INTRODUCTION

Soft drinks are the fastest growing beverage category in the UK. In 1995, 9.6 billion litres of soft drinks, including fruit juices and bottled waters, were sold. This was an 8% increase in volume over the previous year. The industry is aiming to reach a target of 10 billion litres by the year 2000.

Important factors for market growth are changes in lifestyle, particularly an increase in leisure time, an ageing population and a trend towards 'healthier' and more 'natural' products. The next few years will see the first generation brought up on soft drinks become the 20-to-30 year old age group. This is likely to result in a further expansion in the market.

RAW MATERIALS

FRUIT RAW MATERIALS

Fruit juices

Fruit juices, as defined in the UK by the Fruit Juice and Fruit Nectars Regulations 1977 as amended, are 100% pure fruit juices made from fresh fruit or fruit concentrates. Only the flesh of the fruit can be used in juice production and not the pith or peel.

Some fruit juices, such as orange, grapefruit, apple, pineapple, tomato and certain tropical fruits are marketed as pure juice products. They are also often added as ingredients to other soft drinks. Fruit juices that are usually only used as soft drink ingredients include lemon, lime, blackcurrant, strawberry, raspberry and peach.

Citrus juices

The production of citrus juices is now such that in many countries a high proportion of the total fruit production is processed into juice. The major
market share is taken by orange but large volumes of grapefruit, lemon and lime are also produced. Most of the citrus juice for use in products manufactured in Europe is concentrated in the country of origin before shipping, but some is exported as single strength juice. The major areas of production of orange for the European market are Brazil, USA (Florida and California) and the Mediterranean area. Grapefruit juice is mainly produced in the USA, Israel and central America, lemon juice in the Mediterranean countries, Argentina and the USA and lime juice in central and South America.

Apple juice

Apple juice is produced and consumed extensively in many countries. The product can be either clear or cloudy. The production of apple juice is essentially a milling and pressing operation. Cloudy apple juice is merely centrifuged after pressing the fruit and clear apple juice is obtained by clarification. The traditional apple growing areas of the world are the temperate zones of North America, Europe, Argentina, South Africa and New Zealand. The most popular cultivar for juice production in the USA is Delicious. In the rest of the world Golden Delicious predominates. However there are many different cultivars with a wide range of taste characteristics that may be used for juice production.

Tropical juices

In terms of volume, pineapple is by far the major tropical fruit juice. The main producing countries are the Philippines, Brazil, Thailand, Kenya, USA and South Africa. The main process varieties are Cayenne and Perola. In most countries, except Brazil, the juice is a by-product of fruit canning. With a wider awareness among consumers, a number of other tropical fruit juices are now popular, particularly in combinations having a ‘tropical’ flavour. The predominant fruits here are passion fruit and mango, with some banana, kiwi, melon and guava.

Soft fruit juices

The major soft fruit juice is blackcurrant. This is becoming increasingly popular in soft drinks. The main production areas for blackcurrant are Europe and China. Blackcurrant juice is produced by a milling and pressing operation. Pectin degradation is an essential feature of the process and is performed on the milled fruit to enable pressing to take place. The juice is then clarified. Other popular soft fruits mainly used as blends in soft drinks are raspberry, strawberry, redcurrant and cranberry.

Tomato juice

The tomato is not classed as a fruit under the Fruit Juice and Fruit Juice Nectars Regulations 1977 and is included in the EEC Vegetable Juice Directive. Tomato juice is mostly obtained from tomato concentrate. The major concentrate producing areas are Italy, Greece, Turkey, Portugal and USA (California).

Comminuted citrus bases

The comminuted citrus base has been largely developed in the UK for producers of whole fruit concentrated drinks. The bases are prepared in the citrus producing areas from the whole fruit ingredients and exported to the UK. The ingredient combinations are usually producer specific and may contain the following: juice concentrate, essential oil, peel flakes and cloudy concentrate. The main producers of comminuted orange products are Spain, Sicily, Israel and South Africa. Comminuted lemon and grapefruit are produced to a much lesser extent.

VEGETABLE JUICES

Apart from tomato and rhubarb, which should be strictly classified as vegetables, significant quantities of juices are also made from some other vegetables, notably carrot, celery, beetroot and cabbage. These vegetables are all widely grown. The fresh vegetables are coarsely milled and then pressed to extract the juice.

OTHER RAW MATERIALS

Water

Water is the major constituent of soft drinks, including fruit juices. It is important that the water used in production does not affect the products being made in terms of composition, organoleptic and microbiological acceptability.
Waters from different areas have different characteristics. For example, ‘hard’ waters drawn from limestone sources contain calcium and magnesium salts, ‘soft’ waters drawn from surface sources usually contain the sulphates, chlorides or nitrates of sodium and potassium. Softer waters with low alkalinity are usually preferred for soft drink production. It is common for soft drink production sites to have their own water treatment facilities to ensure end product uniformity. The types of water treatment will be dependent on the geographical location of the production site and the particular products being manufactured. The water also needs to be sterilized and purified.

There are three main types of water treatment facility, coagulation, ion exchange with dealkalization, and reverse osmosis or nanofiltration. The use of reverse osmosis plants is becoming more widespread as very pure water can be produced with minimal chemical addition.

Where canned beverages are filled into coated steel cans, the level of nitrates in the water needs to be low as they act as a catalyst for corrosion.

