cake and maximum effi-
ciency in terms of juice removal. Depending upon the fruit type there will be
several charges of mash to feed the pressing sequence until a ‘full load’ has been
achieved.

At the end of a complete pressing sequence the pomace residue is dis-
charged by rotating the whole press body with the piston fully retracted and
moving the cylinder flanges away from the endplate to create an opening
through which the dry pomace is released for collection; usually along a screw
conveyor with a suitable storage hopper. The standard Bucher-Guyer press,
the HPX 5005i (similar to the one shown in Figure 3.4), is designed to
comfortably accept a 10 tonne loading, although with suitable selection and
pre-treatment of the fruit, quantities in excess of this can be handled quite eas-
ily. Good quality fruit (e.g. apples) will yield 85–95% by weight of expressed
juice (depending on pre-treatment and degree of post-extraction). It is quite
feasible therefore for a press of this size to handle in excess of ten tonnes of
fruit mash, in stages, leaving around one tonne of pomace to discharge.

3.4.1.3 The use of centrifuges in processing
Although direct pressure has previously been an obvious choice of processing
method, in comparatively recent times there has been a move towards employ-
ing centrifugal separation of juice from a continuous fruit mash stream. The
modern decanter centrifuge can be used in conjunction with a pressing system
as a preliminary step to increase throughput efficiency, or, when two units
are used, as a complete separation system providing a coarse primary stage,
followed by a final clarification stage.
Figure 3.4  Horizontal rotary press: Universal Fruit Press HP5000 (Bucher-Guyer).

Figure 3.5  Clarifying decanter (horizontal scroll centrifuge).  
Source: Courtesy of Westfalia Separator Ltd.
The decanter is a horizontal scroll centrifuge with a cylindrical-conical solid-wall bowl for the continuous separation of solids out of suspensions (see Figure 3.5). Centrifugation has a particular advantage when producing single-strength cloudy juices for direct consumption since a better definition in terms of particle size distribution can be attained. Typically, with decanter juice, 60% of the particles in suspension are smaller than 1 μM, whereas this figure is reduced to around 20% for pressed juice. Hence there is greater likelihood in the latter for instability and sedimentation. It should be noted that the major factor in the production of ‘naturally cloudy’ juices is the rate of processing and that to ensure stability the juicing stage should be followed immediately by pasteurisation in order to deactivate the enzymes naturally present in the fruit.

Decanters are also of use in the production of fruit purée, where the aim is to remove only the undesired particles such as pips, stalk fragments, skin fragments and coarse tissue material, leaving the crushed fruit flesh evenly distributed throughout the juice. By setting the machine parameters accordingly, the undesired components can be selectively removed from the liquid stream output of purée.

Decanters are frequently used in conjunction with disc-stack-type centrifuges in the pre-preparation of clear juices and juice concentrates, where the initial decanter treatment results in a partially clarified juice with a low level of suspended solids. This is followed by a clarification stage using a disc-stack whereby the solids are thrown outwards from the through-flow juice stream into a solids-holding space and automatically discharged therefrom as and when an optimum level of solids is reached (see Figure 3.6).

3.4.2 The use of enzymes in fruit juice processing

Pectin is an essential structural component of fruits, where in combination with hemi-cellulose it binds single cells to form the fruit tissues. Pectins are chains formed almost exclusively of D-galacturonic acid units, partially esterified with methanol. These chains are often referred to as ‘polygalacturonic acid’ or its synonym ‘homogalacturonane’. In the immature fruit the pectins are mainly insoluble, but as the fruit ripens there is a gradual breakdown of some of the pectic substances in the skin and flesh cell walls, resulting in the formation of polysaccharide component materials. The general term ‘pectic substances’ covers not just pectins but just about everything resulting from the degradation processes involving pectin that take place as the fruit maturates, soluble forms included.

As fruit becomes softer, less acidic and sweeter and heads towards its optimum state of maturity, such changes need to be taken into account by the juice processor. Apples, in particular, are best processed prior to their fully ripened state, as solubilised pectin and softened fruit tissues will seriously affect the
efficiency of separation of the juice and low yields will result. Other fruits, such as the berry fruits, need to be fully ripened in order to optimise flavour. Broadly speaking, therefore, if the resulting juice is to be clarified, enzyme treatment is required at some stage in order to break down the pectin and to enable precipitation or sedimentation of the resulting pectic substances. Particularly important when the final product is to be a juice concentrate is that no pectin should be left available to ‘jam up’ the operation.

As a general rule it is the juice of the apple, not the fruit, that is to be treated with pectolytic enzymes (i.e. after pressing) whereas the soft fruit varieties are ‘de-pectinised’ at the mash stage, before pressing to facilitate processing. There are, of course, natural enzymes in the proximity of the fruit, borne within any traces of surface moulds, and the pre-washing stage is designed partly to reduce the effect of these. Also, the milling of fruit is violently disruptive and, apart from accessing juice for ease of separation, will initiate a host of interactions as the integral enzyme systems natural to the fruit are introduced to suitable substrate materials. Thus the presence of pectin esterase will, during the milling, pressing and clarification stages, prior to any pasteurisation or heat treatment, result in the de-methoxylation of the pectin chain, liberating methyl alcohol, which will appear later as a trace contaminant in the aroma volatiles fraction. In some processes, therefore, by passing the milled fruit pulp through a tubular heat exchanger, these rogue enzymes are denatured by a pasteurisation stage prior to juice separation.

