The Complete Technology Book on Alcoholic and Non-Alcoholic Beverages (Fruit Juices, Whisky, Beer, Rum and Wine)
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The alcoholic and non-alcoholic beverages are being used by human beings since centuries back. Accompanying the increase in the variety of consumption there has been a parallel increase in the variety of alcoholic and non-alcoholic beverages offered for sale. The alcoholic drinks market is broadly classified into five classes, starting from beers, wines, hard liquors, liqueurs and others. Similarly, the non-alcoholic drinks market is broadly classified into carbonated drinks, non-carbonated drinks, and hot beverages. These include juices, energy drinks, carbonated drinks, tea, coffee, and bottled water. The commercial success of a soft drink formulation depends upon a number of factors. A strong, well-placed advertising campaign will bring the consumer to purchase the new product, but thereafter, the level of repeat sales will reflect the degree of enthusiasm with which the new drink has been received. The dramatic growth of fruit juice and non-carbonated fruit beverage markets worldwide has been made possible by the development of new packs and packing systems and improvements in traditional packaging. Tropical fruits are the newest arrivals on the juice and fruit beverage market. Whisky is the portable spirit obtained by distillation of aqueous extract of an infusion of malted barley and other cereals that has been fermented. It can be considered as the product of distillation of an unhopped beer. Beer is the world's most widely consumed alcoholic beverage; it is the third most popular drink overall, after water and tea. Rum is a distilled alcoholic beverage made from sugarcane by-products such as molasses, or directly from sugarcane juice, by a process of fermentation and distillation. The Indian alcoholic market has been growing rapidly for the last ten years, due to the positive impact of demographic trends and expected changes like rising income levels, changing age profile, changing lifestyles, and reduction in beverage prices.

Some of the fundamentals of the book are flavorings and emulsions, syrup room operation, fruit juices and comminuted bases, acids, colors, preservatives, and other additives, high intensity sweeteners, packaging systems for fruit juices and non-carbonated beverages, grape juice processing, processing of citrus juices, juice processing for pasteurized single strength, equipment for extraction and processing of soft and pome fruit juices, chemistry and technology of citrus juices and by-products, legislation controlling production, labelling and marketing, biochemical events during brewing fermentations, outline of the whisky producing process, types of beer brewed, aroma compounds of rum and their formation, cider and perry, etc.

The alcoholic and non-alcoholic beverages described in this book are beer, wine, rum, whisky, cider, and different types of fruit juices with packaging systems and other relevant parameters related to their manufacturing. The book will be very helpful to technocrats, new entrepreneurs, research scholars, and for those who are already in this field.

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Sample Chapter:
Carbonation and filling

Introduction

In any bottling or canning operation, the filling machine is the interface between the container and the product. For the majority of carbonated soft drink installations, the final product does not exist until a point immediately prior to the filler. The processing operation involves combining finished syrup, treated water and carbon dioxide gas in the correct proportions, and normally this is carried out on a continuous basis, with the beverage being produced at a slightly faster rate than the requirement of the filler. Although there are many plants still operating on the old method of pre dosing the empty bottle with the requisite amount of syrup and then topping up with carbonated water, the modern process of pre mix filling, where the carbonated, finished product is transferred to the container in one filling operation, is now predominant. The accuracy of the syrup/water proportioning and the control of the degree of carbonation are vital to the commercial success of carbonated soft drink production. This chapter details some of the latest advances in the processing equipment. The filling machine is unable to improve the standard of the beverage and the correct function of the processor plays a major role in predetermining the ultimate quality of the product and the overall success of the filling operation.

In the last ten years filling units have continued to increase in complexity and price. Filling valves have been developed in three main areas: to encourage a streamline pattern of liquid flow into the container (vital to successful ambient filling) to improve the control of fill height in the container to adapt to changes in container design. The introduction of the large PET bottles (2, 3 and, recently, 5 litre sizes) has necessitated the production of fillers with appropriately wide filling valve centres to accept these containers hence, although filling machines have increased in the multiplicity of filling valves, they have also increased in physical size owing to wider valve centres. At the time of writing, Krones AG of Neutraubling, West Germany, claim the largest filler of 176 valves and in excess of 6 metres in diameter the fastest filler would appear to be the 120 head can filler from Holstein and Kappert GmbH of Dortmund, West Germany, capable of speeds over 2000 cans per minute.

The advances in filler design have coincided with the development of ambient filling facilities and the almost total replacement of glass by PET plastic in the large bottle sector. The inexorable progress of the latter material casts a shadow over the future of glass for carbonated soft drinks as PET bottles become larger and, more important, are breaking into the less than 1 litre range. The possible success of a returnable PET bottle is a fascinating scenario with its effect on bottling line composition and design, together with the added complications in the areas of distribution and return.

The filling machine still holds pride of place in the production line the individual handling of containers at current outputs cannot fail to be impressive although it is recognised that the modern, high speed labelling machine is a tribute to engineering excellence in dealing with bottles, labels and adhesives at speeds never contemplated twenty years ago. At the filler, the formulated product is introduced into the prepared container, and the management of this operation is crucial high outputs of large bottles demand huge quantities of product, and flow rates of 50,000 litres per hour through fillers are commonplace. Inaccuracy, malfunction or human error can have disastrous effects on yields and operating efficiencies, and the production technologist must be aware of how the equipment is intended to function so that, in the event of failure, corrective actions may be speedily taken before substantial losses are incurred.

Carbonation

The artificial inclusion of a dissolved gas in a soft drink beverage was developed from the popularity of natural occurring mineral waters, which are discharged in a slightly carbonated form from rock formations in
many of the well known spa resorts around the world. The medicinal advantages of spa products have been panegyrised to the point of exaggeration and the ingestion of the dissolved carbon dioxide has always been considered an important part of the therapeutic process. What cannot be denied is that the addition of carbon dioxide makes any soft drink more palatable and visually attractive.

1. The nature and effects of carbonation
Carbonation may be defined as the impregnation of a liquid with carbon dioxide gas (CO2). When applied to a soft drink product, the result is a beverage which sparkles and foams as it is dispensed and consumed. This escape of CO2 during consumption of the drink should complement and enhance the flavour, and will add an exciting tingle that stimulates the palate. The amount of CO2 gas producing the carbonation effect is usually specified as volumes—meaning, in broad terms, the number of times the total volume of dissolved gas may be divided by the volume of the liquid. For example, a 3.0 volume drink will contain CO2 to the extent of three times the volume of the beverage. A more accurate definition involving the parameters of pressure and temperature will be explained later in this chapter.

The organoleptic effects are not the only benefits of the CO2 content at carbonations above 3.0 volumes the CO2 has a preserving property, the extent of which is dependent upon pH, sugar, initial microbial load and the nature of the microorganisms. This desirable attribute of carbonation should be considered as an added bonus and must not be a substitute for other precautions taken to ensure the safety and extended shelf life of a product.

Each soft drink formulation requires a particular degree of carbonation so that the effervescence is appropriate to the flavour and nature of the beverage. Fruit drinks—such as orange, bitter lemon, etc.—should contain low levels of carbonation whereas juice based drinks—colas, ginger beer and cream soda—should be in the medium to high range of CO2 content. Mixer drinks, so called as they are used mainly to mix with spirits, require high carbonations since the addition to other still (non carbonated) liquors dilutes the original carbonation level. Drinks in this category would be tonic water, ginger ale and soda water. Soda water filled into syphons contains the maximum degree of carbonation usually encountered in the industry. These particular containers rely upon internal pressure to dispense the contents and, as the syphon empties, this pressure is replenished from the carbon dioxide dissolved in the product.

In practical terms, carbonation levels vary between 1 volume of CO2 in fruit drinks to 4.7 volumes in mixers and up to 6.0 volumes in soda syphons. Figure 1 shows typical carbonation values for a range of well known drinks a degree of latitude is indicated since individual recipes require their particular carbonations.

The increasingly popular, large PET bottles constitute a special case not only does the CO2 gradually escape through the permeable polymer material producing a marked reduction in the carbonation of the contents over a period of time, but the repeated opening and closing of the container for occasional consumption can result in the final 25/30% of the contents having an unacceptably low carbonation. This latter problem arises because each time the bottle is resealed, CO2 gas escapes from the residual product to pressurise the headspace volume and most of this gas then escapes to atmosphere on the next occasion the bottle is opened. These large containers are not really intended for intermittent consumption and to compensate for the future loss of carbonation, the product is carbonated to a slightly higher level than would be appropriate for the particular drink.

2. Properties of carbon dioxide
Carbon dioxide is a colourless gas with a slightly pungent odour when dissolved in water the resultant carbonic acid mixture has an acidic and biting taste which is not unpleasant. CO2 does not support combustion and is used extensively in fire extinguishers. High concentrations in the atmosphere will quickly suffocate respiratory animals and since the gas is 1.53 times heavier than air at 70 °F, great care must be taken when entering vessels that have contained CO2 and may not have been sufficiently vented and purged in these circumstances, residual CO2 will lie in the base of the tank to trap the unwary entrant.
Carbon dioxide is usually present in atmospheric air at a level of approximately 300 ppm by volume and it is dangerous to breathe atmospheres containing more than 5% by volume. It has been postulated that workers may be safely exposed to a maximum concentration of 5000 ppm CO2 by volume for 8 hours per day.

CO2 is one of the very few gases suitable for providing the effervescence in soft drinks. It is non toxic, inert, virtually tasteless, readily available at moderate cost and may be liquefied at reasonable temperatures and pressures, allowing convenient bulk transportation and storage. The solubility of CO2 in both water and soft drink product allows an acceptable retention of the gas in solution at atmospheric pressure and room temperature, although slight agitation will promote an evolution of gas bubbles from the body of the drink which creates the attractive sparkling effect.

The bulk storage of liquid CO2 in soft drinks plants is now commonplace all over the world. Pressurised and insulated tanks holding CO2 at 20 bar and maintained at a temperature of –17ºC by a small refrigeration unit, are available in various sizes from 5 to 50 tonnes in both horizontal and vertical modes. In order to obtain a sufficient supply of dry gas to feed the carbonation equipment, etc., it is necessary to utilise a suitable vaporiser unit which may be heated by water, steam or electricity.

Small scale production plants still use thick walled cylinders containing approximately 25 kg of liquid CO2 at 60 bar and these are usually connected in banks to allow a reasonable off take rate without recourse to additional heating. In the more remote areas of the world, carbon dioxide is still generated on site by the chemical action between an acid and a carbonate, e.g. sulphuric acid and sodium bicarbonate. Alternatives would be the combustion of fuel oil or the extraction of CO2 from the flue gas of a boiler operation or similar heating facility.

3. Equilibrium pressure

In common with other gases, carbon dioxide increases in solubility as the liquid temperature decreases, and for every combination of (I) the amount of CO2 in solution and the temperature of the liquid there is a finite minimum pressure that is necessary to retain the gas in solution. This is a condition known as equilibrium where, owing to molecular movement, the gas leaving solution is equalled and balanced by the gas entering solution. At equilibrium pressure the gas/liquid mixture is just stable but any decrease in pressure or increase in temperature will render the mixture metastable (or supersaturated) in that the pressure/temperature combination is insufficient to keep the CO2 in solution. In this circumstance, gas will be spontaneously released (particularly if there is some agitation of, or irritant applied to, the solution) a condition known as foaming or foaming and usually apparent when a bottle of carbonated product is opened to atmospheric pressure. The inability of a carbonated beverage to retain its full CO2 content in solution at atmospheric pressure gives rise to the attractive ebullience observed during the act of pouring the drink into a glass and the liberation of further CO2 during the actual consumption.

Carbonated product held in a container that is open to the atmosphere will gradually lose carbonation as the gas is liberated and escapes from the liquid. In a closed container, this evolution of gas proceeds to fill the headspace volume and gradually increases the pressure, quickly at first and then more slowly as the equilibrium condition is approached. The actual rate of the transfer of gas from product to headspace depends not only on the proximity of the headspace pressure to equilibrium pressure but also on the temperature of the liquid, the nature of the beverage and the extent of any agitation or irritation imposed on the liquid. A quiescent, stable product not subjected to vibrations or movement may take many hours to reach equilibrium whereas the same product, roughly shaken, will, take only seconds to attain the equilibrium state. The CO2 gas leaves the beverage and collects in the headspace volume to provide the necessary equilibrium pressure to keep the remaining gas in solution at a slightly lower carbonation than the original value. This condition applies to all bottles and cans that have been filled with carbonated beverage and then sealed with the appropriate closure.
4. Measurement of carbonation
Since the degree of carbonation is such an important factor in the formulation of a soft drink, it is imperative that a standard form of measurement of carbonation should be available. This would allow the production of particular products at different times and in different locations and yet ensure that the carbonation of these products meets the required, agreed standard. Previously, it has been mentioned that carbonation may be quantified in volumes. A volume of gas is indeterminate unless the parameters of pressure and temperature are specified and two scales are in current use. In the UK the term volumes Bunsen is popular where the gas volume is measured at atmospheric pressure (760 mm of mercury) and the freezing point of water (32°F or 0°C). An alternative scale used in the USA (and therefore followed by many franchise bottlers throughout the world) is volumes Ostwald, where measurement is also carried out at atmospheric pressure but any temperature adjustment is ignored. A third method, used on the European continent, measures carbonation in grams per litre and since one volume (Bunsen) is equivalent to 1.96 grams CO2 per litre, doubling the volumes of carbonation will give an acceptable approximation of the grams of CO2 per litre of product.