Sweeteners

Sugar and sugar syrups
The traditional sweetener for soft drinks was cane or beet sugar, which is 99% or more pure sucrose. The sugar can be either in granulated form, requiring it to be dissolved to make a syrup, or ready dissolved as a syrup. Other syrups such as glucose syrup and high fructose syrups are also used. These are produced by the enzymic treatment of starch, most commonly corn starch.

Artificial sweeteners
These have sweetening power many times that of sucrose. The artificial sweeteners permitted in the EC are:

E950 Acesulfame-K
E951 Aspartame
E952 Cyclamic acid and its sodium and calcium salts
E954 Saccharin and its sodium, potassium and calcium salts
E959 Neohesperidine

Saccharin is still widely used in soft drinks due to its wide availability, low cost and good solubility. It is permitted at a maximum level of 80 mg l⁻¹. Aspartame is not totally stable under the acidic conditions found in soft drinks and slowly decomposes to the constituent amino acids. Nevertheless, it has achieved wide acceptance in low calorie soft drinks because of its excellent sweetness profile.

Low calorie or ‘diet’ drinks are sweetened with mixtures of saccharin and acesulfame-K or aspartame. These mixtures have improved flavour profiles compared with those made with saccharin alone, which exhibit a bitter aftertaste.

Colouring materials

Natural and nature-identical colours
These materials have long been available but now due to increased consumer demand they make up a high proportion of the colours used in the industry. Despite problems of lower intensity and brightness than the alternative synthetic colours, and lower stability to light and (in some cases) to acid and SO₂ preservative, a range of satisfactory products has now been formulated using natural or nature-identical colours. It is usually necessary to ensure an efficient retail chain to avoid the possibility of significant fading before the end of commercial shelf life.

The permitted natural and nature-identical colours are:

(i) Carotenoids – carotenoids, β-apo-8-carotenal and its ethyl ester, lycopene, lutein, betanin, capsanthin and capsorubin. These give yellow, orange and red colours.
(ii) Chlorophylls – chlorophyll and chlorophyllins and copper complexes of chlorophyll and chlorophyllins.
(iii) Anthocyanins – these give red and purple colours.

Artificial colours
These are still widely used, both to impart an attractive appearance and to overcome the bleaching effect of SO₂ used as a preservative. The colours need to be stable to fruit acids, sulphur dioxide and light. The permitted synthetic colours are:

E102 Tartrazine (yellow)
E104 Quinolene yellow
E110 Sunset yellow
E122 Carmoisine (red)
E124 Ponceau 4R (red)
E129 Allura Red AC
E131 Patent Blue V
E132 Indigo Carmine (reddish blue)
E133 Brilliant Blue FCF  
E142 Green S (greenish blue)  
E151 Brilliant Black BN  
E155 Brown HT  

Due to consumer pressure, the use of tartrazine in soft drinks has been greatly reduced.

**Others**

There are a few other colouring materials that are also permitted. These include:

- E150 Caramel  
- E153 Vegetable carbon  
- E172 Iron oxides and hydroxides.

**Preservatives**

The use of preservatives is essential in concentrated drink and squash products where an open-bottle life of several weeks is to be expected. The presence of preservative also eases the production of carbonated ready-to-drink beverages.

Three groups of preservatives are permitted in soft drinks in the EU:

(i) *Sulphur dioxide* group includes sodium, potassium or calcium sulphites, sodium, potassium or calcium hydrogen sulphites, sodium or potassium metabisulphite. Sulphur dioxide has certain advantages as a preservative particularly in lemon, grapefruit and other pale products, in that it also inhibits browning. Its main disadvantages are that it is gradually evolved from the product and lost even from closed bottles, so that in time the preservative effect disappears. It also has the disadvantage of binding to aldehyde or ketone groups, and thus the effective preservative content may be lower than the total SO₂ content.

Sulphur dioxide is the only preservative permitted for addition to fruit juices and juice concentrates. Non-alcoholic flavoured drinks containing fruit juice are permitted to contain a maximum of 20 mg l⁻¹ SO₂ as carry over from the concentrate.

(ii) *Benzoic acid* group includes its sodium, potassium or calcium salts. Benzoic acid has no inhibiting effect on browning, but usually has a less deleterious effect than SO₂ on natural or artificial colours. It requires a little care in use since it can precipitate if exposed to a high local concentration of acid such as might occur during the mixing of a batch. Once precipitated, it is very hard to redissolve.

(iii) *Sorbic acid* group includes its potassium or calcium salts. As a result of increasing resistance recently by consumer groups to sulphur dioxide and benzoic acid, there has been an upsurge of interest in sorbic acid. This material is an effective preservative, is not lost with time and does not combine with other ingredients to reduce its potency. It does not appear to break down in the presence of acids, light, etc. or to cause fading of colours. However, sorbic acid cannot prevent the browning of fruit juices and it does have its own particular flavour.

The use of mixed preservative systems can solve many problems.

**Clouding agents**

Clouding agents are substances added to a naturally clear drink or one whose cloudiness is less than desired, to give it a denser or a more stable cloud. Some clouding agents, also called ‘dispersing agents’, work in citrus juice preparations by dissolving in the citrus oil and approximating its specific gravity to that of the rest of the drink. Thus the oil does not float to form a coloured ring at the surface but stays uniformly dispersed throughout the drink, so contributing to cloudiness.

Extract of quillaia or various emulsifiers, stabilizers or modified starches may be used to hold natural cloud particles or cloud-forming oils in suspension.