Figure 3.6 Self-cleaning clarifier (disc-stack centrifuge).
Source: Courtesy of Westfalia Separator Ltd.
Where the juice is destined for concentration it is essential for the pectin to be destroyed, or degraded, as already mentioned. Pectinase or poly(1,4-α-D-galacturonide) glycanohydrolase, in its commercially available form, is produced from fungal sources (i.e. *Asperillus* sp., *Rhizopus* sp.) and possesses a wide variety of component activities. It operates comfortably between pH 2.5 and 6.0 and subject to supplier type can function well at specified temperatures between 30 and 60°C. Activities include

1. **Esterase** (polymethylgalacturonase esterase), where the action is to de-esterify pectins, with the removal of methoxy groups, to form pectic acid.

2. **Depolymerases** (polymethylgalacturonases with either endo- or exo-activity). Several different mechanisms take place by which the polymer chain is completely disrupted into fragments. The term ‘endo-’ refers to those polygalacturonases which act at random within the chain, and ‘exo-’ to those where the attack is sequential along the length of the chain starting at one end.

3. Another form of depolymerase activity is given by pectinlyases, which operate at glycosidic linkages either side of which carries an esterified, or methoxylated, group.

**Amylases.** In the case of pome fruits other enzyme activities are sometimes required. When fruit has been picked before maturity and then ripened under controlled atmospheric conditions in a cool store, there is a likelihood of starch retention originating from the unripe fruit. This starch can become gelatinised during juice processing and can give rise to precipitation and haze effects in the final product. Amylases are used here to break down any residual starch and overcome such problems.

**Cellulases.** These enzymes may be used to facilitate the rapid removal of colour during fruit processing. Such enzymes have also been employed to good effect in recent years in the ‘total’ liquefaction of plant tissues during processing, obviating the need to use a press, yet increasing yields.

The usual way of employing enzymes, in the case of soft fruits, is to dose at the recommended level (e.g. 0.1%) into the pre-warmed mash, which is well mixed and left to stand for a recommended period and constant (optimum) temperature. For a typical pectinase, the standing period for blackcurrants and other soft fruits will be around 1.5 h. The exact time is determined by taking a series of samples of the mash during the enzymation stage, pressing or filtering off some of the juice and treating this with an excess of alcohol (e.g. 40 ml single-strength juices +60 ml alcohol in a 100 ml measuring cylinder). Dissolved pectin, if present, will be thrown out of solution as an insoluble gel, whereas if it is fully degraded, it will form a flocculent precipitate of pectic substances settling to the bottom of the measuring cylinder.
Although this is a purely empirical test, it will give an experienced operator correct information on the required process parameters.

3.4.3 Extraction of citrus juices

As already discussed, fleshy fruits yield juice upon pressing. A pre-treatment is necessary, but effectively the whole fruit (or de-pitted fruit in the case of drupe fruit) is used for the resulting extraction. Citrus fruits, however, are handled in an entirely different manner because of their structure.

3.4.3.1 The Fruit Machinery Corporation extractor

The epicarp or outer peel of the citrus fruit contains a rich source of the essential oil in oblate, spherically shaped oil glands situated in that part of the flavedo just below the waxy surface layer. Citrus oils are of great importance in the flavour industries, being widely used, as might be expected, in beverage formulations. They command a strong place in the market. Many different processes have been employed worldwide across the range of citrus types for separation of both the oil and the juice. Typically, the fruit will be passed over a rasping device, for example, an abrasive roller, to pierce and disrupt the oil glands within the flavedo layers, thus releasing the oil which is washed away for collection by a water spray. Thereafter it can be recovered by centrifugation and dried. The rasped fruit is moved into an extractor, where the juice is expressed and recovered, to leave the albedo (pith) and flavedo (outer peel).

The expressed juice is subjected to screening before being further processed. A rotary brush sieve, followed by a centrifugal separator, may be used to bring the suspended particles into the stability range of below 1 µm diameter, at which point the juice can be pasteurised and aseptically packed for direct consumption as single-strength juice or concentrated as required.

Lemons and limes are processed, in a similar manner, by direct pressure on the washed fruit.

Perhaps the most frequently encountered processing sequence is that provided by an extractor manufactured by the Fruit Machinery Corporation (FMC), generally employed for orange types. The extraction unit is designed to process individual fruits in rapid succession. In the processing hall these units are usually set up in banks of 8–10 to accommodate a continuous stream of washed and clean fruit separated into size bands. The fruit passes along feed channels to the appropriate size of extractor.

Each extractor, constructed of stainless steel, comprises two cups, one inverted above the other. During operation, fruit is received into the lower cup and the upper cup descends to press down upon it. Simultaneously, a perforated stainless steel tube is forced up through a channel in the lower cup, cutting
a plug out of the bottom part of the fruit. As pressure continues to be applied, the juice is forced out through the perforations in the wall of the tube, which also acts as a screen to retain the plug, seeds and any pulp debris. The solids are later ejected at the end of the process cycle in readiness for the next pressing operation. As the two cups move together to enclose the fruit, the oil vesicles in the outer peel are ruptured to release the oil. While the juice is being expressed from inside the fruit, the oil is removed, together with some skin debris, by water spray, from the outside surface of the fruit. It passes via a conveyer to a cold-pressed oil recovery system.

The expressed juice flows into a manifold attached to the line of extractors and thence to the so-called finishing stages, wherein the juice is progressively screened to remove excess pulp and to bring it into the range set by plant quality standards, effectively minimising the level of insoluble solid material and rendering the juice suitable for further processing.