5. Carbonation determination
An obvious method of gauging the degree of carbonation would be to extract the total CO2 content from a known volume of product, adjust the gas volume to atmospheric pressure and, where desired, mathematically convert this volume to 0°C. The ratio of gas volume to original beverage volume will give the figure for carbonation.

This procedure is used in some QC laboratories but is usually restricted to low carbonation products as the routine is somewhat cumbersome.

A superior procedure (and still used extensively in the industry despite the introduction of later, sophisticated techniques) makes use of the equilibrium phenomenon described earlier. If the temperature and equilibrium pressure of a product are known, then there must be a fixed carbonation level based on these two factors. From laboratory measurements of the maximum amounts of CO2 dissolved in water at various pressures and temperatures and by the application of Henry's Law, a graph may be produced of the three-way relationship between dissolved volumes, temperatures and equilibrium pressures. Figure 2 shows the maximum volumes of CO2 (adjusted to 760 mm Hg and 0°C) which may be dissolved at various temperatures and pressures. Fitting a pressure gauge to a container of carbonated beverage and shaking vigorously until the pressure stabilises will give the equilibrium reading. Having also noted the temperature of the product, these two readings may be applied to the graph and the degree of carbonation determined.

For example, an equilibrium pressure of 2 bar at a temperature of 6°C would indicate a carbonation of 4.0 volumes.

Unfortunately, this simple procedure is prone to inaccuracy owing to the possible inclusion of air in the beverage. (The presence of air in a carbonated product will radically affect the future quality and shelf life of the drink since the oxygen element of the air promotes aerobic spoilage and oxidation of certain constituents.) A further complication is that air is roughly one fiftieth the solubility of carbon dioxide, and although it may be considered that this small fraction renders the presence of any air inconsequential, the opposite is actually the case. Any air contained in the product will exclude approximately fifty times its own volume of CO2. In fact, air in its normal composition of 21% oxygen and 79% nitrogen (ignoring trace gases and water vapour) does not dissolve in liquids to produce dissolved oxygen and nitrogen in these same proportions. Owing to the differing solubilities and proportions of the two main constituents, the dissolved air is actually 35% oxygen plus 65% nitrogen. This enrichment of the oxygen proportion is unfortunate since it is this particular component that is responsible for many of the spoilage problems associated with air contamination.

When measuring the equilibrium pressure of a sample of carbonated product, other gases (such as oxygen and nitrogen dissolved from atmospheric air), if present, will also exert partial pressures dependent upon...
the individual presences and solubilities. In the case of oxygen and nitrogen, although the proportions may be small, the solubilities are much lower than that of CO2 and therefore the partial pressures necessary to keep the foreign gases in solution will be higher. In this eventuality, the total equilibrium pressure (being the summation of the partial pressures of CO2, O2 and N2) will be greater than that produced by the carbon dioxide content alone. This enhanced pressure, gauge reading during the carbonation test will indicate a higher carbonation level than is actually present. A high air content not only produces a false reading of the carbonation level but also imparts a flatness or lack of sparkle to the beverage and results in a stale flavour.

In order to avoid a distortion in the carbonation reading produced by dissolved oxygen and nitrogen, a simple modification applied to the pressure/temperature procedure previously described will allow a more accurate determination of the CO2 content: when the container is shaken to equilibrium, the first pressure is allowed to escape slowly to atmosphere and the container then agitated again to the equilibrium condition, which is the pressure used to compute the carbonation level from the graph in Figure 2. This adaptation is often referred to as the second shake method and eliminates the misleading effect of any dissolved air since the latter, being less soluble than CO2, will leave solution during the first shake and will be vented off as the container is depressurised.

The equipment used to determine the equilibrium pressure in a container will vary according to the supplier, but basically consists of a hollow piercer (or lance) which enters the bottle cap or can lid and is connected to a pressure gauge and a release valve. Glass bottles should always be enclosed in a metal cylinder during the agitating operation but plastic bottles and cans may be held in an open frame as shown in Figure 3.

When a filled bottle or can is selected for a carbonation test it may have been obtained directly from the production line, or it may have been extracted from warehouse stock, or it may have been delivered to a central laboratory from a satellite factory. In the last two instances, the containers will have attained equilibrium pressure but bottles and cans taken from the production line will not have reached that condition and require special attention before being tested. The container should be wrapped in a cloth dampened with cold water and shaken vigorously for at least 30 seconds and then allowed to rest undisturbed for another 5 minutes; this procedure will ensure that equilibrium conditions have been obtained for all gases in the package, i.e. the gases will have been distributed between the headspace and the product according to their solubilities and presences.

The test may now proceed as follows:

(1) Check that the release valve is tightly closed.
(2) Place the bottle or can in the apparatus and puncture the crown, cap or can base with a firm movement to ensure that a seal is made.
(3) Check that the pressure gauge has registered and record this reading for possible comparison with the second shake pressure.
(4) Open the release valve slightly and allow the top pressure to escape in a controlled manner until the gauge reads zero or bubbles escape from the beverage.
(5) Firmly close the release valve.
(6) Shake the container and tester vigorously until the pressure gauge rises to a maximum reading and no further shaking will increase it; record this pressure.
(7) Release the pressure, remove the container from the tester and immediately measure the temperature of the product; taking care to do nothing that would raise this temperature.
(8) Using the pressure reading obtained in (6) and the temperature obtained in (7), determine the carbonation from the chart in Figure 2 where the vertical pressure line meets the horizontal temperature line.

If the point of intersection of these lines lies between particular carbonation curves, it is usually satisfactory
to estimate the actual carbonation level to obtain greater accuracy, the proportion of the horizontal (pressure) values may be used for interpolation of the exact carbonation. Instruments should be carefully maintained and regularly checked; any inaccuracies in measuring temperatures and pressures will obviously produce imprecision in the carbonation reading.

The difference between the first shake and the second shake pressures is significant. If the beverage is completely free of all gases except carbon dioxide and the headspace volume is of the order of 5% of the total container capacity (as is usual in most bottles and cans), then the percentage fall in equilibrium (gauge) pressure between first and second shakes will be approximately 5%. If the process is repeated several times, the pressure will reduce by 5% each time until all the carbonation is lost. Taking into account the CO2 lost between shakes and the internal volume of the apparatus plus pressure gauge, etc., a reduction of 7.8% between first and second shakes could be considered acceptable. Results in excess of this figure will indicate that dissolved air is probably present and the cause should be investigated and rectified if reasonably air free (and oxygen free) products are to be produced.

Effective application of quality control

Introduction

Although the organoleptic qualities of soft drinks and some of their major ingredients present specific problems in the attainment of consistent high quality, this challenge has been successfully met by the introduction of comprehensive quality control (QC) and quality assurance (QA) systems incorporating advanced laboratory and in-line instrumentation aided by the application of statistical and microbiological techniques relevant to high-speed packaging operations.

The effects of increasing legislation, added to the growing consumer insistence on safer products and higher quality standards in a competitive market, have augmented the prime objective of the modern quality technologist—the achievement of consistent product quality within company standards. Supportive expertise must now be provided to reduce manufacturing costs by tighter controls on raw material quality and utilisation, and to improve production line efficiencies.

This chapter reviews the evolution and growing importance of both QC and QA in the soft drinks industry. Particular emphasis is accorded to the practical problems of establishing and operating effective quality systems in three types of business, viz. small to medium, national and international: not surprisingly, the wider scale of quality supervision demanded by both national and international operations receives principal attention, although the particular issues relevant to smaller companies are also highlighted.

As production speeds increase and equipment becomes more complex, it is particularly important that the QA systems are geared to prevent defectives as distinct from the QC systems applied in plant in order to detect defectives.

Finally, the chapter examines some of the important technical factors that are likely to influence the industry’s growth and development, emphasising the contribution required from quality technologists both now and in the future and stressing the prospect of challenging and exciting careers for newcomers to the soft drinks industry.

Evolution of QC in the soft drinks industry

1. Concept of quality

Before beginning to describe the development and increasingly important role of QC in soft drinks manufacture, it is important to first lay down the ground rules for achieving consistent first-class quality, as this requires a multidisciplined approach within each company in order to be successful. Put simply, manufacturers produce their various product flavours to formulations which incorporate predetermined quality standards governed by consumers’ expectations of a consistent, good-flavoured and refreshing...
drink, at a reasonable price. We therefore have three critical areas of quality to consider.

- Quality of design  what we believe our consumers want
- Quality of manufacture  our best efforts at making it
- Quality of marketing  what the consumer actually gets.

These shall now be examined in more detail.

Quality of design. This is an R&D and marketing responsibility, to quantify what the consumer wants (no mean task) and develop formulations that match this expectation. Raw material sourcing, costs and availability, compositional legislation and processing requirements all feature in this important development stage. As there continue to be many notable failures with new soft drink products, it must be assumed that this area of quality continues to prove most difficult to quantify accurately. QC input at this stage is normally limited to establishing the necessary tolerances for the quality parameters to be used in production control and verifying that the processing requirements can be met.

Quality of manufacture. The bulk of this chapter will be devoted to the application of QC during the manufacturing process for carbonated soft drinks, requiring the combined disciplines of chemistry, physics, engineering, statistics, microbiology  and common sense! With high volume production and using statistical sampling methods, the achievement of 100% product fully within specification is not normally possible. A more practical target is to ensure the maximum expected quality according to the process capability of the production line, which should have been selected to meet the companys quality standards.

Quality of marketing. In addition to their role in the development of new products (or re formulation of existing products), the marketing function has an important responsibility for ensuring that their companys product range reaches the market in the same condition as it was when produced. Through co ordination and liaison with sales, production and distribution, marketing can help ensure that products reach the consumer well within shelf life and are competitively priced and packaged. The effects of age, heat, sunlight and dampness during storage before sale, the interaction of some ingredients plus possible microbiological activity in the product, all combine to reduce the factory fresh product quality. Although soft drinks suffer far less from these factors than many other products and have, in most cases, a shelf life of up to one year, products containing light or heat sensitive ingredients such as ascorbic acid, quinine, aspartame and certain food colours, can deteriorate appreciably and lose their palatability and attractive appearance. This can be a significant problem in certain overseas markets.

These three key areas of quality must be borne in mind when setting up a comprehensive quality system extending from raw material supplies right through to final point of sale.

2. Evolution of soft drinks QC

A number of key factors in the development of the industry after the Second World War helped to accelerate the evolution of soft drinks technology and the need for in plant QC. These included

- Increased demand for international branded soft drinks  particularly colas
- Introduction of soft drinks legislation covering product composition, contents (volume), labeling, ingredients and prescribed container sizes
- Significant new product and package developments, including the introduction of comminuted fruit drinks, low calorie drinks and one trip containers  particularly PET bottles.

These factors brought in train the introduction of the pre mix filler design (where the finished product and not carbonated water, is handled in the filler bowl) and the coagulation chemical treatment of the raw water, which required more technical supervision in plant. Although, initially, laboratories were staffed by either qualified chemists (who tended to be laboratory, rather than plant, oriented) or trained production personnel (as in the USA), evaluation of the procedures and QC approach used by the major inter-national franchisors enabled these to be selectively applied in the industry, demanding the employment of multi disciplined technologists with direct plant experience. As their contribution to the business increased, so did their
status in the industry. The following sections review the application, in practice, of quality systems in three different levels of business:

• The small to medium business
• The national manufacturer with multiple plants
• The international (franchise) business.

The small to medium sized business
Many of these were family owned businesses supplying local sales and with strong brand loyalty. After many years of heavy dependence on experienced, reliable production personnel for quality supervision, the need for closer technical control of production became increasingly apparent as production speeds increased, formulations became more complex and one trip packaging was introduced. These companies were also competing with the high quality branded products supplied by national companies and had to reassess their quality of design, manufacture and marketing to stay fully competitive. With increasing dependence on the new QC function and its vital contribution in the control of raw material utilisation and costs, QC became more firmly established in the management team and progressively assimilated the necessary techniques to apply the new skills of microbiology and statistics in their quality plan. Where two or more plants were operated, a central QC coordinating role became necessary to ensure common standards, procedures and quality performance, and these responsibilities were coupled with product and packaging development. QA systems began to be developed to prevent production of defectives as well as further improvement in QC procedures and equipment for the detection of defectives.

1. Contract packing
As larger companies turned to contracting out production as an alternative to building new, expensive plant, this development became an important catalyst for smaller businesses with latent expansion plans. The high plant and product standards demanded by the contractors frequently required upgrading of plants, resources and, in particular, the QC function. Marks and Spencer have provided a good example of the growth potential for their suppliers through contract packing in the UK provided that the packers recognise the critical role of quality in this type of operation.

2. Setting up a cost effective system for QC
As close control of overheads became increasingly necessary in the highly competitive drinks market, there were major constraints in the smaller companies on the introduction and expansion of QC and progress was somewhat slower than in larger companies. Basic tests for Brix, carbonation and contents were initially introduced, but as product development became increasingly important, more experienced chemists were engaged to handle both QC and product/packaging development. This also enabled a more professional approach to be taken and prime attention was given to the principal sources of substandard quality by setting tighter Brix and carbonation standards and by checking these key quality parameters at regular intervals throughout production. Similarly, procedures for ingredient processing and accuracy were improved through the introduction of Brix and acidity standards and closer laboratory supervision of flavoured syrup preparation.