**Flavours**

*Natural and nature-identical flavours*

Natural flavours are extracted in water or other solvents from various parts of plants such as fruit, seeds and leaves. The extracts may then be further purified. This type of flavour is common for citrus drinks, an example is the essential oil of the fruit extracted as part of the fruit processing. Nature identical flavours are chemically synthesized to match the natural flavours, for example, benzaldehyde. The natural flavour is extracted from almonds or the nature identical flavour can be produced from the oxidation of benzene carbinol.

*Artificial flavours*

Synthetic flavours are usually blends of chemicals mixed together to give the required flavour
product. The chemical constituents are mainly volatile components such as esters, aldehydes and ketones. Flavour matches can be made in this way for products such as pineapple, banana and strawberry and for non-fruit drinks such as colas and lemonades.

PRIMARY MANUFACTURE

FRUIT AND VEGETABLE PREPARATION

The incoming fruit and vegetables for juice processing should be as free as possible from rotten fruit, leaves, stalks and other debris. The specific preparation depends on the type of fruit or vegetables being processed but all should be washed to remove dirt, debris and any pesticides from the skins. The wash can be a weak detergent solution. For citrus fruits, brushes are used to remove dirt. Fruits such as apples are hand sorted to remove rotten fruit.

JUICE EXTRACTION

The methods used to recover juices from fruits and vegetables vary widely depending on the fruit or vegetable type. Fruits fall into two main classes:

(i) Those which need to be reduced to a pulp before extraction of the juice can take place. The pulp is usually obtained by a milling process and the juice is generally removed by pressure.

(ii) The citrus fruits and others such as pineapple which are normally processed with specialized extraction machinery.

Milling

In fruit processing, four main types of mill may be encountered, roller, grater, hammer and paste mills. The first three are used to obtain a fruit pulp for juice extraction. The fourth is for production of specialized products.

Roller mills

Roller mills are commonly used in grape processing and consist of two rollers each fluted down its length. Frequently the flutes are quite wide and deep, so that the two rollers mesh together like gear wheels. Their effect is to crush the fruit sufficiently for its contents to be released, while leaving large coarse pieces of skin, etc., intact. These large particles make the pulp porous and assist the removal of juice in the later extraction process.

Grater mills

Apples and pears require the use of grater mills which fall into two categories. The first of these has a drum with serrated knives arranged lengthwise at intervals around its circumference; the drum rotates close to the casing which surrounds it. The fruit is retained by the casing until it has been completely shredded by the knives. The second type has similar serrated knives arranged around the cylindrical casing with slots between knives. A rotor with two or more arms on it spins just clear of the knives and as fruit falls into the mill it is pushed over the knives by the rotor. Again the fruit is retained in the mill until it is completely shredded. The pulp escapes through the slots between the knives.

The advantages of the grater mill are that it does not break up the seeds, which would release bitter principles into the pulp, and also that the pulp itself, while fine enough to allow its juice to be extracted, still retains its cellular structure which assists the normal juice pressing process. Such mills are frequently used in the processing of soft fruits because of these factors.

Hammer mills

There are numerous variants of the hammer mill, which consists basically of a shaft carrying a number of projecting blades rotating within a casing, the outlet of which is usually fitted with a screen. The blades themselves may be sharp to deal with fibrous materials, or blunt to smash up cellular products; they may be rigid or hinged. These machines tend to be used for special purposes, such as producing fruit purees for confectionery uses. As a rule hammer mills are not suitable for milling fruit before juice extraction, as their action is usually too drastic.

Paste mills

Paste mills have entered the field of fruit juice processing with the advent of the comminuted type of citrus beverages. In this case, a proportion of the citrus peel has to be blended into the juice and the paste mill is ideal for this purpose. Essentially, the machine comprises a carborundum stone wheel rotating in close proximity to a similar fixed stone, the gap between the stones being as small as 0.001
inch (0.02 mm). Intense shearing forces are set up as material passes through the gap, disintegrating solids and homogenizing liquids.

Extraction – temperate fruits

The temperate fruits give pulps of widely differing physical characteristics. Raspberries and strawberries yield highly fluid pulps, while apples can give pulps that are granular and easy to extract, or they may be viscous and almost impossible to deal with. Blackcurrants give a finely divided pulp, the particles of which tend to deform and compact under pressure, while fermented grape pulps with their content of hard seeds, woody stalks and large pieces of fruit skin have an open structure from which high yields of juice can be obtained by simple drainage. Consideration of these differences between fruits and their pulps, together with practical experience in dealing with the extraction of juice from them, leads to the conclusion that the extraction efficiency (as a function of yield and processing time) depends on four main factors:

(i) the juice viscosity,
(ii) the resistance to deformation of the solid phase of the pulp,
(iii) the porosity of the pulp,
(iv) the pressure or force applied.

Most of these factors are dependent on physical characteristics of the pulp to be extracted which are subject to change during the course of the extraction. Thus, besides the obvious decrease in volume and the proportional increase in the solid phase that occurs during the pressing operation, it can be shown that pulp adjacent to the perforated surface through which the juice escapes is subject to a greater compression than the pulp elsewhere in the mass. In general, it follows that juice extraction is best carried out using thin layers of pulp, or else the pulp should be mixed at stages during the process.