The pulp recovered during screening may be transferred to a pulp-wash operation to yield further soluble solids by counter-current extraction with water. The washed pulp may be held for further processing or included with the bulk of ejected peel material from the extractors. This is milled, treated with lime (calcium hydroxide or calcium oxide) to break down pectin and reduce water retention, pressed, dried to c.10–12% moisture content and finally converted to pellets. Being high in carbohydrates these are used as ‘filler’ in livestock feed blends.

3.5 Juice processing following extraction, ‘cleaning’ and clarification

The requirements for further processing will depend to some extent on the juice type. In the case of cloudy juices, heat treatment via pasteurisation is used to denature any residual enzymes released from the fruit during processing and also to eliminate spoilage organisms such as yeasts and moulds that arise also arising from the natural fruit source. The stability of a cloudy juice will very much depend upon the ‘cleaning’ stages after pressing, which are timed at rapid removal of pulpy and sedimentary material. Brush screens, decanter and disc-stack centrifuges may be used online to remove potentially unstable suspended solid material in order to provide a juice of uniform consistency and cloud, in readiness for pasteurisation. Pasteurisation of citrus juice is carried out at temperatures above 95°C to eliminate the undesirable effects of pectolytic enzymes, particularly pectin esterase, whose action in demethoxylation of pectin will give rise to cross-linking between resulting polygalacturonic acid molecules, gelation effects and loss of cloud stability.

Natural-strength juices for direct consumption are pasteurised and processed under aseptic conditions, where the product is then packed without contamination into sterile containers and hermetically sealed.
There are a number of well-established systems for the aseptic packaging of liquids. Notable among these are those packs constructed, box form, *in situ* on the filling line from a cardboard, aluminium, plastic laminate sheet, such as TetraPak or Combi-box. In the TetraPak system, the packing material enters the filling machine from a feed roll; the sheet contact surface is sterilised with warm hydrogen peroxide solution; it is formed into a tube, and its lower end is heat-sealed across the width; the tube is filled, sealed at the upper end, cut and then folded into a box shape. This produces a continuous output of filled cartons with premium utilisation of bulk storage capacity.

A second, and highly efficient, aseptic packaging system uses a plastic laminated bag with a novel filling and sterile sealing facility. There are several designs available but in general the bags are supplied in a sterilised condition (having been $\gamma$-irradiated for that purpose). The neck of the bag is sealed with a plastic membrane that, during the filling action, is automatically steam-sterilised and then ruptured upon the introduction of the pasteurised juice stream. When the filling operation is complete, a non-return valve enables removal of the inlet feed tube without loss of liquid and the neck is capped and sealed. The bags are available in a wide range of sizes and are designed for packing into boxes from 5 to 25 l capacity, into 200 l drums, and into rigid outer containers of up to 1000-l capacity.

Clarified juices, where pectin has been actively removed by enzyme treatment as an integral part of the process, are filtered bright and then either pasteurised or rendered sterile by the use of membrane filters to eliminate yeasts and moulds directly. Ultra-filtration techniques are used in which the juice feed flows transversely, under pressure, across a membrane support tube to avoid ‘blinding’ of the filter surfaces. For sterile filtrations such membranes provide a porosity value of, typically, $0.02 \, \mu m$, ensuring the removal of spoilage organisms. Clarified, sterile juice passes from within the tube for storage under sterile conditions. Periodically, the circulating liquors on the feed-side of the filter are run off and replaced with fresh juice input.

### 3.5.1 Juice concentration, by evaporation

When the final juice product is a concentrate, the clear filtered or ‘cleaned’ cloudy juices are automatically subjected to heat treatment during the course of their concentration. (Figure 3.7 provides an overview of the concentration process.) Heat treatment of juices is an area where the design of process requires careful consideration in order to avoid any detrimental effects on flavour and appearance of the product. Early evaporators had demonstrated that high-vacuum–low-temperature processing produced concentrate of good flavour quality, but it was soon discovered that there was a drawback in that the heat treatment was insufficient to deactivate pectin methylesterase, which gave rise...
to gelation in the final product. The effect was not immediately apparent, but was seen to occur after a few weeks’ storage, when the contents of a filled drum of, say, orange concentrate might be found to have gelled. The introduction of short-term high-temperature pasteurisation into the concentration process, bringing the juice temperature to around 95°C with sufficient ‘holding’ time to eliminate microorganisms and to denature the enzyme, was used to offset the effect. Early evaporators operated by recycling the juice feed until the desired level of concentration was reached; this also increased the heating effect on the juice. The industry has since progressed to evaporators of a multi-effect, multi-stage, single-pass design, which as well as being highly efficient in heat...
utilisation, have the added advantage of being easier to control when there are Brix variations in the incoming single-strength juice feed. At the present time, thermally accelerated short-time evaporators (TASTE) are in worldwide use across the processing industry.

Although a combination of product quality and cost considerations will dictate the methods used for bulk processing of fruit juices, there are instances where the flavour components present in the juice are vulnerable to any form of heating during concentration. Strawberry juice is perhaps the best example of this, being one of the most heat sensitive of fruits, and it works well with alternative processes for concentration such as freeze-concentration and hyperfiltration.