Finally, the introduction of benzoate preserved comminuted bases for fruit drinks, replacing juice based drinks preserved with the more effective sulphur dioxide, highlighted the need for more stringent hygiene procedures and routine microbiological control.

It is interesting to note that until QC had proved itself in many organisations, initial reporting relationships were to production management and this is still the norm in many US plants where trained production personnel handle the QC responsibilities. Independent reporting to general management developed as the value of effective QC became more apparent.

In summary, therefore, with limited resources available, the operating costs of QC were more than off set
by the savings in ingredient utilisation during processing, i.e. through less waste and by tighter control of
the syrup/water proportioning during the pre filling blending and carbonating process. Reductions in line
rejects and in consumer complaints were other areas of cost benefit through the introduction of QC.
Finally, elimination of trade spoilage (which could affect considerable quantities of stock in the trade) was
achieved through more frequent intensive sanitation procedures, including the introduction of hot sanitation
techniques before and after production of the more sensitive beverages containing comminuted fruit bases.

3. Product and packaging innovation

Companies in this category had a significant advantage over larger companies in being able to launch new
products or packaging more quickly and with less investment risk. This greater flexibility enabled the more
alert companies to capitalise on current consumer trends with minimum advertising spend, i.e. through local
launches. Where necessary, the companys own technical resources could be augmented by specialist
consultancy support and a number of examples exist of important innovations to the industry introduced in
this way and adopted later by larger companies. A major contribution to the success of such innovations
was made by the chief chemists, quality managers or technical managers of these smaller operations.
Some companies also had the good fortune (or wisdom) to have acquired natural spring or well water
sources which could be more fully exploited with the dramatic growth in bottled waters.
Although the soft drinks industrys concentration in recent years has sadly led to the closure of many smaller
businesses, those that have survived through shrewd marketing, contract packing, or by becoming low cost
producers, have also contributed to the industrys technological development and owe this, in some
measure, to the efforts of their QC staff.

National operations with multiple plants

1. Impact of industry concentration

The increasing concentration of the international beverage business, through acquisitions, joint venture and
equity share, has significantly reduced the number of soft drinks manufacturers in Europe and the USA. In
the UK, for example, there are less than a dozen major carbonated drink manufacturers operating high
speed, low cost production units generally on a multi shift basis. This has required some adjustment in
approach to the control of quality through updating of test procedures, sampling plans and use of in line
inspection equipment. Through improved plant design, both processing and filling plant have increased
reliabilities but the sheer scale of the operation can mean major cost penalties when things go wrong. With
1000 bottles per minute (bpm), bottling lines capable of producing over eight million cases of product per
annum and canning lines now operating much faster than this, QC response to line problems has to be
immediate, the problem rapidly assessed and remedial action implemented without delay.
Reduction in operating plants has, however, eliminated some of the problems of product quality variability
between plants a significant issue in the past in some organisations.

2. Organisation of QC at plant level

A key requirement for plants operating shift systems is the achievement of equal quality performance on all
shifts. This is normally a people related problem requiring considerable company effort in the selection,
training, motivation and supervision of key line personnel particularly as automation reduces the number
of line operators, all of whom make some contribution towards product quality.
Basic requirements for an effective QC system include
• Comprehensive raw material, processing and finished product specifications
• A quality plan (endorsed in a company technical manual) identifying the sampling frequency and source,
tests required and test equipment to be used
• Well equipped laboratory facilities, ideally located close to both production floor and key processing
operations and including separate microbiological laboratory
• A clear understanding of the QC functions responsibilities and level of authority by both plant and central management
• A positive, planned programme for the training, retraining and motivation of the QC team.

3. Centralised organisation for quality
In a multi plant operation, coordination and standardisation of quality systems are fundamental to the achievement of consistent quality standards. This responsibility may be vested in a quality controller or manager, with a small support team for statistical data processing, development of new test procedures and a hygiene specialist (or microbiologist) for plant sanitation audits. Regular auditing of all company plants will be a key responsibility of the central quality function to assure senior management that quality is indeed, under control. This is therefore a quality assurance responsibility, rather than one of quality control and helps to differentiate the respective roles within the quality organisation.

In a larger organisation, the central quality function may be included with engineering and R&D, and be placed under a technical director with full board authority. Clear functional and reporting responsibilities of the plant QC manager with both plant and central management must be defined. One favoured structure is for the QC manager to report to the factory manager with functional responsibility to the central quality controller.

The central quality function would also have responsibility for the preparation and updating of all technical manuals, for liaison with both R&D and marketing in the development and introduction of new products, packaging and ingredients and with R&D and engineering in the development of new process systems.

4. Bottling versus canning QC requirements
Although a number of routine tests are common to both canned and bottled products (e.g. Brix, carbonation, pH or acidity, fill contents and microbiological status) there are certain important differences in either test procedure or emphasis that need highlighting. Owing largely to the design and material of the modern can, higher production efficiencies are generally obtained on canning lines than on glass bottling lines and, with fewer stoppages, quality tends to be more consistent. The quality integrity of the can and its contents depend heavily, however, on close control of the end seaming operation and effective headspace air removal through flushing with CO2 or nitrogen immediately prior to can end application. Nitrate levels in process water must be low as can corrosion may develop with high nitrate content. Sugar for canning must be free from sulphur dioxide preservative (still used in some parts of the world) and it is essential that any proposed change in the design, composition or specification of the can or end component is advised to the canner by the supplier and, where considered necessary, thoroughly checked out before adoption. This is particularly relevant to the internal lacquering system used and the PVC compound on the end component. Can contents are normally checked by an in line fill height inspector which employs a radioactive isotope source.

In bottling operations, high quality glass or PET containers are vital for good line performance. While crown closure application is quite simple and presents few quality problems, close control of cap application (both plastic and aluminium caps) is necessary for good carbonation retention yet easy consumer removal.

Contents variability between bottles can occur with low calorie and some foaming products at the narrow neck fill point of the bottles, making it difficult to balance equipment settings to provide both good fill and standard carbonation.

Efficient utilisation of ingredients through tight control of fill contents and Brix (or acidity for low calorie drinks) is a significant QC responsibility in both canning and bottling and will avoid major cumulative losses on high speed units particularly. Consistent high quality normally means maximum raw material conversion with minimum wastage.

5. Equipment selection for quality
In view of the major investment involved for modern high speed bottling and canning lines (e.g. £4 million
for a 1000 bpm returnable bottle line) the capability of the line to meet all of the company's quality standards must be carefully assessed before purchase. Each equipment component contributes to the final product and package quality, and it is important for QC to participate in equipment selection from the outset through to commissioning and final assessment of the plants process capability against the quality tolerances demanded by the company.

6. Development of in line quality monitoring equipment

Following the major increase in production speeds in recent years, periodic on line sampling followed by laboratory testing proved to be inadequate as action response to substandard quality was too slow. Development of in line test equipment has accelerated in both Europe and the USA and alternative equipment is now available to monitor key parameters such as Brix, carbonation, pH, colour, clarity, etc. Although earlier equipment was designed to monitor the appropriate quality parameters, the latest designs transmit the test results to the process control mechanism, ensuring that any out of standard situation is rapidly corrected. Prime interest in Brix and carbonation has provided equipment available from a range of manufacturers including Terris, Anacon and GAC in the USA and also Maselli and Embra in Europe. Density monitoring in line, as an alternative to Brix, is preferred by some soft drinks manufacturers and equipment is available from Paar Scientific Ltd, London. Increased popularity of diet drinks (containing no added sugar) has required alternative control parameters such as acidity, and in line instrumentation using infrared spectroscopy is now available.

In addition to the basic tests for carbonated products, water treatment plant control can be readily exercised by the use of various types of in line instrumentation for monitoring pH, total dissolved solids, alkalinity, residual chlorine, etc. Other well established systems include in line empty bottle inspection (after washing) utilising new camera techniques, bottle washer detergent strength monitoring by conductivity and fill height inspection for both bottles and cans.

Recent developments include multiple label inspection (an increasingly important requirement on high speed bottling lines as manning levels are reduced) and in line microbiological sampling linked to rapid test methods for evaluation of finished product stability before release to the trade. Clearly, this has become a major feature in the quality control of high speed soft drink production lines demanding familiarisation of QC personnel with the operating principles and techniques of this equipment.

7. Potential quality problem areas

The prime sources of variable product quality in a typical large production plant will now be examined in detail. These problems tend to stem from five principal sources:

- Poor material quality
- Process malfunction through either equipment failure or human error
- Ingredient omission through either equipment failure or human error
- Inadequate sanitation
- Malfunction or inadequate control of filling/carbonating/proportioning equipment.

Raw material quality. From the range of ingredients used, chemical additives produced to BP or equivalent standards are unlikely to provide quality problems and the quality plan should therefore focus on sugar, CO2 and fruit materials. Although these particular ingredients should be tightly specified and quality controlled during manufacture, they are more likely to provide problems in some parts of the world compared with other ingredients. The quality plan should, therefore, include batch sampling and at least physical examination of the fruit materials, taste and odour checks on CO2 and Brix, colour, taste and micro checks on each batch of sugar. Water, as a prime ingredient and liable to seasonal quality variation, requires particular QC attention in respect of both incoming water quality and control of treatment used. See Section which covers this vital area in more detail. Packaging materials can present short, sharp, serious problems on the production line and inspection policies differ from one company to another. Some
companies develop a comprehensive vendor rating scheme which includes regular inspection visits to suppliers plants by QC staff from the bottling or canning plant, with free access to the suppliers quality records. Alternatively, incoming goods inspection schemes can be established for statistical sampling and examination of incoming packaging for approval (or rejection) before use. Selection of the best system will depend on the reliability of the supplier and availability of the packaging - a real problem in certain countries. In view of the critical importance of container dimensions for good filling and handling on the production line, spot sampling (at least) for dimensional checks is a worthwhile insurance before the containers are filled. Unfortunately, in many countries, serious packaging defects continue to be discovered either on the production line or, worse still, in the trade, through lack of appreciation of the value of pre use inspection schemes.

Process malfunction. Although a malfunction or operator error can occur at any time in either water treatment or flavoured syrup preparation, morning start up (particularly Mondays or after holiday shut down periods) tends to be the most vulnerable period when QC needs to be on guard against unusual problems developing. Coagulation water treatment plants can be notoriously unreliable after shut down periods and when they are subjected to peak early morning demands. In flavoured syrup preparation, some products require special processing such as filtration, pasteurisation or homogenisation which, under peak pressure conditions, can be inadequately processed with disastrous effects on the finished product in the trade. Each important stage or the ingredient processing operations has to be highlighted in the Quality Plan, with appropriate supervisory checks by QC staff and the status of the process logged for each days production.

Ingredient omission. Although effectively part of the previous section on process malfunction, omission of vital ingredients continues to be a costly vulnerable area of processing operation in many companies. This is recognised by the major international franchisors who normally supply their bottlers with a unit pack which includes all the key ingredients for flavoured syrup preparation except sugar, making the syrup process much simpler and more reliable. Where unit packs are not used, formulae need to be clear and unambiguous, with the ingredients added in an optimum sequence as certain, ingredients can interact. Various systems are used to verify the accurate addition of all the ingredients, including operators double checking each others measurement and addition of every ingredient and logging these in a batch report.

While the successful application of modern laboratory techniques such as HPLC has enabled analytical verification of Ingredients such as saccharin, benzoate preservative and caffeine, other ingredients such as flavour (essence) content, fruit juice or comminuted fruit content, quinine, aspartame, sodium citrate, etc., cannot be readily checked before the syrup is required for production. Fortunately, more advanced syrup or finished product blending systems are being developed and are already operating with apparent high reliability, including in line monitoring instrumentation. In most world wide plants, heavy dependence continues on reliable operator processing, backed up by independent QC checking. In addition, the important organoleptic check on the flavoured syrup prior to bottling creates a related problem, particularly in large operations producing flavoured syrups on a batch basis as the considerable number of batches produced daily places a heavy load on the sensory capacity of the QC staff. The industry continues therefore to seek a suitable instrumental sniffer/taster to deal with this problem, although development of highly reliable processing plant is clearly a better option. Until then, it remains important for QC laboratories to include adequately trained, skilled tasters for the vital test.

Inadequate sanitation. Major soft drinks companies operate comprehensive plant sanitation programmes to ensure good product shelf life without trade spoilage. The use of fruit juices or comminuted fruit bases, and the growing trend away from the use of chemical preservatives, demands the consistent application of stringent hygiene procedures. Hot sanitation methods using programmed CIP systems have proved most effective employing, for example, 1% caustic solution at 80 °C or, alternatively, an initial cold detergent treatment followed by hot water sterilisation at 80 °C, for 20 30 min. In certain equipment systems,
temporary removal of refrigerant is necessary before the hot treatment. Suspect areas of plant cleaning tend to be pipeline dead legs, pump rotor faces, filler head springs and valves, i.e. where fruit juice pulp can rapidly accumulate and provide a source of infection. QC monitoring of plant hygiene must, therefore, include periodic physical dismantling and inspection of plant after sanitation, followed by microbiological swabbing. As it is normally impracticable to hold finished product stock until micro clearance by QC (i.e. 3 5 days after production), the recent development of rapid micro methods using impedance and luminescence techniques has enabled results to be available in 12 24 hours (depending on the degree of contamination) and before stock is despatched to the trade.