Batch presses

Modern batch presses are largely based on the early basket press in which a moveable platen is pressed into a perforated cylinder containing the pulp. Typical of new designs are machines in which the cylinder is arranged horizontally and a large number of plastic strands link the face of the movable platen and the closed end of the cylinder. As the platen moves forward, the strings are randomly embedded in the pulp and the juice from the pulp is led along the strands towards the perforated wall of the cylinder, from which it escapes. As the platen is withdrawn, the strands tighten to break the compressed pulp and this, together with rotation of the cylinder, has a good mixing action. In a somewhat similar press, the cylinder walls are not perforated and the plastic strands are replaced by heavier plastic rods carrying small grooves which conduct the juice away from the centre of the pulp mass. The rods finish in special manifolds in the end of the cylinder and in the platen from which the juice is led away.

Another version of the basket press has a tough rubber tube fitting inside the perforated cylinder, which is filled with pulp. It rotates to encourage drainage and to spread the pulp evenly around its walls. At the same time the rubber tube is inflated with compressed air, squeezing the pulp between it and the wall of the cylinder.

The conventional pack press, despite its demand on labour, is still widely used. With this system, the pulp is contained in cloths separated by wooden or metal racks so constructed as to have a number of channels on both sides. The pulp is thus split up into thin layers and the resulting ‘cheese’ is squeezed in a vertical hydraulic press. The method has the advantage of flexibility which may be desirable if more than one type of fruit is to be processed in the same installation.

Continuous presses

Broadly, there are four main types of continuous pressing systems:

(i) Intermittent or ‘continuous batch’ presses
(ii) Roller presses
(iii) Belt presses
(iv) Screw presses.

Intermittent presses consist of a perforated conveyor belt which moves intermittently and carries the fruit pulp beneath a press platen which descends when the belt is stationary. Special gates arranged around the sides of the platen prevent the pulp from exuding sideways when pressure is applied. Such presses have been used for grape juice extraction.

Two basic types of roller press have been developed in America and have been used for reclaiming juice from cannery fruit wastes. One type has two large horizontally mounted rollers with perforated faces covered with filter cloth. A special dome is arranged above the point where the drums contact each other, so that the fruit pulp may be fed to this point under a small pressure. Pressing takes place between the two drums, with the liquor flowing to their interior to be
removed by a special discharge system, while the residue is removed from their outsides by a scraper or string-discharge system. Another type employs two drums with vertical axes rotating one inside the other and in the same direction. They are pressed together at one point, and again the liquor passes through the perforations in the drums and the solid residue is scraped from them. A third variant uses a single perforated drum, the pressure being applied by a series of solid pressure rolls mounted on it. Difficulties arise mainly in the selection of the size of the perforations in the drum walls and in the cloths used to cover them. The efficiency of these machines tends to be low since the applied pressure and the duration of its application are both small.

With belt presses, the pulp is conveyed between two continuous perforated belts to be squeezed between sets of solid rollers. When the pressing is complete, the belts are separated and the residue removed from them by devices such as rotating brushes. Several variants have been developed, such as a machine which employs a single belt to compress the pulp against a large roller. Two of these have been used in series to give good results with the expression of apple juice.

Screw presses generally consist of a screw conveyor running inside a reinforced perforated cylinder, the discharge end of which is closed by a cone or valve system positioned by various mechanical means. Several modified systems have been developed for special purposes. Unfortunately, fruit pulps are quite fluid and tend to slip back over the screw flights instead of moving forward with them, so that in general, this type of press is only used to extract juice from pulps which have been thickened by previous drainage or similar treatment. Processing aids such as pretreatment with enzymes or the addition of diatomaceous earth may be used to increase yields.

Centrifuges are not widely used in primary fruit juice extraction. Probably, the relatively high cost of centrifugal separators, together with mechanical limitations, have prevented the development of this technique. They may however be used for the preliminary clarification, before final filtration of extracted juices.

Extraction - citrus fruits and pineapple

The extraction of juice from citrus fruits is achieved by passing the unpeeled fruits through special extractors. The basis of the majority of designs is the rotating reamer which tears the juice cells from the previously halved fruit. Machines of this type may be semi-automatic, single head units or fully automatic machines of high output. Older Sicilian extractors generally halve the fruit and present the halves to a row of reamers so that the machines have an intermittent action. A variant of this system halves each fruit vertically as it rolls down a conveyor, then turns the halves to lie with their peel sides uppermost and directs them into two rotating turrets on either side of the feed conveyor. Here fingers grip the halves and hold them over reaming heads which are lifted into them while rotating; fruit and reamers move together in a circular path. In the FMC extractor, which is the most efficient and most popular in use worldwide, the fruit drops into a lower cup fitted with a cutting tube which removes a plug from the base of the fruit; an upper cup comes down, pressure is applied evenly to all surfaces of the fruit and the inner contents are pushed out into a finishing tube where the juice and cells are separated from the seeds and membranes.

Pineapple juice can be obtained by a whole fruit extraction. The ‘Pine-O-Mat’ extractor halves the topped fruit which is then passed between an extractor drum and perforated grid. The flesh is sheared and pressed from the fruit half shells to give a pulpy slurry which then passes to a finisher.

Extraction - tomato

The juice is usually extracted by multistage pulping equipment using one of three techniques depending on the properties desired for the final product.

Cold-break. Fruit is chopped cold and some time elapses before the pulp is heated, allowing pectin to be destroyed by natural enzymes. This gives a less viscous final product.

Thermal-break. Fruit is chopped cold but is immediately heated prior to extraction of the juice. This gives less time for the natural enzymes to act on the pectin.