3.5.2 Freeze-concentration

In general, the advantage of freeze-concentration is that there is no loss of volatile flavour components as in the evaporation procedures. Freeze-concentration is carried out by crystallisation of water from the juice. Depectinised juice is cooled to low temperature within a scraped-surface heat exchanger, to form a slurry of ripening water crystals as the heat of crystallisation is withdrawn from a well-mixed suspension of crystals. The crystals are removed by screening or centrifugation. On an industrial scale, freeze concentration is generally carried out as a multi-stage operation where the overall crystallisation rate, which strongly decreases with increasing concentration, is higher than in a single-stage operation. Viscosity is a determining value of the degree of concentration attainable. An upper limit of 55% refractometric solids (RS) is claimed, below that of standard evaporative processes. In this process the majority of the volatile flavour components are retained, although some traces (<10 ppm) are lost during the removal of the ice crystals.

3.5.3 Hyper- and ultrafiltration

By use of selective membranes, water can be removed by filtration from the juice in order to effect its concentration. Depending upon the molecular size of the compounds and the cut-off value of the membrane used, there is likely to be some loss of flavour components. These may be recovered from the permeate by distillation and returned to the juice concentrate. Concentration by these methods is less effective in terms of ‘folding’ than other methods but can provide advantages in specific cases; for example, capital costs associated with hyperfiltration are around 10–30% less than for evaporative systems with aroma recovery equipment.

Table 3.1 shows the degree of concentration that can be achieved using these different processes.
3.6 Volatile components

The characterisation of a fruit type or variety will be reflected in the flavour profile of its volatile components. Analytical techniques can produce an accurate peak profile using gas chromatography, but in simpler terms the sensory receptors of most individuals can quickly differentiate between fruit varieties. We have four basic taste senses, sometimes described as sweet, sour, acid and bitter, and these are identified by taste receptors situated mainly on the tongue. The key component of flavour differentiation, so-called top-notes and the like, is detected not so much by taste as by aroma in the nasal cavity. Thus, during the process of eating and drinking, the release of aroma volatiles can be identified and an assessment of their value arrived at.

It is not always necessary to return aroma volatiles to the juice concentrate, as this is dependent upon the intended application of the latter. However, if the concentrate is to be reconstituted for use in a soft drink formulation, then the addition of flavouring top-notes will almost certainly be a necessity. Aroma volatiles recovered during evaporative concentration of juices provide a prime source of natural flavouring. However, as already detailed, from the moment the fruit is milled in readiness for processing changes will occur due to the release of natural enzymes and the initiation of biosynthetic pathways, resulting in the formation of some atypical flavour components. Hence, to create a more representative extraction of flavour it is preferable to remove volatiles at the earliest possible stage in the process. The term ‘pulp-stripping’ applies to the technique of inline removal of volatiles from the pulped fruit before its depectinisation in readiness for the pressing stage. This may be effected by passing the pulped fruit through a tubular or scraped-surface pre-heater/pasteuriser into a suitably sized evaporator to remove something in the region of a 5% strip, carrying the larger part of the volatiles fraction, before cooling and returning back to process (Figure 3.8). The volatiles may be further concentrated by distillation or stored frozen at the strength produced.

The condition of incoming fruit is always of the greatest importance and there will inevitably have been a certain amount of fermentation due to natural yeasts

<table>
<thead>
<tr>
<th>Equipment type</th>
<th>Juice concentrate (% m/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scraped film evaporators</td>
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<tr>
<td>Plate evaporators (recycling effect)</td>
<td>65–75</td>
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<tr>
<td>Falling film evaporators</td>
<td>65–75</td>
</tr>
<tr>
<td>Freeze-concentration</td>
<td>45–55</td>
</tr>
<tr>
<td>Hyperfiltration</td>
<td>15–25</td>
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</table>
present on the fruit. Rapid processing minimises the effect, but there will almost certainly be a certain amount of ethanol present in the stripped volatiles fraction. Levels of ethanol up to 5 or 6% are not uncommon, and they are often deemed acceptable, but above this the balance of flavour may be seriously affected. Design of plant is critical, and the rate of heat input is carefully controlled to enable a steady-state and optimum level of volatiles strip for a particular fruit system. Separator designs vary from the simple cylindrical chamber with side entry and steady input of pre-heated pulp to high-speed tangential entry units creating a thin-film effect and larger surface area for more efficient removal of volatiles, or to the more technically efficient counter-current system producing multi-stage effects, of which the spinning cone column is a prime example.

3.6.1 Spinning cone column

Although conventional separators are successful in removing the volatiles from juice streams, the resulting strip will usually require further rectification and thereby concentration in order to render it a flavour component in its own right.

Additional heat treatment inevitably involves losses in efficiency as there are likely to be subtle changes in quality and yields due to heat degradation of some of the components. The spinning cone column (Figure 3.9) is designed to selectively isolate a volatiles fraction in one operation. It is in effect a
counter-current extractor, incorporating a central, vertically placed, rotating shaft, along the length of which are a series of upturned cone-shaped cups. In operation, the cups rotate smoothly within a similar series of cone-shaped stators attached to the inner wall of the column.

The juice feed is introduced at the top of the column, on to a distributor disc, and runs down the column in a thinly layered stream between the stators and spinning cone assembly. Counter to its flow and moving up the column is a gas phase, which may be non-intrusive, such as nitrogen, or more commonly a ‘live’ steam feed. The multiple-stage effect produces a highly efficient separation of the component volatiles from the juice stream and an enriched fraction is produced.