Malfunction or inadequate control of filling/carbonating/proportioning equipment. This is frequently the most common source of variable product quality through a combination of equipment maintenance inadequacies or poor operator control. As described earlier, it is important to know the process capability of the plant (which may vary between products) before defining the quality tolerances to be applied. The frequency of sampling must be determined according to output speed and expected machine performance and, in some companies, the line operators are made responsible for the start-up of the plant to the necessary Brix and carbonation standards and for checking output quality at regular intervals. The QC checks are therefore confirmatory but include more comprehensive product analyses and packaging examination. Critical periods demanding close operator and QC attention are flavour or package changes and start up/shut down of plant, as errors are more likely to occur at these times.

Flavourings and emulsions

Flavourings

Although flavourings are normally used in extremely small quantities in a carbonated soft drink, their impact can make the difference between a tasty product and one that is bland and uninteresting. If follows, therefore, that many flavourings are highly concentrated and their application dose rate must be optimised with great care.

1. Legislation

The use of flavourings is controlled in most countries by the Food Regulations, which should be checked very carefully. Flavourings are normally classified into three categories:

• Natural flavourings, in which the components are obtained by an appropriate physical process (including distillation and solvent extraction) or an enzymatic or microbiological process from material of vegetable or animal origin, either in the raw state or after processing for human consumption by traditional processes of food preparation (including drying, torrefaction and fermentation).

• Nature identical flavourings, which are produced by chemical synthesis or isolated by a chemical process, and are chemically identical to a substance naturally present in material of vegetable or animal origin.

• Artificial flavourings, which are produced by chemical synthesis but are not chemically identical to a substance naturally present in material of vegetable or animal origin.

To illustrate this, consider bitter almond oil or, as it is commonly known, benzaldehyde. When it is extracted totally from almonds, it is natural. When it is produced by either the oxidation of benzene carbinol or by chlorinating toluene to produce dichlorotoluene and then saponifying with lime water, it is nature identical. In some instances, the use of an artificial ingredient may be preferable, because it contains no impurities. Analysis can be undertaken with such accuracy that traces of undesirable components can easily be detected. Some of these impurities may be harmful and too costly to remove. However if the trace components are not harmful, the material may be used.

Although many flavourings will contain ingredients from two or even all three of these categories, it is normal for the status of a flavour to be given as that of the lowest percentage component. This can often
mean that a flavouring that contains 99.5% of natural components and only 0.5% artificial ones will be given
the status artificial.

2. Creation
The creation of new flavourings is a skilled job and can only be undertaken by someone with several years
experience. A flavourist will have a wide range of raw materials available, arranged on an organ from which
the appropriate ingredients will be selected. A flavouring will often consist of over 25 individual ingredients.
For example, raspberry can be broken down to several basic types top notes, fruity, green, berry,
background, woody, pippy, and sweet the whole of which will combine to give a full round flavouring.

3. Production
The production of flavourings can be as simple as mixing two or three ingredients together. In most cases,
however, the use of sophisticated and specialised equipment is necessary. Below is a brief description of
some of the various techniques used by the flavour industry.

Distillation. A typical example of this method uses soft fruit. The fruit is crushed and at the point of
fermentation pure alcohol is added. The flavour and aroma pass into the solvent. The alcoholic solution is
then filtered and by fractionated distillation the alcohol is recovered (for further use) leaving the
concentrated flavouring behind. This is done under vacuum conditions so as not to harm the delicate
flavour which may be damaged by excessive heat.

Extraction. Probably the best known extraction process is in the manufacture of separation flavourings. In
this method, a citrus oil can be washed with a mixture of solvent and water to extract the oxygenated
(flavour containing) compounds from the insoluble terpenes. The resulting soluble flavouring can be
boosted with other ingredients to give the desired finished flavouring.

Maceration. As the word implies, this method involves soaking the raw material. It is commonly used for
citrus peel, herbs, such as basil and mint, or spices such as ginger or chillies. The material is ground and
placed in a tank with solvent to extract the flavour. A period of time may be allowed to elapse for full
extraction, and this may vary from a few hours to several months. Eventually, the liquid is separated by
decantation and is filtered. The use of ultra waves can speed up this process and is now being used
successfully on large scale production.

Carbon dioxide extraction. Carbon dioxide can exist as a solid, liquid or gas, and is easily isolated in any of
these forms. At normal atmospheric temperature and pressure, the solid form becomes gas without passing
through the liquid phase. However, when solid carbon dioxide is heated under pressure, the liquid form is
produced. The use of liquid carbon dioxide is becoming increasingly important for the extraction of delicate
natural products.

Natural products usually contain a large number of different chemical compounds, which, with different
solvents, can be extracted to a greater or lesser extent depending on their solubility in that solvent. The use
of carbon dioxide can be very important with delicate compounds as extractions are normally carried out at
low temperatures (20 °C to +20 °C) thus ensuring that the material is not damaged by excessive heat.
The use of materials produced by carbon dioxide extraction is growing, enabling the flavour industry to
develop flavourings more true to nature than previously.

Emulsions
An emulsion can be described as a dispersion of one liquid in another in which it would not normally be
miscible. Most emulsions used in carbonated soft drinks consist of two phases, which are homogenised
under positive pressure. The following indicates some of the ingredients used in beverage emulsions.
Although a wide range of materials is used to produce these emulsions, the ingredients are normally
controlled by the Food Regulations which specify not only the flavourings but also the emulsifiers and
stabilisers that can be used.
The main use of emulsions in carbonated soft drinks is as a clouding agent. When considering the organoleptical features of a soft drink, the visual appearance is extremely important as the eye appeal can often be the determining factor in deciding which drink is actually purchased.

## Syrup room operation

### Introduction

It is possibly true to say that the design of any syrup room depends upon the desired end product. This chapter attempts to detail some of the equipment and materials that are necessary for a modern syrup room operation. In designing a syrup room, there are many considerations to be taken into account. These may be grouped as follows.

**Hygiene related.** The design of infrastructure, tanks and pipework must ensure sterility and safeguard the end product from future spoilage. The choice of detergent and type of CIP (Clean in Place) system is important.

**Product related.** To do with the raw material, its storage, handling and treatment, all of which affect the future quality of the drink.

**Process related.** Plant and equipment. From the humble origins of the syrup rooms of the 1930s and 1940s (when syrup batches of 100 and 250 litres were commonplace and 1000 litre batches were unusual), the concept has evolved to the present day syrup room being considered as a mini factory within the main soft drinks complex clinically designed, staffed and operated by qualified technicians assisted by modern plant and sophisticated instrumentation.

Present developments include the automated and computerised systems currently available, and the latest advances where a multiple component mixing plant prepares finished product as opposed to the conventional preparation of syrup. These areas, together with the storage and handling of raw materials, are discussed to give an appreciation of the size, complexity and importance of any syrup room operation.

### Syrup room design

#### 1. Wall finishes

An elaborate interior is not necessary, but a critical area of any syrup room is the finish on the walls as these are constantly exposed to harsh cleaning compounds as well as the acid components of the product for wall surfaces to last, they must be impervious to this kind of treatment. With continual use of water and inevitable sugar deposition, these surfaces are extremely prone to mould growth. Ceramic tiling has generally been used but tends to be expensive and spray tile finishes may be used as an alternative this finish is applied directly to masonry blocks and consists of several layers of epoxy enamel paint covered with a glaze coating.

#### 2. Floors and drainage

A surface coating capable of resisting strong acid and alkaline solutions is necessary unprotected concrete surfaces offer little resistance to these types of solutions. Quarry tiling is an excellent surface but, again, can be very expensive several less costly products have now been introduced, based on epoxy finishes that have been developed to resist the corrosive effects of specific compounds. Proper drainage must be installed to allow fast flow of waste to reduce contact time of corrosive products on floor areas, and drains should always be designed to allow adequate cleaning.

#### 3. Ceilings and lighting

A concealed or dropped ceiling system is generally used and is supplied as lightweight panels the surface should be resistant to the type of products used in a syrup room since vapours are often carried upwards and deposits can occur. Fluorescent lighting systems are most commonly used and should be waterproof to reduce the effects of corrosion and prevent ingress of insects.
4. Heating, ventilating and air conditioning
Environmental conditioning is preferable but is not installed in many factories in the UK. The advantages of these types of systems are:

1. They reduce relative humidity which, in turn, reduces condensation on equipment and piping that could support mould growth.
2. They reduce airborne contamination by filtering out dust, etc.
3. They reduce ambient syrup temperatures which could affect filling performance.
4. They improve equipment performances by permitting them to operate at cooler temperatures.

Syrup room equipment

1. Storage, mixing tanks and systems
Tanks are used for a number of purposes and can vary from a small vessel for dissolving purposes to large storage tanks. Some factories are equipped with syrup tanks of capacities greater than 30000 litres, although many factories still use tank sizes of 5000 to 20000 litres and consider such batches economical. The number and sizes of tanks are determined by many factors:

- Number of hours in a working day
- Line filling speed
- Variety of products and flavour changes
- Filtration requirements of syrup
- Sterilisation requirements between critical flavours
- Ageing or maturation time of syrups
- De aeration of syrups after mixing

Traditional syrup rooms had tanks with open tops and the only form of agitation was manual, often using a wooden paddle. Modern syrup room tanks are now designed to be fully enclosed and are fitted with manholes, inspection lamps, agitators, high and low level probes and full CIP spray ball assemblies: level indication is often by sight glass or the use of load cells.

Mixing systems. The correct amount of agitation in a tank is very important; the agitation should be smooth since violent agitation leads to aeration which is difficult to remove and causes problems at the filler. A comprehensive range of mixers is now available and can vary from propeller type mixers to high shear mixers. The positioning and type of mixer to be used should be carefully selected depending upon the size of tank and the nature and viscosity of product to be mixed.

Mixers can be attached to the tops of tanks or by more permanent mountings at the bottom or side entries. Variable speed motors can be fitted to ensure that excessive aeration does not occur when low levels of syrup are mixed in large tanks. One of the major problems encountered in mixing syrup is the exclusion of air; it is good practice when preparing syrup to first add water to the tank. The agitators should not be set in motion until they are well covered with liquid. All ingredient pipework should be directed to run additions down the side of the tank instead of allowing them to splash into the bulk of the liquid. Some tanks have inlet points of the bottom feed type and these help in reducing splashing, foaming and aeration. Syrup batches should generally be allowed to stand to de-aerate before filling to allow any entrapped air to escape; it is usual to allow at least one hour minimum or two hours ideally for sugar based syrups.

High shear mixers. High shear mixers are often employed in the soft drinks industry to disperse stabilisers, e.g. xanthan gum and sodium carboxymethyl cellulose; these can be very difficult to dissolve unless the correct technique is employed. The high shear mixer should be started in water and the powder added as quickly as possible; the use of a venturi to pre-wet the particles is particularly useful. The powder is sucked down into the disintegrating head and dispersed before the viscosity has developed. It is important that the
powder should never be added slowly since it will mean that the last of the powder is added to a mix that is already of high viscosity and will inevitably form lumps that will be difficult to disperse.

Liquid jet mixers. These offer an alternative to conventional agitators and have been used successfully for the production of finished syrup. The system provides a homogeneous mixture with very little entrained air; this is due to the short mixing time as the mixing process starts while the vessel is being filled. The application for liquid jet mixers is determined by the viscosity of the liquid to be mixed; generally, these mixers can be used where centrifugal pumps are capable of transferring the liquids to be circulated.

Jet mixers are normally installed at the lowest point possible in a tank to ensure adequate and efficient blending. In the event of a low liquid level, the installation of a jet mixing nozzle in the base of a mixing tank and the circulation of liquid is illustrated in Figure 1.

The jet of liquid flowing out of the diffusion nozzle at high speed generates a reduced pressure in the inlet cone of the diffuser which causes a liquid stream to be sucked out of the vessel and carried along. The diffusion jet mingles with the drawn-off liquid, increasing its velocity. The turbulence in the diffuser produces a homogeneous liquid mixture and the entire contents of the vessel are blended in a short time without creating circular movement.

2. Pipework, fittings and connections

The majority of pipework is stainless steel and if suspended ceilings are used the pipework can be run above the ceiling. All pipework to the syrup manufacturing area should be marked or colour coded: this helps to eliminate mistakes and promotes safety.

Various fittings and valves are used to connect pipes, e.g., bends, tees and reducers, sight glasses and instrument ports, and valves for directing and regulating the flow and the pressure.

 Permanent joints are sometimes used by welding or expansion. Where disconnection of pipework is required, the pipe coupling is in the form of a threaded union which has a seal or gasket in between. Swing bends are often used where a piping run needs to be switched from one line to another, e.g., connecting CIP line to the syrup line. All pipe connections should be tightened firmly to prevent air being sucked into the system and to prevent leakage of syrup. Sight glasses are often located in the pipeline where a visual check on the ingredient is required. Connections may be provided to allow the mounting of measuring instruments such as thermometers, pressure gauges, conductivity probes (to detect liquid). Sampling ports can be included, but it is essential that the sampling port does not allow contamination to occur to the ingredient.