Hot-break. Fruit is chopped hot, thereby inactivating the enzymes before they destroy the natural pectin.

Pulp wash

With non-citrus fruits, where it is intended to make a juice concentrate, it is not unusual to wash the solids from the first extraction with fresh water and press again in order to extract as much of the remaining juice as possible; the diluted juice from the second pressing goes forward for concentration, which removes all of the wash water.
With citrus fruits, however, the pulp wash is of inferior quality to the juice from the first pressing because it contains relatively large amounts of extractives from the peel (e.g. pectins and bitter-tasting substances) in addition to any recoverable fruit juice. The presence of pulp wash in a citrus juice is considered to be adulteration.

CLARIFICATION

Many fruit and vegetable juices are cloudy when first prepared and some are definitely preferred by the consumer to be cloudy. This is particularly true of orange and lemon juices. Blackcurrant and other soft fruit products are invariably presented in a clear form whilst apple juice may be either clear or cloudy. The cloud consists of fragments and colloidal suspensions of components from the cells, the composition varying greatly from product to product. The rate at which the natural cloud settles to leave a clear supernatant juice is related to its composition, especially the particle size and the amount and types of any pectins present. Hence the settling rate also varies considerably between different products.

Clarification is practised particularly in the processing of blackcurrants, other soft fruits and apples. Clarified lemon, orange and lime juices are also produced. The practice may be subdivided into chemical processes, in which cloud retaining elements are destroyed, and physical processes, in which minute particles of tissue, etc., are removed.

Chemical treatments

Pectolytic enzymes

Commercial preparations contain a large number of separate enzymes, among them polymethylgalacturonases, pectinmethylesterases and polygalacturonases. These act on the pectin to give degradation products that include pectinic acid (partially demethylated pectins), pectic acids (completely demethylated pectins) and oligogalacturonides of two or more galacturonic acid units.

The use of pectolytic enzymes is essential in the production of blackcurrant and other soft fruit juices to enable the juice to be expressed from the fruit; this is due to the quantities of pectin present. The milled fruit pulp is passed through a tubular heat exchanger and the temperature raised to 40–50°C. Pectolytic enzyme is added and the pulp held for 2–8 h (depending on the activity and concentration of the enzyme) until all pectin has been hydrolysed. In the clarification of lemon and lime juices, the natural pectolytic enzymes of the fruit are utilized. The cloud retaining pectin of the juice is destroyed and the pulp acts as a floc former, clarifying the juice and leaving a clear upper layer on standing.

Gelatin precipitation

This technique is employed to remove colloidal particles which continue to form a haze, particularly in apple juice after enzyme treatment. The addition of gelatin in solution results in the formation of a flocculent precipitate. The settlement of the flocculent deposit is greatly helped by providing efficient enzyme action so that the viscosity of the juice at the time of adding gelatin is very low. It will be found that the quantity of gelatin required will vary throughout the processing season. The deposit of colloidal material and its enveloping tissue from the juice should be formed in about one hour. The rapidity of this settlement is dependent on the right amounts of clarifying agents being used and thus forming the right size and density of flocs. It is preferable to allow the flocs to settle naturally, but the thick deposit which contains much juice may be passed through a centrifuge to recover the greater part of the liquid phase.

Physical treatments

Centrifugation

Centrifuges are normally used for removing relatively large amounts of coarse particles from fruit juices. They are frequently capable of giving a high degree of clarification but do not usually give the brilliance and ‘polish’ achieved by fine filtration. There are several types of centrifuges the simplest being the tubular bowl clarifier which has a small solids space and limited rate of throughput. The machines most frequently used are of the disc-bowl type, where the bowl contains a number of closely spaced thin metal cones. These divide the liquid flow into thin layers as it moves from the centre outwards, effectively giving a longer path to the liquid and increasing the efficiency of solid/liquid separation. The solids are collected beyond the conical discs on the inner wall of the bowl proper and the clarified liquid is led upwards to a pumping device which discharges it from the machine. Variants of this general type include nozzle designs in which solids are continuously discharged through nozzles arranged on the periphery of the bowl casing.
Intermittent discharge types in which the outer bowl opens at preset intervals to release accumulated discharges, and basket centrifuges, do not usually find application in fruit juice processing. However, the former have been applied to the extraction of juice from pulps, and the latter to separate ice crystals from fruit concentrates prepared by freeze concentration.

Filtration

All methods of filtration involve the use of filter aid, typically a fine, treated diatomaceous earth. This permits the filter to be coarse enough merely to retain peel/pulp particles. A deposit of filter aid is built up on the filter and this is responsible for the main filtration effect, removing the fine and colloidal particles in the juice. The filter aid is mixed with the juice prior to filtration, and a slurry-in-water or juice may be passed through the filter in order to provide a precoating. Since the filtering surface is constantly being renewed as a result of the deposition of more filter aid, it does not become coated with gelatinous pectinous particles and continuous filtration can be carried out. The principal forms of filter are as follows:

(i) Woven cloths on a plate and frame.
Woven cloths are useful if large amounts of juice are to be filtered, since this type of filter allows the build-up of a considerable depth of filter aid.

(ii) Asbestos or cellulose pads on a plate and frame.
The asbestos pad can produce the finest filtration, and if a suitable grade of pad is employed a sterile juice can be obtained. It is customary to pass citric acid solutions through the pads prior to use in order to remove materials which would otherwise taint the product. For small scale operations such as experimental work, it is advisable to wash the filter aid with citric acid also. The citric acid wash is followed by passing water through the pads until all traces of the acid have been removed. Suppliers of asbestos pads advise that in normal use they present no safety hazard. However, because of general concern regarding the use of this material, alternatives are being developed and gradually being introduced.