3.6.2 Fruit juice volatiles composition

As already mentioned, it is the volatile constituents that serve to identify fruit type and variety. Broadly speaking, qualitative analysis will identify the principal substances present in the volatiles fraction as representative of a particular fruit type, but it is the relative proportions of these substances that will reflect the variety. Alcohols, volatile acids, esters, carbonyl compounds, and low-boiling hydrocarbons are the principal groups represented. Analysis by GC–MS (gas chromatography coupled with mass spectroscopy) can be used to provide quantification and identification of the various constituents.
3.7 Legislative concerns

Fruit juices, whether of natural strength or concentrated, are materials of commerce, to be sold direct or for use in a variety of food and drink applications. It is essential that they conform to legislative requirements for authenticity and purity, whether for labelling purposes (in avoidance of misleading statements), nutritional standards or in respect of food safety in the final product.

On a global scale, there is good correlation between quality standards for fruit and fruit juice processed in different regions. In the European Union, legislative controls are set up, or modified, by the central European Council of Ministers, usually following discussion with and between trade organisations from the EU member countries. A new directive, once agreed and approved, is translated into the statutory laws of the member countries concerned.

3.7.1 European fruit juice and nectars directive

In the European Union, Council Directive 2001/112/EC relating to fruit juices and certain other products intended for human consumption was published in the European Official Journal on 12 January 2002, thereby becoming law and revoking several earlier regulations (as amended) dating from 1977. The new directive, effectively an update on a range of previous amendments, invokes various provisions from the Food Safety Act 1990, Council Directive 95/2/EC (Miscellaneous additives) and Council Directive 2001/111/EC (Sugars). Definitions and descriptions are given (Schedule 1) for fruit juice and concentrated fruit juice and also for fruit juice from concentrate. It is this latter category that has involved some difficulty in the interpretation of the regulations.

The commercial importance of juice concentration lies, of course, in the area of transportation. The removal of a large volatile fraction including both water and flavour top-note components from the natural strength juice will reduce both weight and volume of product and result in worthwhile cost savings on transport. At the same time, there are benefits over natural strength juice in that the higher concentration of dissolved solids (usually 66–72% m/m RS) will exert an osmotic effect upon microorganisms, if present, and inhibit their growth, hence the greater stability and extended shelf-life under cool storage conditions of the so-called commercially sterile juice concentrates. Some difficulty is likely to occur, however, when the concentrated juice is reconstituted.

In an ideal situation, both water and flavour components removed during concentration should be returned when reproducing the diluted form. This approach would seem to be commercially untenable, yet is included in part of the legislation. Recent guidelines (UK Food Standards Authority) provide an extension of the description of ‘fruit juice from concentrate’ that enables a more
practical approach. The following designation is given:

The product obtained by replacing, in concentrated fruit juice, water extracted from that juice during concentration, and by restoring the flavours and, if appropriate, pulp and cells lost from the juice but recovered during the process of producing the fruit juice in question or fruit juice of the same kind; in which the water added must display such chemical, microbiological, organoleptic and, if appropriate, other characteristics as will guarantee the essential qualities of the juice; and the product must display organoleptic and analytical characteristics at least equivalent to those of an average type of fruit obtained from fruit or fruits of the same kind.

3.7.2 AIJN guidelines

Central to the processing of fruits and juice products within the member countries of the European Union is the Association of the Industry of Juices and Nectars from Fruits and Vegetables of the European Union, familiarly termed AIJN. This body has, through its technical committee, issued guidelines detailing standards for the range of juice products manufactured in the European Union, and also on issues of good manufacturing practice (GMP). During its draft stage, the 2001/112/EC Directive led to much discussion on the subject of the restoration of flavour to fruit juice reconstituted from concentrate. AIJN guidelines have been published in clarification of this part of the directive. Add-backs, restoration aromas and flavours are focused upon in an effort to clarify any controversy over their use. Section 5 of the guidelines is perhaps the most important as it refers to permitted solvents to be used in the preparation of the restoration aromas:

‘. . . Additives & Solvents permitted in the manufacture of Natural Restoration Aromas’: The natural status of these aromas should not be jeopardised by the use of materials not from the named fruit. Water, food grade CO₂, and ethanol from non-GMO foodstuffs may be used as solvents, and also in extraction. Other solvents and additives, even those allowed by the EU Flavouring Directive (88/388/EU) and subsequent amendments, are not permitted.’

3.7.3 Labelling regulations and authenticity

All things should be laid bare, so that the buyer may not be in any way ignorant of anything the seller knows. (Cicero)

This has always been an objective of fair trade, but the temptation to enhance profitability too frequently intervenes and it is necessary for the buyer at times to carry out testing to ensure the authenticity of a purchased raw material so that the declaration subsequently given can meet the requirements of labelling. Fruit juices have often, over the years, been subjected to sophistry. As analytical techniques have become more objective and accurate in discovering fraud,
so the methods used by the fraudsters have also become more technically devious. The most frequent method of deception is to dilute the concentrated juice product with sugar syrup and to adjust flavour levels and colour levels as necessary. Thirty years ago the ‘stretching’ of juices was carried out in a fairly basic fashion, using sugars that did not match the fruit, booster flavourings likewise and sometimes colours that might have been more at home on an artist’s palette. Nowadays, such subterfuges would be easily recognised. Periodically, there have been attempts at using analytical profiling of certain of the juice components. Amino acid profiles were at one time thought to be an ideal route to proving authenticity, particularly in the case of citrus juice concentrate, until it was discovered that a carefully selected blend of amino acids could be used to restore balance, at least on an analytical scale, and so such testing went out of vogue. However, the testing of a wide range of parameters was for many years still the only real method of arriving at a sensible assessment of authenticity.