Valves. Many designs of valves are available for process systems and can vary from manual operation to air-operated types. The choice of valve is important for a number of reasons:

• Valves should be leaktight against known line pressures.
• Air valves should close on air failure.
• Diaphragms should be of approved food grade material.
• Valves should be resistant to harsh corrosive products, should be reliable and should be designed for minimum maintenance.

Shut off and changeover valves have distinct positions. A regulating valve allows the passage or flow of liquid to be controlled gradually and is used for the fine control of flow and pressure at various points in the piping system.

Check valves are fitted where it is necessary to prevent product from flowing in the wrong direction. The valve is normally kept open by the flow of liquid in the right direction. If the pressure on the downstream side of the valve becomes greater than the flow pressure, the valve disc is forced against its seat by the back pressure and the valve is effectively closed against reversal of the flow.

Pressure relief valves are used for regulating the pressure of the product in the piping. If the pressure is too low, the spring presses the plug against its seat; when the pressure reaches a certain level, the force of the
plug overcomes the spring and the valve opens. Spring tension is adjusted to set the desired opening pressure.

3. Ingredient flow
Pipework should be designed to prevent any pockets occurring along the line where the product or cleaning detergent can collect; this could lead to microbiological spoilage or contamination of the syrup by a detergent. It is also desirable to ensure that low points are designed into pipe work so that full drainage may be obtained via a valve at that point.

It is essential to design the pipe sizes to give adequate flow but ensure that mechanical bruising of the product does not occur. Flow resistance will occur in pipework due to friction in straight pipe lengths, changes in direction of flow due to bends, valves and other fittings. The flow resistance is expressed in terms of the column or head of water necessary to compensate for loss of pressure due to resistance. Traditional syrup rooms had tanks on a floor above the filling lines and the pressure arising from the head of syrup was usually sufficient to transport it to the production line at the required flow rate. In modern factories, which are designed on high output, it is more difficult to gravity feed and so pumps are therefore used to generate the pressure required.

The resistance to the flow of a liquid results in a loss of pressure and the component is therefore said to cause a pressure drop in the pipe. The pressure drop is measured in terms of head and is equivalent to the resistance of the ingredient, the size of pressure drop being governed by the velocity of the flow, i.e. flow rate and size of pipe. If the velocity exceeds a certain value (dependent upon the nature of the liquid) then not only does the frictional head increase (requiring a more powerful pump) but the flow in the pipe becomes turbulent and disturbed, producing a possible adverse effect on the syrup.

4. Pumps
Nowadays, with high throughput operations, it is necessary to convey large quantities of liquid through pipelines often with large numbers of bends, valves, etc., and through pasteurisers, homogenisers and other associated equipment which could all possibly contribute to pressure drop. Pumps need to be fitted at various points in the line to convey the liquid and compensate for the loss of head; however, pumping agitates the product and it is essential that the correct pump is chosen. Many different types are available from the range of centrifugal, diaphragm, peristaltic, gear and positive displacement pumps.

Centrifugal pumps. These are often used since they can be manufactured to a sanitary design, are suitable for CIP and are not capable of producing accidental over pressure. A centrifugal pump comprises an impeller rotating in a casing, a delivery chamber and an electrical drive. Liquid entering the pump at the centre of the casing is carried round by vanes. If the liquid has to be pumped up to a tank at a higher level, the pump discharge pressure must be sufficient to raise the liquid to that height. This type of head is known as a static delivery head. The pump characteristics supplied by a manufacturer usually relate to water; the viscosity of a product makes a difference. When highly viscous liquids are pumped, the pressure losses in the pump are higher and so the energy of the product leaving the impeller will be lower than for water. During pumping, liquid is carried from one side of the pump to the other, creating a partial vacuum in the space once occupied by the liquid. This space on the suction side is then refilled with more liquid. Cavitation on a pump can occur when the pressure at the suction falls below the saturation pressure of the liquid (varies with temperature) and dissolved oxygen comes out of solution; this can be avoided by reducing the pressure drop on the suction line, e.g., large pipe size, fewer valves, raising liquid level above pump inlet, etc.

Flow controllers are often used to maintain a constant flow rate; an effective method of flow control is to vary the speed of the pump, which can be achieved mechanically, hydraulically or electrically. The centrifugal pump can be used to handle a wide range of liquids provided the viscosity is not too high; the pump is not self-priming and the suction line and pump casing should be filled with liquid before switching on.
Positive displacement pumps (rotary). There are many types of self priming positive displacement pumps. The rotary pumps work on the principle of two synchronised driven lobed rotors, which have a very close clearance but do not actually touch each other. As the rotors turn, the volume between the lobes at the suction port increases and the partial vacuum created causes liquid to enter the pump. The liquid is carried in the space between the lobes and the pump casing to the outlet as the volume between the lobes is reduced, the pressure increases and the product is discharged. In order to prevent excessively high pressures, positive displacement pumps usually have some form of relief valve, which automatically returns some of the liquid to the inlet if the pressure becomes too great. Flow is normally regulated by varying the speed of the pump. Positive displacement pumps are generally used for handling high viscosity liquids.

5. Measurement of liquid
The contents of tanks may be measured using meters, dipsticks, sight glasses or load cells. The use of load cells is a common method for monitoring ingredients these, however, have some disadvantages in that all additions need to be converted to weight. Reliable sanitary meters have been developed for measuring liquids. Accurate meters are the most practical method of measuring quantities of liquid into a tank. Registering meters are normally fitted with shut off valves which automatically close at a predetermined setting, shutting off the flow of liquid. Meters do have an advantage in that multiple additions may be made simultaneously, thus saving time and often aiding mixing. In the absence of meters, the dipstick method of measuring liquid is reliable and has been widely used for many years. These are made from stainless steel and have a hooked end to facilitate hanging the strip from a specially marked spot on the side of the tank. With the use of dipsticks, each tank must be calibrated individually. Using an accurate meter or calibrated measure, water is introduced into the mixing tank: the dipstick is then calibrated to this level and marked. The mark is checked by repeating the process several times, being certain to hang the dipstick from the same point each time. Once the calibration has been accurately established, the level is scribed permanently into the stainless steel. A sight glass, mounted on the side of a syrup tank with sanitary mountings, is another means of measuring contents in a tank. The sight glass should be accurately calibrated and marked. Unless careful cleaning is employed, sight glasses can offer hiding places for contamination.

6. Filtration of ingredients
A number of ingredients in syrup manufacture and, indeed, in certain instances, the syrup itself require some form of filtration, which could range from a simple mesh filter to a more sophisticated plate and frame or cartridge type system. Micro filtration is nowadays a safe and efficient method of removal of unwanted particles and other turbidity components. Where high carbonation mixer drinks are concerned, it is preferable to ensure all active centres are removed to aid good filling: the syrup itself can be filtered typically through a nominal 50mm cartridge for this purpose. In contrast to the conventional filter plate systems the modern cartridge housing concept has numerous advantages.

• Completely enclosed, sanitary and leak free
• Quick change out of filter media
• Short cleaning and sterilisation times
Some cartridges can be cleaned in forward flow with hot water and significantly reduce costs by prolonging cartridge life. Typical cartridge systems feature a polypropylene centre core, outer cage and end caps and either a cotton wound cartridge or often a charged nylon membrane. The components are thermo welded to eliminate the use of glue or resins, which may impart unwanted off flavours.
Acids, colours, preservatives and other additives

Introduction
The commercial success of a soft drink formulation depends upon a number of factors. A strong, well placed advertising campaign will bring the consumer to purchase the new product but, thereafter, the level of repeat sales will reflect the degree of enthusiasm with which the new drink has been received. Taste panelling and market trials are also preliminaries to a successful launch, yet continuity of sales will ultimately depend upon the product itself, primarily its appearance and taste, as assessed by the consumer, and then, perhaps, the reproducibility of quality in both manufacture and storage these latter being the major concerns of the producer and soft drinks retailer, who must maintain a regular turnover to survive. It is hardly surprising that the development of a new drink product can take many months, while all aspects of its appearance, organoleptic properties and stability are tuned to requirements. In the final analysis, organoleptic properties are paramount, and the aroma, taste and mouth feel must be complementary in their contribution to the resulting drink. However, the immediacy of colour and its importance to the success of the product cannot be underestimated.

In recent years, the use of synthesised ingredients has frequently been under attack by the media and, as a result, market forces in many countries have initiated a rapid move in the direction of natural ingredients. We have seen an influx of various natural colour extracts to the food industry which, being largely pH dependent and light sensitive, have found limited use in soft drinks. A few have found acceptance, but even so are still open to scrutiny in terms of adverse metabolic effects. Many have no recommended ADI (Acceptable Daily Intake in mg/kg body weight) values, while others have values allocated which are not far removed from those of the synthetic colours they have replaced. Preservatives also show signs of being phased out, as improved methods of pasteurisation and aseptic filling are devised. The ability of carbon dioxide to act as a preservative places carbonated drinks in a strong position for future development.

A typical carbonated soft drink comprises carbonated water, sugar, citric acid, flavouring, acidity regulators (e.g. sodium citrate), colouring, preservative and artificial sweeteners, if used. The flavour component is presented against a finely tuned backcloth of the other ingredients, providing the right degree of sweetness, bitterness, sourness, and acidity (pH) to enhance drink palatability.

Acids
Following water and sugar, the acid component is third in terms of concentration. Its presence tends to be taken for granted, yet, without its contribution, the other formula components are left lacking in character. Because of the general tartness or sourness in taste, acidity is useful in modifying the sweetness of sugar. It will increase the thirst quenching effect of the drink by stimulating the flow of saliva in the mouth and also, because of a reduction in pH level, tends to act as a mild preservative. While the majority of soft drinks contain acids, it is the carbonated drinks that have the additional effect of dissolved carbon dioxide. Not officially recognised as an acid addition, the presence of carbon dioxide under pressure certainly provide that extra sparkle to mouth feel, flavour and sharpness (or bite) to the drink, so it has been included here under the identity given to its soluble form.

1. Carbonic Acid
The solution of carbon dioxide in water exploits weakly acidic properties. Neither liquefied nor dry gaseous carbon dioxide affects dry blue litmus indicator paper, but if the paper is moistened it will provide an acid reaction in contact with the gas. There is little doubt that in solution some of the gas forms carbonic acid by combination with water.
Potassium and sodium carbonates can be used in the production of dry carbonated drink mixes, where a blend of sugars, fruit acid crystals, spray dried flavourings and other additives such as stabilisers is formulated to produce a drink which, when dissolved in water, has a carbonation level of about 1 1½ volumes carbon dioxide. In its more regular role, during the production of carbonated drinks, carbon dioxide is introduced as part of the bottling sequence, being dissolved under pressure before or after dilution of the bottling syrup with water. Measured in volumes of dissolved gas per unit volume of water at a specified temperature and pressure (usually Volumes Bunsen at 0°C and 1 atm), the average level employed is in the region of three volumes although extremes of perhaps one volume and six volumes are sometimes encountered where highly specialised flavoured products are required.

2. Citric acid
This is by far the most widely used acid in fruit flavoured beverages. It has a light fruity character that blends well with most fruits and, in fact, is found as a major constituent in many of them, e.g. unripe lemons contain 5 8% of the acid. It is also the chief acid constituent of currants, cranberries, etc., and is associated with malic acid in apples, apricots, blueberries, cherries, goose-berries, loganberries, peaches, plums, pears, strawberries and raspberries, with isocitric acid in blackberries and with tartaric acid in grapes. It was originally obtained commercially from lemons, limes or bergamots by pressing the fruit, concentrating the expressed juice and precipitating citric acid as its calcium salt by running in, with constant stirring, a slurry of chalk and water. The crude calcium citrate was then filtered off, filter pressed and washed prior to treatment with sulphuric acid to yield the free citric acid, which was then filtered from the precipitated calcium sulphate, and finally isolated by concentration of its solution by boiling, from which crystals of the monohydrate formed.

It was noted at the time of Dr Martins Treatise on Industrial and Manufacturing Chemistry that a known organism existed Mucor Piriformis (C. Wehmer, German Patent 72,957) that could ferment sugar directly into citric acid. Owing to the low market prices of Sicilian lemon juice, no wide technical application of this early enzyme process had been made. However, citric acid is now produced by the action of specific enzymes upon glucose and other sugars.

Citric acid is a white crystalline solid and can be purchased in its powdered form or as the monohydrate. This latter state is more convenient in terms of storage, as it does not have a tendency to absorb moisture, as does the anhydrous form.

3. Tartaric acid
This acid occurs naturally in grapes as the acid potassium salt and, during fermentation of grape juice, will be seen to deposit from solution as its solubility decreases with increasing alcoholic content of the wine. The acid can be obtained in four forms: dextro, laevo, meso tartaric and the mixed isomer equilibrium, or racemic acid. Commercially it is usually available as the dextro tartaric acid. The acid possesses a sharper flavour than citric and, as such, may be used at a slightly lower rate to give an equivalent palate acidity. (Note that palate acidity is a purely subjective measurement and it is generally agreed that a number of acids may be used at a concentration different to that indicated by their chemical acid equivalent).

Tartaric acid may be isolated from the crude deposit of tartrates obtained from the wine fermentation process in a similar manner to that originally used for citric acid by leaching the deposit with boiling HCl solution, filtering clear and re precipitation of the tartrates as the calcium salt. Further treatment with sulphuric acid is used to liberate the acid, which can then be purified by crystallisation.