If sterile filtration is to be performed, the filter must first be sterilized. This can be achieved by connecting the output nozzle to a clean supply of 'live' steam, allowing this to flow until it is jetting from the input nozzle and then continuing for a further 20 min.

Sterile traps should then be placed on both nozzles while the filter cools. There is a little application for sterile filtration in the UK but it is quite common elsewhere in Europe and in the USA. For normal filtration purposes, the life of the pads can be prolonged by interleaving with sheets of filter paper; these will allow the deposits of filter aid to be easily removed and the pads to be re-used.

(iii) ‘Candles’ composed of metal washers.
The ‘candle’ filter consists of a large number of metal washers, correctly placed on a fluted rod and retained with a nut. Each washer has a flat side and an indented side. These candles hang in a chamber of unfiltered material. Their upper ends are arranged so that the filtered juice is pumped through the candles from their outside inwards and discharged into a separate chamber. The number of candles is variable and depends upon the design throughput of the plant. During precoating, usually carried out with a slurry consisting of filter aid and juice, the filtrate is cloudy until a coat has been formed. It must therefore be passed back into the bulk for refiltration.

With this type of filter, the maintenance of a continuous pressure on the juice feed is essential, since if it is allowed to fall, the coating of filter aid tends to come off the candle and unfiltered material will pass through the machine.

(iv) Rotary vacuum filter.
The rotary vacuum filter provides a convenient continuous method of clarifying juices and is commonly used for apple juice. A filter cloth is attached to the curved surface of a perforated drum and a vacuum applied to the inside. The drum is rotated and a precoat of filter aid is applied. A slurry of juice and filter aid is sprayed onto the outside of the drum. The juice passes through the layer of filter-aid and the cloth to the inside of the drum and then to store through a convenient discharge system. The layer of filter aid is prevented from building up beyond a given thickness by use of a ‘doctor’ knife set at an appropriate distance from the surface of the drum.

CONCENTRATION

Evaporation

The most common and convenient form of concentration employed on fruit juices is vacuum eva-
aporation, usually preceded by a preheating treatment that is adequate to ensure destruction of enzymes and micro-organisms. Some processes for making frozen concentrate utilize evaporation at low temperature throughout and omit the pasteurization step. The juice usually needs screening to remove solid material.

The process of evaporation also removes volatile flavours and various techniques are employed either to remove these before evaporation or to minimize the effect upon the quality of the juice. Practically all evaporators in use are of multiple effect design in which the juice passes from one effect to another at increasing concentrations and decreasing temperature. The vapours from the earlier hotter effects are used to provide the heating in the later, cooler effects, thus producing high efficiencies in terms of steam usage. Thermo-compression (the injection of high pressure steam into the vapours, thus increasing the pressure and therefore the temperature) is also widely used. The principal forms of evaporators are outlined below:

**Tubular evaporators**

In these evaporators, the juice is made to boil inside vertical tubes. A thin film of liquid is formed on the surface of the tube and vapour rises up the centre. The juice may be introduced into either the top or the bottom of the tubes, depending upon whether the evaporator is of the ‘falling-film’ or ‘climbing-film’ type. The tubes connect to a cyclone separator from which the vapour passes either to a condenser or to a further evaporator effect. Similarly, the concentrate is led from the separator, either out of the machine or to another effect for further evaporation.

Tubular evaporators also include designs which employ inclined or horizontal tubes and where viscous products are involved, circulation through the tubes may be increased by the use of pumps.

**Wiped-film evaporators**

These machines consist essentially of a wide vertical steam jacketed tube fitted with a rotating central shaft carrying a number of vanes which almost touch the interior of the tube. The juice enters at the top of the tube and evaporates as a thick film on its surface. This film is agitated by the rotating vanes and their action results in a high evaporation efficiency. Such plants are particularly useful with viscous products and are sometimes employed as finishing evaporators when a high density final concentrate is desired.

**Plate-type evaporators**

One of the more recent developments, the plate-type evaporator, has the advantage of requiring less headroom than most other types and its surfaces are readily accessible for cleaning. It consists of a number of specially designed plates compressed together in a frame and arranged so that steam is applied to one side of the plate while the product to be evaporated is in contact with the other. The arrangement gives a climbing film effect alternating with a falling film effect as the product passes through the plant. The design lends itself admirably to multieffect operation, and with its rapid evaporation and low hold-up of product, high density concentrates of good quality are obtained.

**Centrifugal evaporators**

The centrifugal evaporator is essentially a single effect vacuum evaporator, consisting of an outer cylindrical shell inside which is a stack of hollow cone-shaped discs carried upon a vertical shaft. An ingenious arrangement of parts admits steam to the underside of each disc while the product to be evaporated is fed to the centre of their upper sides. Thus, as the stack rotates at high speed, the product is spread over the disc surface in a thin layer and centrifugal force causes it to pass swiftly over the heated surfaces to their edges. A very rapid evaporation takes place and the concentrate is discharged from the stack of discs upwards and out of the machine. The vapour produced is collected in the outer shell and led to a condenser system.

This type of evaporator, with its rapid action, gives excellent concentrates which suffer little heat damage. However, due to mechanical considerations, the size of the machine is limited.