Perhaps the most detailed system was that developed in the early 1970s under the auspices of the Association of the German Fruit Juice Industry. A special working group of experts from backgrounds in research, industry and food control was set up with the objective of devising a method of evaluation of fruit juices. The initial results were published in 1977 under the title ‘Richwerte und Schwankungsbreiten bestimmter Kennzahlen für Apfel-, Trauben- und Orangensäfte’ (Guide values and ranges of specific reference numbers for apple juice, grape juice and orange juice). The system of RSK-values (named from the title of this report) was officially recognised within the Federal Republic of Germany in 1980. RSK-values for other fruit juices were published in following years. The appraisal relies upon the degree of correlation within a full set of analytical values, and the process can be quite time consuming as something of the order of 30 values can be included in the assessment.

Although AIJN and RSK-value guidelines are of great use in the evaluation of fruit juices, there is always the risk of fraud. Today, more sophisticated techniques involving the analysis of stable isotope ratios of the sugars present in juices are a more reliable means of assessing authenticity.

3.8 Quality issues

Quality can be regarded as a measure of the suitability of a fruit juice, fruit juice concentrate or fruit juice extract for an intended application. In general, whatever the application, it will be the consistency in performance of the product, from batch to batch and season to season, that is the prime concern. In order to meet quality targets, therefore, it becomes critical that processing is carried out in the correct manner using fruit of an optimum level of maturity, and that the product is stored under suitable conditions to limit effects of degradation during a required shelf-life.
3.8.1 Absolute requirements

As previously indicated, the evaluation of fruit juice will, as a rule, require an expert appraisal of the entire analysis. In practice there will be key parameters to be noted and adhered to during the manufacture of fruit juices and related products. Of these, the soluble solids content and titratable acidity are the major indicators to be taken into account when identifying the status and suitability of a juice product for use in an application.

3.8.1.1 Soluble solids

The soluble solids content will relate directly to both the sugars and fruit acids, as these are the main contributors. Pectins, glycosidic materials and the salts of metals (sodium, potassium, magnesium, calcium etc.), when present, will also register a small but insignificant influence on the solids figure.

Although the soluble solids can be determined gravimetrically from a juice sample (filtered clear if necessary from any suspended solids), it is usual to refer to the more accessible determination of Brix value. Since it is dissolved solids that influence the measurement, there is a direct relationship between the Brix value and the specific gravity of the solution. Although the measurement is most accurately determined using a Brix hydrometer, which reads the percentage of sucrose directly, for the higher viscosities of concentrated fruit juices it is more convenient to use a Brix-calibrated optical refractometer, thereby providing a direct reading of % w/w sucrose. Although the term ‘% w/w RS’ (i.e. refractometric solids) would be more appropriate to fruit juices when measured in this way than ‘degrees Brix’, it is the latter that is in general use in the fruit juice industry to indicate the degree of concentration or ‘folding’.

Refractometer readings can be affected by the presence of other dissolved solids. The presence of fruit acids in particular can influence the refractometric Brix reading and should strictly be taken into account when calculating juice concentration. In most cases the effect is not significant; however, when there are appreciable levels of acid in the juice, for example, lemon and lime juices, there will be a need to apply the correction.

Stevens and Baier (1939) produced a table that gives a correction for obtaining Brix from refractometer readings from juices or other acid-containing sugar solutions. Based on the citric acid content of juices, the corresponding correction is to be added to the refractometer reading.

Tables 3.2 and 3.3 provide Brix values and corresponding specific gravities and sucrose contents, and Brix values for a range of fruit juices.

3.8.1.2 Titratable acidity

The acidic character of a juice contributes to its flavour type and is taken into consideration when assessing the value of the juice for inclusion into new
Table 3.2  Brix table

<table>
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<th>Apparent SG at 20/20°C</th>
<th>Grams of sucrose per 1,000 ml (in air)</th>
<th>Brix % w/w sucrose</th>
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<td>1.448</td>
<td>1228.3</td>
</tr>
<tr>
<td>26.0</td>
<td>1.110</td>
<td>287.9</td>
<td>56.0</td>
<td>1.266</td>
<td>706.9</td>
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</tr>
<tr>
<td>27.0</td>
<td>1.115</td>
<td>300.2</td>
<td>57.0</td>
<td>1.272</td>
<td>722.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28.0</td>
<td>1.120</td>
<td>312.6</td>
<td>58.0</td>
<td>1.277</td>
<td>738.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29.0</td>
<td>1.124</td>
<td>325.2</td>
<td>59.0</td>
<td>1.283</td>
<td>755.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30.0</td>
<td>1.129</td>
<td>337.8</td>
<td>60.0</td>
<td>1.289</td>
<td>771.3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

beverage product formulations. Acid content (% w/w) is determined using a pH meter by direct titration against standardised alkali solution (e.g. 0.1 M sodium hydroxide) to an end-point at pH 8.1. When the juice is naturally clear, or has been clarified, and is of low colour intensity, the end-point may be accurately found using phenolphthalein as indicator.