Tartaric acid (dextro form) exists as a white crystalline solid mp 171-174°C. If used in beverage production, the acid must be perfectly pure and guaranteed for food use. It has disadvantages in that its salts are of a lower solubility than those of citric, particularly the salts of calcium and magnesium. When using hard water, it is therefore advisable to use citric acid to avoid unsightly deposition of insoluble tartrates.

4. Phosphoric acid
The acid is derived from mineral and not vegetable sources although occurring naturally in some fruits, e.g. limes, grapes, in the form of phosphates. It is used in some beverages as a substitute for, or in addition to, citric and tartaric acids, having a sharper and drier flavour than either of the above acids. Its taste is of flat sourness, in contrast with the sharp fruitiness of citric acid, and it seems to blend better with most non fruit drinks. In the UK, it is not allowed in drinks claiming the presence of fruit juices and comminuted fruits. Its main use is in cola flavoured beverages, where its special type of acidity complements the dry, sometimes balsamic, character of the cola drinks.

Pure phosphoric acid is a colourless crystalline solid (mp 42.35 °C) but is usually used in solution as a strong, syrupy liquid, miscible in water in all proportions. It is commercially available in concentrations of 75, 80 and 90%. The syrupy character is the result of hydrogen bonding, which occurs at concentrations greater than 50%, between the phosphate molecules. It is corrosive to most construction materials and rubber lined steel or food grade stainless steel are recommended for holding vessels.

5. Lactic acid
Sometimes used for the acidification of beverages, lactic acid possesses a smoother flavour than any of the foregoing acids. It is supplied commercially as an odourless and colourless viscous liquid and is obtained from the fermentation of sugars by lactic acid bacillus.

6. Acetic acid
As in the case with phosphoric acid, under UK legislation this acid is limited to use in non fruit juice drinks and really only qualifies where its vinegary character can contribute to a suitable flavour balance. Pure glacial acetic acid is a colourless, crystalline solid of mp 16 °C and is one of the strongest of the organic acids in terms of its dissociation constant and displacing carbonic acid from its carbonates.

7. Malic acid
This is the natural acid found in apples and other fruits. A crystalline white solid (mp 100°C), it is highly soluble in water. Being less hygroscopic than citric acid it possesses improved storage and shelf life properties.

Malic acid is slightly stronger than citric in terms of perceived palate acidity and imparts a fuller, smoother, fruity flavour. It is of course, first choice for apple flavoured drinks.

Unlike tartaric, its calcium and magnesium salts are highly soluble and the acid presents no problems in hard water areas.

8. Fumaric acid
Not permitted under UK soft drinks legislation, fumaric acid is widely used in other countries as an acidulant, notably in the US market.
In terms of equivalent palate acidity it can be used at a lower rate than citric acid and typical replacement can be employed at two parts fumaric per three parts citric in water, sugar water and carbonated sugar water. Its main drawback is a reduced solubility compared with the citric acid and special methods need to be employed in getting it into solution.

9. Ascorbic acid
This acid (known as Vitamin C) is not only used as a contributory acidulant but rather as a stabiliser within the soft drinks system and its anti oxidant properties improve the shelf life stability of the flavour component in many cases.

Many of the ingredients used in flavourings are susceptible to oxidation, particularly the aldehydes, ketones and keto esters. Ascorbic acid shields these from attack by itself becoming preferentially oxidised and lost, leaving the flavour component unaffected. It should be noted, however, that while a browning inhibitor in unprocessed fruit juices, the effect can later be reversed should the juice be subsequently heat treated (pasteurised) when the ascorbic acid present can itself initiate a chemical browning reaction. Another disadvantage of ascorbic acid is its effect upon some colours in the presence of light.
Colours

The sensory perception of colour will influence the taster’s reception of the drink. It has been generally demonstrated that the colour can far outweigh the flavour in the impression made upon the consumer. Both quality and quantity of colour are of importance and certain colours provoke, or perhaps complement, a particular taste. Reds will favour the fruitiness of soft drinks, e.g. blackcurrant, raspberry, strawberry, etc. Orange and yellow tend towards the citrus flavours. Greens and blues reflect the character of peppermints, spearmint and cool flavours, sometimes herb like and balsamic and the browns align with the heavier flavours, e.g. colas, shandies, dandelion and burdock.

There is little doubt that in the early years many questionable practices were involved in beverage production and there is an interesting reference in Skuses Complete Confectioner A Practical Guide to the Art of Sugar Boiling in all its Branches. This book, published c. 1890, contained information on cordials and other beverages and, under its section on flavours and colours, the author felt it necessary to point out the dangers of using certain colours such as sulphate of arsenic, iodide of lead, sulphate of mercury, carbonate or sulphate of copper and seriously admonished the used of chrome yellow (lead chromate) by certain confectioners who were partial to using a little chrome yellow for stripes in sweets. Such colours were officially banned from food use in 1925.

Today, the use of food colouring is carefully controlled under various legislations, with an ongoing programme of toxicological studies where there is suspicion of harmful or allergic effects. Both the EEC (European Economic Community) and the FDA (Food and Drug Administration of the USA) have published permitted lists that are under regular review. Most concern has been expressed over the azo colours as certain people can demonstrate an allergic reaction to some of them. Toxicological and allergic reactions have been reported most frequently with Sunset Yellow (E 110) and Tartrazine (yellow) E 162.

It has been found by experience that a number of food colours give a broadly satisfactory performance in soft drinks and carbonated beverages.

The colour properties can be affected by a number of soft drink ingredients and good storage stability is required in the presence of acids, flavouring compounds and, where necessary, the preservative. The colour component must also be stable in the presence of light. It is well known that the combination of ascorbic acid and light has a detrimental effect on many colours. While it can be said that the colours permitted for soft drinks have a reasonably good all round performance, there is no substitute for storage trials in new product development to ascertain the real behaviour in the finished beverage.

The colours most commonly encountered in the soft drinks industry are Tartrazine, Sunset Yellow FCF, Carmoisine, Green S, Chocolate Brown HT, the caramels and the nature identical carotenes. Amaranth, previously widely used, has lost ground since its exclusion from the US permitted list by the FDA of America in January 1976. Although Amaranth (E123) is still permitted in Europe, there has been a tendency towards the use of Carmoisine instead. Tartrazine and Sunset Yellow are being replaced more frequently by Quinoline Yellow, the slight differences in colour tone being compensated for in terms of intensity by altering dosage rates.

The consumer, also being remarkably tolerant, tends to demonstrate the fact that, unless one can make immediate comparisons and batches of beverages using different colour types are not presented side by side then the changeover to a new colour will have little effect on sales. In recent years there, has also been an increase in the usage of natural colour extracts within the regulatory lists. Curcumin, carotenoids, (caramel) flavenoids, anthocyanins and chlorophyll have all been produced where necessary in water soluble forms (emulsions, salts, etc.) with varying success. During the eighteenth century there was little need for rigid laws controlling additives in food or drinks. Until
the Industrial Revolution, food had been produced in Britain for the immediate needs of the local communities, and trade was restricted likewise to the immediate area. Producer and consumer were often neighbours with a high level of trust between them. However, the result of the new industrialisation changed all that.

Between 1834 and 1856 it was discovered that aniline, produced from coal tar (a by product of coal gas manufacture), could, in conjunction with other agents, provide a wide range of vivid and fast colours. The patent taken out by a young chemist, William Henry Perkin, for a mauve colour produced from aniline, opened the door to a succession of new dye stuffs from coal tar products. These transformed the textile industry which had hitherto relied upon natural colouring extracts. Low cost and bright hues ousted the use of natural colours and had a marked effect upon world trade. In 1868, alizarin, the colouring principal of the madder root (Rhubia tinctoria), was prepared synthetically and, during the same period, natural indigo was also being displaced in commerce by the artificial version.

Textile manufacture was not the only use to which the new products were directed and a selection of them soon became available for food use, often with dire results to the consumer. In 1925 the compounds of arsenic, antimony, cadmium, etc. (referred to earlier), were finally officially banned from use as legislation began to take hold. Even so, it appears that little was done until the early 1950s to regulate the use of food colours other than to ban from use those colours that had become obviously unsuitable for consumption, usually at the behest of interested parties following the outbreak of poisoning owing to excessive use of a particular additive. In 1954, a list of acceptable food colours was drawn up (hitherto only negative lists had been available) and subsequently, in 1957 and 1973, the list as we know it today was drawn up of both natural and synthetic colours.

In line with greater concern over the food we consume, there is a greater regard to the toxicological effects of food additives in general and accordingly, not only do we consider the suitability but also the Acceptable Daily Intake (ADI). This is expressed in milligrams per kilograms of body weight as the amount of food additive that can be taken daily in the diet, without risk.

Within the EEC, the allocation of ADI values is the responsibility of JECFA (the Joint Expert Committee on Food Additives), which comprises experts representing the World Health Organisation (Geneva) and the Food and Agricultural Organisation of the United Nations, (often referred to as WHO/FAO).

Control of food additives in the USA comes under the auspices of the FDA, who have devised a permitted list of additives. The EEC and FDA lists, while subjected to a similar degree of toxicological testing, may differ in content. For instance, Amaranth, permitted by the EEC list, was de listed by the FDA in 1976.

The subject is controversial and it is often difficult to identify the actual number of persons showing the allergic reaction, as the offending substance may only show adverse effects when in combination with a food or beverage to which the person is also allergic. The major deterrent is the list of ingredients on the label, which enables those who are allergic to identify the substance and avoid intake.

High intensity sweeteners

Introduction

The low calorie/sugar free soft drinks market and therefore, the use of intense sweeteners has grown dramatically in many world markets over the last five years. The major reasons for growth are:

(1) Sweetener development: that is, improvement in the taste quality of high intensity sweeteners permitted for use in soft drinks and consequently more acceptable low calorie/sugar free products.

(2) An increase in consumer awareness of nutrition and healthy eating, making the reduction of sugar intake in the diet desirable for the majority of developed societies.

Saccharin was the first high intensity sweetener to be marketed, and its usage increased during the First
World War owing to a sugar scarcity. Cyclamate entered the UK market during the 1960s and was later controversially banned in many countries as a potential carcinogen. The 1970 cyclamate ban brought to an end the use of saccharin cyclamate blends in many soft drinks markets. Soft drinks sweetened only with saccharin did not deliver the sweetness taste quality of the blend and this highlighted the need for alternative high intensity sweeteners. It was a further 11 years before other high intensity sweeteners (aspartame, acesulfame K and thaumatin) gained approval for use in foods in major world markets.

Use of intense sweeteners
Use of sweeteners in soft drinks is not restricted to low calorie or dietetic products. In some countries, particularly where sugar prices are comparatively high, intense sweeteners are used in combination with sugar or glucose syrups to give more cost effective formulations. Intense sweeteners provide sweetness, the amount supplied i.e. the relative sweetness of all intense sweeteners will depend on application. The values quoted in this chapter are only a guide and demonstrate the wide range of values obtainable under different conditions. Intense sweeteners do not supply the mouth feel of sugar and, in some cases, they may supply undesirable side tastes or prove to be incompatible with some flavours. For these reasons, use of intense sweeteners in soft drinks is rarely a case of direct substitution of sucrose in the regular product formulation: more often than not, total reformulation is necessary. It may be necessary to adjust the acidity and use buffers to assist stability of some sweeteners. Some adjustment of the flavour system used is commonly required and the use of gums or small amounts of sugars can improve mouth feel and control foaming during filling. Use of ingredients that mask undesirable side tastes may also be required. Increasing the carbonation of low calorie products may also help mask undesirable side tastes and give the illusion of better mouth feel. Sweetness synergy occurs with many combinations of intense and bulk sweeteners. The effects can be twofold: a higher perceived sweetness than would be expected from the theoretical sum of the relative sweetness values of the individual sweeteners used and, in some cases, a marked improvement in taste quality of sweeteners that have undesirable side tastes. The optimum sweetener system will vary depending on the product and will not necessarily be a sweetener blend. However, if a sweetener blend is to be used, a useful starting point often quoted for blends of two intense sweeteners is that sweeteners are used in an inverse ratio to their relative sweetness (to each other), so that each sweetener contributes 50% of the total sweetness. For example, if sweetener A is half as sweet as sweetener B, the sweetener blend would contain twice the amount of sweetener A than sweetener B. Optimum sweetener blends for three or more sweeteners are not predictable and should be determined by sensory evaluation. Several intense sweeteners are now approved for use in soft drinks. Four compounds acesulfame K, aspartame, cyclamate and saccharin have major importance in the soft drinks market. This chapter will give a brief review of these, together with three other compounds (stevioside, thaumatin and neohesperidin dihydrochalcone) that have limited world wide approval for use in soft drinks and two other new intense sweeteners alitame and sucralose currently seeking approval.