**Heat-pump evaporators**

Certain evaporators of the tubular type have been designed to operate on the heat-pump principle. This involves the use of a compressor acting on ammonia, or other refrigerant gas, thereby raising its temperature. The hot gas is used to boil the juice in the evaporator tubes; as a result, the gas itself is cooled. The cool gas, still at high pressure, passes through an expansion valve, as in a refrigerator, where it is cooled further and liquefied. In this state, it is used to condense the vapours
boiled from the juice and during the process the condensed refrigerant is revaporized and passes back to the suction side of the compressor.

Plants operating on this principle are useful in areas where steam and cooling water are in short supply. They are claimed to have lower running costs than conventional plants. However, because of the high pressures involved on the refrigerant side, their specialized construction involves a high capital cost.

**Reverse osmosis**

Osmosis occurs when a relatively concentrated solution is separated from a pure solvent by a semi-permeable membrane. It results in the passage of solvent through the membrane and into the concentrated solution which thereby becomes progressively diluted. The migration of the solvent can be halted or reversed by applying a pressure to the concentrated solution which is greater than or equal to the osmotic pressure developed by the solvent. Recent developments have applied this principle to the desalination of sea water and latterly to the concentration of fruit juices. There are still some difficulties to overcome, mainly in respect of the preparation of the membranes, which have to be permeable yet withstand pressure of up to 500 lb in\(^{-2}\) (3.45 MPa).

**Membrane permeation**

This is a technique in which a semi-permeable membrane is interposed between the liquid and the vapour phases in a single effect vacuum evaporator. Depending upon the characteristic of the membrane, this can be arranged so that water vapour will permeate through it but organic vapours are impeded. The process is, therefore, claimed to produce juice concentrates in which the normally volatile aromas and flavours are retained without the use of a conventional volatile recovery step beforehand.

**Freeze concentration**

Freeze concentration relies on the fact that on freezing solutions initially form crystals of pure solvent. This continues until the solute concentration reaches the so-called eutectic point, at which the whole solution freezes. The degree of concentration of juices is therefore limited by the eutectic point of the juice concerned and is usually not greater than 50° Brix. The process consists of freezing water out of the juice in the form of ice crystals and separating them by centrifugation or filtration. A high quality product is obtained since all volatile materials are retained.

**Cutting back**

As previously mentioned, the juices concentrated by evaporation may be devoid of volatile flavour; this effect can be minimized by the process of ‘cutting back’ the concentrate with a quantity of fresh juice. For example, a sixfold evaporated juice may be blended with fresh single strength juice to give a fourfold concentrate which has some of its volatile flavours restored.

A concentrate is usually described as four-, five- or sixfold, indicating that one volume of concentrate can be diluted with water to give four, five or six volumes of juice.

**ESTER RECOVERY**

The process of evaporation of juices leads to the loss of volatile flavours which steam distil from the juice and in most cases are lost in the condensate from the evaporator. In the case of apple, blackcurrant and other soft fruits, the volatile flavours can be removed by a controlled partial concentration prior to full concentration, but ester recovery from citrus materials has met with little success until recently.

Around 1940, the Kestner Evaporator and Engineering Company Ltd fitted their fruit juice evaporators with a system which attempted to condense the vapours removed initially from the juice as it entered the plant to give an ‘ester’ fraction. However, as this fraction was removed under vacuum, many of the more volatile components were not condensed out. The concentration of volatile constituents was very low in any case, so that the stability of the ester fraction itself in storage was poor. If the fraction was added directly to its associated juice concentrate, the latter usually became diluted to an undesirable extent. Nevertheless, the system was probably the first practical attempt to recover volatile flavours, even though its value was limited.

Modern ester recovery techniques consist of heating the fruit juice to boiling at atmospheric pressure and evaporating some 10–25% by volume. The vapours are passed through a fractionating column with reflux and then condensed to give an ‘essence’ containing the bulk of the volatile constituents of the juice. The volume of the ‘essence’ is typically 0.5–1.0% that of the original juice, and the material usually has good storage properties which are enhanced if refrigerated.
storage is available. The so-called ‘stripped’ juice is rapidly cooled as it leaves the equipment and can be concentrated normally in a suitable evaporator.

The amount of evaporation required in the volatile recovery plant depends upon the type of juice being treated. The major portion of the volatile constituents of apple juice are recovered with about 10% evaporation; with blackcurrant juices, 15% evaporation is required, and up to 25% may be needed with strawberry juices. When the final juice concentrate is reconstituted with water and an aliquot of ‘essence’, the product closely resembles the original juice. The process stimulated great interest in the examination of the flavour-influencing components of fruit juices, particularly by the use of gas-liquid chromatography (GLC).

Other forms of volatile recovery equipment have also been devised. Some work under vacuum conditions. In others, the volatile constituents are adsorbed on activated carbon, from which they are removed by solvents and later separated. More recent developments have combined volatile recovery systems with evaporators and these systems are now very widely used.

ESSENTIAL OILS

The production of essential oils is a noticeable feature of the citrus industry, these materials being used for general perfumery and flavour applications. The citrus essential oils are contained in the flavedo (outer layers of the peel) of the fruit and are extracted by a variety of methods. The traditional process followed in Sicily involves taking the halved peels from the juice extractor and soaking them in calcium hydroxide solution. This precipitates the pectins of the peel as their calcium salt and renders the peel less absorbent to the oil when it is released from the oil sacs. The treated peels are usually allowed to stand overnight for hardening to occur and are then rasped under water sprays. This yields a water–oil emulsion which is centrifuged and the water recycled to the sprays. By this means, the water becomes saturated with water-soluble components of the oil and their loss is minimized.