Although there are other acids present in fruit juices (e.g. oxalic, iso-citric, tartaric), it is usual to record acidity in terms of citric acid, both for citrus fruit
juices and for the majority of soft fruit juices. Where apple and other pome fruit juices are concerned, the major organic acids are malic and citric, although usually malic predominates. In some varieties of pears, the two acids can occur in approximately equal proportions. Nevertheless, it is general practice to quote titratable acidity for pome fruit juices as % w/w malic acid, and the adjustments required, if the juice is to be used in the production of apple-based drinks, will be effected by the addition of malic acid. Both acids are usually measured in % w/w terms in their anhydrous form, although it is sometimes convenient to determine titratable acidity for citric acid in terms of its monohydrate form, as this form of the acid may be used in the formulation of certain beverages.

As a general rule, the acidity of juices will decrease with increasing maturity of the fruit source, or with increasing levels of sugars in the resulting juice. Hence the ratio of soluble solids (e.g. Brix values) to acidity is an important value in the assessment of juice quality. The Brix/acid ratio is frequently used to establish standard sensory, or taste, qualities for incoming juice supplies and to minimise the effect of seasonal variation. The higher the Brix value in relation to the acid content of the juice, the higher the ratio and the ‘sweeter’ the taste.

Table 3.3  List of current Brix values for single-strength juices direct and from concentrate

<table>
<thead>
<tr>
<th>Fruit juice</th>
<th>Direct juice Rel. density 20/20°C</th>
<th>Single-strength minimum Brix (direct juice)</th>
<th>From concentrate Rel. density 20/20°C</th>
<th>Single-strength minimum Brix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orange</td>
<td>1.040</td>
<td>10.000</td>
<td>1.045</td>
<td>11.200</td>
</tr>
<tr>
<td>Grapefruit</td>
<td>1.038</td>
<td>9.500</td>
<td>1.040</td>
<td>10.000</td>
</tr>
<tr>
<td>Apple</td>
<td>1.040</td>
<td>10.000</td>
<td>1.045</td>
<td>11.200</td>
</tr>
<tr>
<td>Grape</td>
<td>1.055</td>
<td>13.500</td>
<td>1.065</td>
<td>15.900</td>
</tr>
<tr>
<td>Pineapple</td>
<td>1.055</td>
<td>11.200</td>
<td>1.052</td>
<td>12.800</td>
</tr>
<tr>
<td>Lemon</td>
<td>1.028</td>
<td>7.000</td>
<td>1.032</td>
<td>8.000</td>
</tr>
<tr>
<td>Passion Fruit</td>
<td>1.050</td>
<td>12.400</td>
<td>1.055</td>
<td>13.500</td>
</tr>
<tr>
<td>Mandarin</td>
<td>1.042</td>
<td>10.50</td>
<td>1.045</td>
<td>11.200</td>
</tr>
<tr>
<td>Pear</td>
<td>1.044</td>
<td>11.000</td>
<td>1.048</td>
<td>11.900</td>
</tr>
<tr>
<td>Apricot</td>
<td>1.041</td>
<td>10.200</td>
<td>1.045</td>
<td>11.200</td>
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<tr>
<td>Tomato</td>
<td>1.015</td>
<td>4.000</td>
<td>1.012</td>
<td>5.000</td>
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<tr>
<td>Blackcurrant</td>
<td>1.040</td>
<td>10.000</td>
<td>1.046</td>
<td>11.400</td>
</tr>
<tr>
<td>Sour cherry</td>
<td>1.050</td>
<td>12.400</td>
<td>1.055</td>
<td>13.500</td>
</tr>
<tr>
<td>Raspberry</td>
<td>1.025</td>
<td>6.300</td>
<td>1.028</td>
<td>7.000</td>
</tr>
<tr>
<td>Strawberry</td>
<td>1.025</td>
<td>6.300</td>
<td>1.028</td>
<td>7.000</td>
</tr>
<tr>
<td>Peach</td>
<td>1.036</td>
<td>9.000</td>
<td>1.040</td>
<td>10.000</td>
</tr>
<tr>
<td>Mango</td>
<td>1.057</td>
<td>14.000</td>
<td>1.061</td>
<td>15.000</td>
</tr>
<tr>
<td>Guava</td>
<td>1.034</td>
<td>8.50</td>
<td>1.038</td>
<td>9.500</td>
</tr>
<tr>
<td>Banana</td>
<td>1.083</td>
<td>20.00</td>
<td>1.088</td>
<td>21.000</td>
</tr>
</tbody>
</table>

Source: AIJN reference guidelines for the evaluation of fruit and vegetable juices. (Revised completion 2001.)
3.8.1.3 Other quality considerations

In order to create a quality standard for a particular juice, natural strength or concentrate, there are a number of fairly routine analytical test parameters to be considered. These include