Current sweeteners
1. Acesulfame K
Acesulfame K is the generic name for the potassium salt of 6 methyl 1,2,3 oxathiazine 4(3H) one 2,2,dioxide it is a derivative of acetoacetic acid and was discovered by the German company Hoechst AG in 1967. Acesulfame K is a white, non hygroscopic crystalline substance at room temperature solubility is good (270 g/l) in water, poor in organic solvents, but increases in solvent water mixtures.
Application in soft drinks, (a) Sensory: As with all intense sweeteners, sweetness potency of acesulfame K. relative to sucrose decreases with increasing concentration and varies with the medium in which the sweetener is being tested and the method used for quantifying sweetness. Values for acesulfame K vary from 110 to 200 at 10% and 3% sucrose equivalence, respectively. The taste profile of acesulfame K is generally considered to be superior to saccharin. It has a rapid onset time but the sweetness quality is marred by a bitter astringent aftertaste that is particularly noticeable at higher concentrations. Sweetness quality can be greatly improved by combining with other intense and bulk sweeteners. High levels of synergism (30% and above) reportedly occur with aspartame and, to a lesser extent, with cyclamate, glucose, fructose and sucrose. Very little synergy is reported to occur with saccharin, possibly because they compete for the same sweet receptor site. The aftertaste of acesulfame K can be masked in some cases by the addition of sugar alcohols, maltol and ethyl maltol.

In soft drinks as a sole sweetener, levels of 600 800 and 550 750 mg/1 for cola and citrus flavoured drinks, respectively, are appropriate. Blending with other sweeteners, in particular aspartame, gives a much more acceptable product. In 50:50 combinations with aspartame, taking into account synergy, levels of 160 170 and 140 150mg/1, respectively, for cola and citrus flavoured beverages would be appropriate.

(b) Stability: Stability of acesulfame K is very good and concentrated stock solutions can be stored and used. In solution, no detectable decomposition occurs at pH 3 at room temperature. Very limited decomposition occurs below pH 3 over extended storage periods. Heat stability is also good. No detectable decomposition occurs during pasteurisation or UHT treatments. In general, acesulfame K appears to be non reactive with other soft drinks ingredients. However, inclusion of acesulfame K adds potassium ions to the beverage and this should be taken into account when selecting clouding agents and stabilisers.

(c) Analysis: Qualitative analysis may be performed using thin layer chromatography. HPLC is the main method available for quantitative analysis owing to the low volatility of acesulfame K, detection being in the UV range. Methods using isotachophoretic techniques can be used to determine acesulfame K, saccharin and cyclamate simultaneously.

Metabolism. Acesulfame K is not metabolised and is excreted unchanged from the body primarily in the urine. It, therefore, has a caloric value of zero. Very few micro organisms have been found to metabolise acesulfame K, indicating that it is also non cariogenic.

Regulation. A large number of toxicological studies were submitted to the regulatory authorities in order to gain approval for acesulfame K. The toxicity of acetoacetamide (the decomposition product of acesulfame K formed under certain conditions) was also studied and they indicated that both products were non toxic. The ADI (Acceptable Daily Intake) assigned by JECFA (Joint FAO/WHO Expert Committee on Food Additives) and the FDA (Food & Drug Administration) are 0.9 and 0.15 mg/kg body weight, respectively. The UK was the first country to approve use of acesulfame K in food and drink with Group A classification in 1983. The FDA gave approval for use in dry mix beverages in 1988. It is approved for use in soft drinks in over 15 countries, with several petitions pending.

Marketing. Acesulfame K is marketed under the brand name Sunett. Legislative constraints, limited production capacity and competition from aspartate, which has better taste qualities, have hindered the development of acesulfame K in the soft drinks market. With capacity problems now overcome and more approvals in different world markets, use of acesulfame K should increase, particularly in areas where aspartate cannot be used. Combination with other sweeteners will take advantage of the improved taste quality and apparent synergism and also assist in keeping within the ADI.

2. Aspartate
Aspartame is the generic name for N alpha aspartyl L phenylalanine methyl ester. It was discovered as a potential high intensity sweetener in 1965 by J. Schlatter in the G.D. Searle laboratories.
Aspartame is a white crystalline powder. Solubility in water is 1.0 g/l at 20 °C and this is adequate for most food applications. Solubility increases in acid conditions and with increasing temperatures allowing stock solutions to be made up however, these solutions should be freshly prepared each day. Aspartame is sparingly soluble in solvents and insoluble in oil.

Application in soft drinks (a) Sensory: Of all the intense sweeteners currently available for use, aspartame has a very similar taste profile to sucrose and this has been the overriding factor contributing to its success in the market place. Relative sweetness values quoted at 4.5% sucrose equivalence in water are in the range 120–215. A relative sweetness value of 180 at 10% sucrose equivalence is often used in soft drink formulations. Taste quality of aspartame is a clean sweet taste without the bitter metallic or licorice aftertaste often associated with intense sweeteners some individuals do, however, notice a slight lingering of the sweet taste. It is synergistic with several other intense sweeteners including saccharin, cyclamates, stevioside, acesulfame K1 and sugars. Flavour enhancement, particularly with fruit flavours, occurs most notably with natural flavours. As the sole sweetener, use levels of approximately 500–600 and 400–600 mg/l are appropriate for cola and lemonade beverages, respectively.

(b) Stability: As would be expected from a compound essentially made up of two amino acids, aspartame undergoes degradation in solution. Hydrolysis of the ester bond gives the dipeptide aspartyl L phenylalanine with the elimination of methanol. At pH 5 and above, the main degradation product is formed by cyclisation to the diketopiperazine (DKP) with the elimination of methanol. DKP may then hydrolyse to the dipeptide which may in turn, hydrolyse to its constituent amino acids, aspartic acid and phenylalanine. The critical factors that dictate the rate of aspartame degradation in soft drinks are pH, temperature, moisture and time. Fortunately, for the soft drinks manufacturer, the optimum pH range for aspartame stability is pH 3 to 5 with maximum stability at pH 4.3.

The effect of UHT aseptic processes on soft drinks containing aspartame is minimal. Typical aspartame losses would be in the range 0.5–5% for most standard treatments. Therefore, the effect of temperature on stability of aspartame in soft drinks is likely to be a function of storage and distribution temperature. Stability of aspartame in concentrates and post mix/fountain syrups is generally lower than in the corresponding ready to drink product due to the lower pH of concentrates. There is no direct relationship between the acceptability of an aspartame sweetened product, its perceived sweetness and the actual loss of aspartame. As the concentration of aspartame decreases, the relative sweetness increases, thereby partially compensating for the degradation of the sweetener. Sensory evaluation has indicated up to 40% loss of aspartame before the soft drink is judged unacceptable. In dry form, when stored correctly, aspartame is stable for several years, making it an ideal sweetener for powdered soft drinks. The improved stability of aspartame has been the subject of several patents most of which involve co-drying with various acidulants and or bulking agents or encapsulation, and are not applicable to liquid systems. However, combinations of aspartame with caramel have been reported to give improved stability and are the subject of one patent application.

(c) Analysis: Qualitative and quantitative spectrophotometric analyses can be performed by traditional amino acid detection methods based on the reaction with ninhydrin. Quantitative analysis may also be effected by HPLC. Some chromatographic methods allow for the simultaneous analysis of other soft drinks constituents. A non chromatographic method based on a non aqueous perchloric acid titration may also be used.

Metabolism. Unlike many other intense sweeteners, aspartame is metabolised by the body. It is hydrolysed into the two constituent amino acids and methanol in the gut. These breakdown products are metabolised...
in the same way as aspartic acid, phenylalanine and methanol from other foods. The aspartame molecule
adds nothing new to the food chain.
People with the rare human genetic disease Phenylketonuria have a deficiency in their ability to metabolise
phenylalanine and their intake of this essential amino acid must be very strictly controlled from birth to
adulthood. Therefore, they must include the phenylalanine content of aspartame in their dietary
calculations.
Aspartame is non cariogenic and has a calorific value of approximately 4 cal/g.
Regulation. The PDA issued approval for the limited use of aspartame in foods and beverages on 24 July
1974. G.D. Searle voluntarily withdrew it from the market shortly afterwards when questions were raised
about the validity of some of the toxicological data used to establish its safety. A stay of effective ness of
the aspartame regulation was published in the Federal Register of December 1975.
Further toxicological studies and re evaluation of the original toxicology data satisfied the PDA that
aspartame was a completely safe food ingredient, and in 1981 it gave approval for use in limited food
applications. JECFA gave aspartame a comparatively high ADI of 40 mg/kg body weights. The FDA ADI is
50 mg/kg body weights.

Carbohydrate sugars

Introduction
Carbohydrate sugars considered in this chapter are those based on sucrose derived from sugar beet and
sugar cane and those derived from starch, e.g. glucose syrups in their various forms.

History
It would appear that the association between sugars and carbonated soft drinks first occurred in the
seventeenth century when lemon juices containing naturally present sugars were added to spring waters.
Sugar was also used during the travels of Captain Cook as an addition to lemon juice in order to preserve
the juice for long periods. From these origins, the use of sugar to improve preservation and to improve the
taste acceptability has rapidly increased. In the UK the soft drinks trade sector is the largest market for
carbohydrate sugars, representing in 1986 87 approximately 21% of the total market. The amount of
carbohydrate sugars used in 1986 was approximately 210000 tonnes, the majority of which was in the form
of sucrose based products. Future usage of carbohydrate sugars is expected to increase to approximately
292000 tonnes in 1995, even though the percentage share of low calorie carbonated soft drinks, which are
entirely artificially sweetened, is expected to reach approximately 18% by the same year. Because of the
present European quota arrangements for sucrose and high fructose glucose syrup, the relative percentage
share of these products as used in UK produced carbonated soft drinks is not expected to alter
dramatically. By comparison, a dramatic swing to the use of high fructose glucose syrup has occurred in the
United States and certain South American countries for reasons of pricing.

Carbohydrate sugars
Carbohydrate sugars used in carbonated soft drinks can be divided into those in a dry, granular form (e.g.
granulated sugar (sucrose)) and those in a liquid or syrup form (e.g. liquid sugar which is a solution of
sucrose in water— and glucose type syrup produced from maize) or, in certain circumstances, wheat (e.g.
glucose syrup or high fructose glucose syrup).
In the UK, a type of granulated sugar is available (mineral water sugar) which, by virtue of its name, could
be viewed as the sugar used for production of mineral waters or soft drinks. Although this sugar type is
eminently suitable for the preparation of carbonated beverages, its name and indicated use are historical
and relate to past times when the quality of standard granulated was deemed unsatisfactory. Nowadays,
standard granulated from both beet and cane is of a substantially higher quality and therefore adequate for
the production of carbonated beverages. Mineral water sugar, which has undergone additional purification stages to reduce the already minute levels of impurities present, is now used for specific pharmaceutical and crystallization processes.

1. Granulated sugar
Granulated sugar is a dry, crystallized disaccharide extracted from sugar beet and sugar cane called sucrose: commercially, however, it is referred to by numerous names—standard granulated sugar, dry sugar or granulated sugar. In Europe and the USA, the quality of granulated sugar is independent of source, being an extremely high purity organic product. However, in some less developed countries the quality of sugar is such that further purification is undertaken by the end user. This normally takes the form of filtration and carbon treatment of a prepared aqueous solution.

Packaging. Granulated sugar is supplied in various weight packages, including sacks (25 and 50kg), 1 tonne flexible containers and bulk tankers. The choice of supply depends on the availability and distribution systems in operation in the country concerned.

When a total choice exists, bulk tanker deliveries are most widely received owing to their advantages over sacked products. These advantages are related to convenience of handling, reduced storage space, reduced labour cost and a decrease in sugar contamination and loss, associated with sack opening and emptying. For those locations that require the convenience of bulk deliveries but do not wish to incur the necessary cost of installing bulk tanker reception facilities, 1 tonne flexible containers provide a useful compromise.

Depending on the country, the price of dry sugars, in particular bulk granulated sugar, can be below the price of an equivalent quantity of sugar in commercially available liquid form (i.e. 67% w/w aqueous solution). This price differential can be sufficiently great to be cost effective for soft drinks manufacturers who currently receive liquid sugar to change to dry sugar and dissolve on their own premises.

Manufacture. After extracting the sucrose from either sugar beet or sugar cane, the juices so produced containing both sugars and non-sugars are subjected to a series of purification steps, which remove the non-sugars and progressively concentrate the sucrose solution. These processes involve precipitation and absorption stages coupled with numerous filtration and evaporation systems. The final purification step involves crystallization of the pure sucrose crystals in vacuum pans. The resulting mixture of sugar crystals and syrup, known as masse cuite, is transferred to centrifugal machines where the syrup is spun off and the remaining thin surface film adhering to the sugar crystals is removed by washing with water. The damp sugar crystals are then dried to a moisture content of about 0.02% w/w using a hot air granulator before being cooled and stored in temperature and humidity controlled sugar silos.

The produced granulated sugar is not screened to a particular particle size distribution—the range of crystal sizes is close to the Gaussian or Normal Distribution pattern of spread, and is controlled during the vacuum pan crystallization stage by skilled operators. However, to remove any over large lumps due to agglomeration of sugar crystals, a coarse sieve is normally incorporated in the system conveying sugar to and from the storage silos. In addition, a comprehensive system of magnets is employed to protect the final product from chance contamination.

2. Liquid Sugar
In the UK, commercially available liquid sugar comprises an aqueous solution of sucrose at a saturated concentration of 67% w/w (67 Brix) at 200C.

Type of delivery. Although available in drum form from some manufacturers, the majority of soft drinks manufacturers receive their supplies by specially designed bulk road tankers capable of transporting up to 3000 gallons of liquid sugar.