Other techniques of oil extraction include simply rasping the peels and pressing the oil from the rasps, or performing a water washing and centrifugation of the oil-rich peel flakes produced by the extractors. These may be pressed in a screw press and the resulting emulsion centrifuged to separate the oil phase.

Natural citrus oils contain dissolved waxes from the skin of the fruit and these tend to precipitate in cold conditions. The winterization process involves storing the oil at a low temperature, allowing this precipitation to occur and then clarifying by centrifuging. The oils themselves consist of water-soluble and water-insoluble fractions. Deterpenization of the oils results in a water-soluble material of high flavour intensity. This process is carried out by fractional distillation or countercurrent solvent extraction.

PACKAGING AND STORAGE

Juices which are to remain at single strength must be pasteurized to inactivate enzymes and control microbial growth. Juices that are concentrated by evaporation are pasteurized during the evaporation stage. After cooling, the juice products may be packed in a number of ways.

Freezing

Most concentrated citrus juices are frozen and maintained at a temperature of −18°C for storage and transport. The frozen concentrates may be packed in 200 l (nominal) steel drums with double high density polyethylene liners or stored in bulk storage tanks. Use of the latter is becoming increasingly popular. The concentrate can be filled from the tanks into road tankers and unloaded at customers’ sites, again into bulk storage tanks. This makes handling very efficient.

Chilling

Temperate fruit juice concentrates such as blackcurrant and apple may be stored satisfactorily under chill conditions. These concentrates may be packed into 200 l (nominal) steel drums with double high density polyethylene liners or into polyethylene drums. Juice concentrates such as peach or plum that are only required in small quantities may be packaged in 40, 25 or even 5 l polyethylene containers.

Aseptic packaging

Aseptically filled fruit juices and concentrates are increasingly becoming available from processors and may be supplied in 208 l bags transported in steel drums, 23 l bags packed in fibreboard boxes and most recently in 1000 l bag-in-box containers.
Aseptically filled products, if unopened, will remain free from microbiological spoilage and can have the same shelf life as their preserved equivalents. They can be stored satisfactorily under ambient or chilled conditions. This method has been in use for some years for packing fruit juices. Cooled pasteurized juice, either single strength or concentrated, is passed to a carefully sterilized filler and filled under aseptic conditions into a sterile polyethylene and metal foil laminated bag, which is either contained in a steel drum or a fibreboard box. Stringent precautions to exclude any spoilage organisms must be taken when using this packaging technique. The filler is often enclosed in an environment of sterile air, although at least one process uses in-line sterilization with hydrogen peroxide and continuous filling.

This method avoids the costly high energy requirements of frozen storage and distribution and is widely used.

Use of preservatives

This technique is not used for concentrates that are to be diluted to yield pure fruit juices. However, it is widely employed for fruit materials that are used as ingredients in soft drinks, for example, squashes, cordials and fruit drinks.

Sulphur dioxide is the preservative of choice; it ensures microbial stability and also acts as an antioxidant, preventing browning. Benzoic acid can also be used and is preferred if the product is to be used as an ingredient in a canned drink, because sulphur dioxide reacts with the can material.

Preserved products are packed into 200 l plastic drums or 1400 l rotoplas containers. More recently, bulk tankers have also started to become available for transporting preserved products, which can be stored under ambient conditions.

Blending of juices

Blending of fruit juices generally occurs at the production site and can be used to overcome the limitations of maturity, varietal characteristics, etc., and thereby extend the production of acceptable fruit juices. For instance, high acidity, early season orange juice can be blended with low acidity, late season juice to produce a product that is much closer to the mid-season optimum. High acidity juice from culinary apples may be blended with low acidity dessert apples to produce a desirable intermediate acidity. Blackcurrants from the Côte d'Or region of France, which have intense colour and flavour characteristics, are incorporated with benefit into blackcurrant juice blends in other parts of Europe.

SOFT DRINK MANUFACTURE

INGREDIENT MIXING

Fruit juices

It is not uncommon for a manufacturer of fruit juice products or soft drinks to blend juices from different geographical sources in order to achieve a desired quality, or even to blend different fruits to produce new or novel products. This means it is possible to duplicate a blend from season to season, even though the flavour of the individual component juices will vary.

Compounds

A popular method of manufacture of ready-to-drink beverages other than fruit juices consists of dilution of a prepared compound with water after addition of sugar and acid, as appropriate. The compound can contain some or all of the following ingredients:

(i) The fruit material
(ii) Essences, oils and other flavouring
(iii) Preservative
(iv) Colouring
(v) Artificial sweetener.

Compounds enable a soft drink bottling operation to be carried out with a minimum of technical control or even consciousness of the composition of the product manufactured. They also fulfill the need of small manufacturers who wish to provide a wide range of products. Compounds can also be obtained that are suitable for the manufacture of squashes or comminuted drinks to be consumed after dilution.

The addition of ingredients to a batch often needs to be carried out in a specific order to ensure that all the ingredients are dissolved properly before the batch is used for production. For example aspartame is sparingly soluble in water and is usually dissolved in a dilute citric acid solution before addition to the batch.

BOTTLING

Soft drinks intended to be consumed after dilution and containing adequate preservatives may be