- **Specific gravity** (20°C/20°C).
- **Acidity** (% w/w) as anhydrous citric acid (or malic acid, as appropriate).
- **Colour measurements.** For clarified juices, strawberry, blackcurrant and like this will be a spectrophotometric determination, recording absorption of monochromatic light of a specified wavelength passing through a 1 cm pathway. Cloudy juices may be assessed directly by visual comparison against a recognised standard using a colorimeter.
- **Pulp content** (cloudy juices only; screened and suspended pulp determinations). In the citrus juice industry, the natural juice cells, or sacs, present in citrus juice are described as ‘screened’ or ‘floating’ pulp. Such pulp is normally removed during processing and can be added back as desired to meet a required specification. ‘Suspended’ pulp is centrifugable to a degree and may be determined thus, or by certain specialised tests where a juice concentrate is diluted into a measured volume of water and allowed to stand and settle over a specified time. These are generally empirical measurements that serve to provide comparisons within agreed parameters – for example, the Imhoff cone test, in which the sedimentable pulp is allowed to settle to the base of a calibrated (inverted) conical vessel, where its apparent volume can be read off.
- **Oil content.** Citrus juices are unique among fruit juices, where normally no oil is present, in containing residual oil after processing, or oil that has been added back to concentrates. It is essential to standardise oil levels, since much of the flavour character is established this way. The oil content is determined using either the Clevenger or Cocking–Middleton procedures. These methods make use of an oil trap apparatus in distilling off, and collecting, the volatile oil fraction of the juice. Both sets of apparatus include a calibrated vertical glass tube in which the steam-distilled volatile oil collects and where it can be easily measured and quantified with respect to the weight of juice taken.
- **Ascorbic acid.** Many juices contain ascorbic acid or vitamin C, which is quantitatively the most important vitamin in soft fruits, ranging from a negligible level in some whortleberries to around 200 mg/100 g in blackcurrants. Ascorbic acid performs a valuable function as an antioxidant in minimising degradation of certain flavour principles, and it is often important for it to be included in the processed juice or in a soft drink formulation. Levels in the range 200–400 mg/kg are typical. It should be noted that ascorbic acid can be added to natural strength juice only if it is
intended for direct use; otherwise, it should be added to the juice
concentrate. Addition to natural strength juice before its concentration will
result in its own degradation during the heating process and ultimate
spoilage of the product when an intense browning reaction takes place.

- **Preservatives.** Modern aseptic processing techniques and packing of
  juices will largely obviate the need to use preservatives, but there are
  instances when they are required and will need to be specified.
  Preservatives are strictly controlled by legislation; upper limits for sorbic
  and benzoic acids used singly in soft drinks are 300 and 150 mg/l (drink-
  ing strength), respectively. When used at higher levels for juice concen-
  trates, it is important to recognise the statutory levels for the final
  application. The use of sulphur dioxide has been severely limited in
  recent years, and in soft drink formulations it is now permitted, under
  European legislation, at just 10 ppm ‘carry-over’ from the use and addi-
  tion of juice concentrates. High-performance liquid chromatography
  (HPLC) techniques for the analysis of sorbic and benzoic acids have
  largely replaced the earlier well-used method whereby the acid was iso-
  lated from its sample by steam-distillation and the determination carried
  out spectrophotometrically on the resulting distillate.

- **Yeasts, moulds and bacteria.** Because of their low pH, fruit juices will
  present less than ideal conditions for pathogenic bacteria species, and
  these therefore are generally of no major concern for the juice producer
  who is operating under good manufacturing practices. There are acid-
  tolerant bacteria, however, whose presence can give rise to off-flavours,
  and this effect can be encountered with citrus juices, where it is thought
  that both diacetyl and acetylmethylcarbinol may be metabolic products of
  the growth of acid-tolerant bacteria. Diacetyl will introduce a mild cheesy
  or buttery note to the juice, whereas acetylmethylcarbinol produces no
  off-flavour although its presence may indicate bacterial growth. Where
  appropriate, it is customary to determine the diacetyl value, and this is
  done using a colorimetric method involving the reaction of diacetyl iso-
  lated from a sample with α-naphthol and the comparison of the optical
density of the resulting colour formation against a standard scale. The
standard plate count (selected agar media, 29–31°C, 3 days) giving the
total viable count (TVC) and the pour plate yeast and mould count meth-
ods (OGY agar, 20–24°C, 3–5 days) are generally used for microbiologi-
cal evaluation to ensure results will be within acceptable limits.
Complications can arise with certain spoilage types, where specialised
control procedures will need to be applied – in particular for osmophilic
yeasts, if present in concentrates, and also for spore-forming yeast or
mould species, which in their inactive state can withstand the effects of
pasteurisation.
3.9 Conclusions

Fruit juices are of great commercial importance in their own right as well as for direct use as ingredients in food and beverage products, and, as we have seen, they form the basis of a worldwide industry. Although production of natural strength juices can be sustained locally for direct consumption, it is the concentrates that offer advantages in transworld trade in view of savings in terms of bulk transportation. Modern methods of processing are aimed at optimising all quality factors by use of highly efficient, short-time processing followed by pasteurisation and aseptic filling. Aseptic filling techniques and sanitisation of plant facilities have now reached a very high standard. Improved conditions of storage incorporating refrigeration are used more and more to offset colour degradation effects and to maximise product shelf-life.

This chapter has touched upon some of the mechanical techniques used to express juice from the fruit source, but it should be noted that there are process variations on those listed that are subject to exclusivity within parts of the industry and the details of which are not publicly available.

Good improvements in the concentration of fruit juices have been achieved in recent years. As it is the case that the majority of concentrates are to be reconstituted in application, the quality achievable for the natural strength remake will be an important issue.

Commercial fruit juice represents the end of a carefully orchestrated chain of events starting with the selection and cultivation of certain fruit-bearing botanical species. Harvesting yields, seasonal changes and maturation, among other factors, have to be taken into account before the processing and juice production take place, and so it is not surprising that we encounter subtle variations in the taste profile of the final product. We can anticipate that in future more focus and research effort will be directed to the recovery and treatment of the aroma volatiles and other natural flavour ingredients and the manner in which their reintroduction into the diluted concentrate is carried out. It is here, in the area of taste, that the consumer finally puts product quality to the test and a resulting guarantee of satisfaction will be essential to future growth and commercial viability throughout the industry.

References and further reading