Normally, liquid sugar is delivered at a temperature within the range 45–60°C when its viscosity is 48.4 and 23.9 Centipoise (cP), respectively. However, it is possible, for soft drinks manufacturers to receive
deliveries that have been cooled to a maximum temperature of 30 °C if higher temperatures would cause problems during their filling operations. Even at this temperature the liquid sugar remains relatively free flowing, having a viscosity of about 114cP (at 30°C).

Manufacture. Certain types of liquid sugar are produced without under-taking a sugar crystallization stage. These “drawn off” syrups from the manufacturing process are, however, of a colour and flavour unsuitable, without further treatment, for most soft drinks manufacturers. Because of the high quality requirement of the soft drinks industry, liquid sugar supplies are normally produced by dissolving high quality granulated sugar in water. This dissolution process is carried out at an elevated temperature to reduce the level of any microflora that may be present. The produced syrup is then normally filtered through a filter aid based system. Carbon filtration and de ionisation, using resin columns, are incorporated by some manufacturers in the liquid sugar production unit if the quality of the granulated sugar is insufficient to produce the necessary standard of liquid product.

Treatment of the liquid sugar with ultraviolet radiation is generally undertaken to minimize further the presence of any microorganisms. This is carried out using an in line system whereby the liquid sugar passes through a number of narrow annuli, which ensures a short path length for the ultraviolet radiation to pass, which is necessary for high absorbing liquids. Temperature adjustment is then carried out, if necessary, by plate heat exchangers before final filtration as the liquid sugar is loaded into despatch tankers.

3. Glucose syrup: high fructose syrup

Glucose syrups and high fructose syrups can be used as a complete, but more usually partial, replacement of sucrose in the majority of carbonated soft drinks. Used in conjunction with sucrose, syrups with appropriate fructose contents enable sweetness levels to be adjusted according to specific market preferences.

Complete sucrose replacement in carbonated soft drinks has occurred in certain non European countries with 55% fructose syrup. However, this is not the case within Europe since high fructose syrup production is governed by the EEC quota system.

Glucose syrups of various types are used exclusively in certain health type soft drinks.

Type of delivery. Glucose syrups, although available in drum containers, are generally supplied in specially designed road tankers. The syrups normally incorporated are: dematerialized 95 DE (dextrose equivalent, see Manufacture below) syrup 63DE syrup high fructose syrup of 42% fructose and various blends of the above, with and without sucrose to produce the required level of sweetness, viscosity and mouth feel. The temperature of delivered glucose syrup depends on the specific type involved. 95 DE is delivered at a minimum temperature of 50 °C because of the possibility of crystallization below that temperature, 63DE at a temperature of 40 45°C and high fructose at 28 30 °C.

It is important to note that 63DE glucose syrup, in particular, will increase its solution colour on storage. Consequently, a dematerialized form is necessary if the product is to be stored for up to three weeks.

Manufacture. Glucose syrups are manufactured by the acid and enzyme hydrolysis of starch, normally of maize or wheat origin. This treatment breaks down the long chain carbo hydrate molecules into a spectrum of simple and higher sugars.

If this conversion is allowed to continue, the end products are dextrose and maltose. However, under controlled conditions syrups of defined composition can be produced. The extent of hydrolysis is defined in terms of dextrose equivalent (DE): this figure represents the total reducing sugar value of the syrup expressed as a percentage of the reducing sugar value of pure dextrose, calculated on a dry basis.

Additional enzyme treatment enables the dextrose content of syrup to be converted to fructose up to 42%, giving the syrup a greater sweetening power. This level can be further increased by chromatographic
enrichment techniques.

Quality

Carbohydrate sugars are used in carbonated soft drinks not only to provide a level of sweetness to balance flavours and acids present but also to provide mouth feel to the product by increasing its viscosity and dissolved solids content. They also provide an easily metabolized source of energy, a fact utilized in the marketing of certain health related soft drinks. The carbohydrate sugars incorporated therefore require to be of a consistently high quality in their physicochemical properties.

1. Trade requirement

Carbohydrate sugars are generally supplied to quality specifications agreed with soft drinks manufacturers and can vary depending on the products into which they are to be incorporated and the particular processing techniques involved at manufacturers premises.

Extraneous matter. The levels of extraneous matter are of particular concern because of (a) their effect on the appearance of the final products and (b) the possibility of loss of carbonation if excessive sites of nucleation are present.

All liquid products supplied (such as liquid sugars and the various types of glucose syrup) can, by virtue of their physical characteristics, be filtered before despatch thus minimizing the above problems. Granulated sugars, although prepared from syrups that have undergone numerous filtration processes, can contain levels of extraneous or water insoluble matter depending on the country of origin. In the UK these levels are extremely low, typically of the order 6 mg/kg sugars, as determined by a membrane filtration method.

Every precaution is taken to minimize the presence of this water insoluble matter, which can consist of filter aid or calcium salts from the manufacturing process. It may therefore be prudent for soft drinks manufacturers to consider the filtration of liquids prepared from granulated sugars using a filtration system of adequate porosity commensurate with realistic filtration rates.

Colour in solution. Especially for those carbonated, soft drinks, which are clear in appearance, carbohydrate sugars of a low solution colour are a prerequisite. In the UK this standard is obtainable, but in other less developed countries further treatment of sugars after receipt is necessary in order to conform to this level. The treatment used is normally that of filtration through plate and frame filters incorporating carbon sheets.

The production specifications of some international soft drinks companies list the use of these carbon filters for all locations in order to cover the world-wide production of soft drinks, with carbohydrate sugars of differing quality parameters. In those countries whose carbohydrate sugar quality can be guaranteed to be of the highest order, the use of these filters may be negotiable.

Acid floc. Floc formation in carbonated soft drinks is a phenomenon observed in acid solutions and normally appears as a white precipitate. This precipitate can take the form of loosely aggregated particles floating within the solution which, in extreme cases, may take on the appearance of well teased out cotton wool or as more dense particles that sink through the solution. On shaking the solution the floc usually disappears as the weak forces between the molecules are disrupted.

Floc has been shown to be associated with sugars (both beet and cane) and also with polysaccharides present in water as a result of the growth of algae and chemicals from water treatment. Sugar floc is normally associated with sugars of low quality and these have caused final product problems in some countries. For this reason, the National Soft Drink Association standards include a method for the evaluation of floc producing substances. This is the Spreckles Qualitative Floc Test Procedure. Since the National Soft Drink Association makes reference to the testing of sugars from beet for floc evaluation, the sugar beet industry in the UK has made extensive efforts over the years to ensure that all
granulated sugars and liquid sugars are free of any substances that could lead to acid floc.
Microbiological. The low moisture content, typically 0.02% w/w, of granulated sugar coupled with its high purity minimizes the possibility of microbiological degradation. In solution, carbohydrate sugars generate high osmotic pressure, which is a major factor in protecting concentrated solutions from microbiological contamination. However, if granulated sugar is allowed to become damp and syrups are diluted, then an increased risk of microbiological degradation occurs. This can happen if there are deficiencies in storage conditions.
In the UK carbohydrate sugar manufacturers target levels for mesophilic bacteria, yeasts and moulds in liquid products are the standards for Bottlers liquid sugars as defined by the National Soft Drink Association. By comparison the target levels for granulated sugar are twice the National Soft Drink Association standards. This difference relates to the fact that, by virtue of their physical form, liquid products can be treated by filtration and ultraviolet radiation to reduce further any microorganisms present. An additional protection operated by some sugar manufacturers is to control the pH of the liquid products to about 8 to reduce even further the chance of spoilage.
In practice, carbohydrate sugar manufacturers undertake regular sanitising programmes of their production and storage systems coupled with comprehensive quality assurance and control, not only to ensure minimal levels of spoilage organisms, but also to ensure freedom from pathogenic bacteria.

2. Quality assurance management
Soft drinks manufacturers in the UK have for some time required guaranteed quality raw materials especially as they introduce Supplier Assurance Systems and Good Manufacturing Practices. Carbohydrate sugar suppliers have responded positively to these requirements by instigating their own quality assurance systems, including certification to British Standard 5750 and the International Standard ISO 9000.
These quality management systems involve documented procedures and instructions, which are self and externally audited, concentrating on all key activities affecting quality of products and service.

3. Sugar analysis
The methods generally used in the analysis of sucrose products are those defined by The International Commission for Uniform Methods of Sugar Analysis, normally referred to as ICUMSA. Many of their methods have been adopted by the European Economic Community and the Codex Alimentarius Commission. The analytical methods used by glucose syrup manufacturers are generally those standardized by the Corn Refiners Association.

Transportation and delivery
The mode of transportation of carbohydrate sugars depends on the type of sugar involved and also on the sophistication of the transport system and reception facilities available in any particular country. Less developed countries normally rely on granulated sugar contained in bags. Ideally this sugar should, for ease of handling, be palletized and transported within covered wagons to reduce contamination of the packaging material, which could eventually contaminate the contained sugar.

1. Bulk delivery of granulated Sugar
Demand by soft drinks manufacturers for bulk deliveries has grown rapidly over the past years since their use offers a number of important advantages over bagged supplies. The advantages relate to: savings in storage space  savings in manpower, both at the reception point and during internal redistribution improved hygiene and the possibility of automated processing to which the system lends itself. Bulk deliveries are made in road tankers, which are specifically designed to maximize efficient discharge of the sugar and, by virtue of the materials used for construction, to minimise product contamination. Additionally they are designed for ease of internal cleaning, which should be carried out at regular intervals.
Grape juice processing

History of grape juice processing in North America

The fruit juice processing industry of the United States is said to have been started by Dr Thomas B. Welch and his son Charles in Vineland, New Jersey in 1868. By applying the theory of Louis Pasteur to the processing of Concord grapes, they were able to produce an unfermented sacramental wine for use in their church. By 1870 this grape product was being produced on a small scale for local church use.

By 1893, grape juice had become a national favourite beverage in the United States as thousands sampled it at the Chicago Worlds Fair. It was during this year that Dr Charles Welch turned his full attention to the marketing of grape juice. In 1897 a new plant location was chosen for processing operations at Westfield, New York. Some 300 metric tons of grapes were processed that year and in 1989 Welchs, now one of the largest producers of processed grape juice in the world, handled some 186000 metric tons of grapes.

Grape cultivars

In the United States, four broad classes of grapes are grown: Vitis lubruscana, hybrids of the northeastern United States native grape Vitis vinifera, European grapes common to California area Vitis rotundifolia, the southern and southeastern Muscadine grapes and French hybrids. Prior to the discovery of the Americas the species, Vitis vinifera, supplied the known worlds grapes. Vinifera grapes are still among the most important in the world but in harsh climates these grapes cannot tolerate severe winters, diseases, and pest problems.

When selections of Vitis lubrusca were crossed with other grapes, new varietals were produced, such as Vitis lubruscana. Ephraim Bull was a horticulturalist who pioneered in this cross breeding and selection process with native American grapes. The Concord grape, a varietal almost synonymous with grape juice in the United States, was a seedling that Bull found in his vineyard. Its parentage is still unknown. Virtually the entire unfermented grape juice industry has developed from this one cultivar.

The average production of Concdorks is approximately 4.5 tons per acre in eastern United States. Yields can reach 7.8 tons in western states. Cultural practices such as irrigation, pruning severity and fertilization can have a very significant influence upon the quality and quantity of grapes harvested.

There are now many hybrids of the native species available for use in the industry. Some of the older cultivars are: Catawba, Delaware and Niagara. The Concord grape, grown throughout the cooler regions of the United States and Canada, is still the principal grape for the industry.

Though not possessing as large a market shares in unfermented grape juice, there are some Vinifera grapes processed into grape juice. They tend to be much higher in sugar and lower in acidity than the Lubruscana grapes, and consequently are not as flavorful.

The genus, Vitis, is generally considered to consist of two sub species, Euvitis and Rotundifolia. All grape species other than muscadines fall into the Euvitis sub genus muscadines alone make up the sub genus, Rotundifolia. For this reasons some botanists do not classify muscadines as grapes. Some basic differences are identifiable such as clustering of the berries and pit configuration however, muscadines are utilized in an identical fashion and treatment as the Euvitis sub genus. Consequently, in matters of commerce and functionality, muscadines are considered grapes.

The chemistry of grape juice

The quality of grape juice can be described almost entirely by its chemistry. Its color is caused by anthocyanins, their glucosides and condensation products, its taste by acids, sugars and phenolics its aroma by a diverse mixture of volatile secondary metabolites in very low concentrations. Since 1967 over 1000 research papers have been abstracted by Chemical Abstract Service describing the chemistry of grapes and grape juice. In these papers thousands of chemicals and their reactions in grapes are
described. However, only a small percent of these chemicals are responsible for the quality attributes that people perceive when they drink grape juice. Table 1 lists the major components of grape juice, their concentrations and inequality attributes they determine. This table shows clearly why it is possible to predict sweetness sourness and acidity in grape juice by measuring certain carbohydrates and organic acids. These compounds are major constituents of grape juice and are measurable by some very simple techniques. For many years the sugar and acid content of grapes have been used to set standards of quality resulting in new horticultural and processing techniques that modify the sugars and acids in grapes in order to optimize juice quality. These developments are the direct result of our knowledge of the chemical causes of quality and the availability of tools to measure them. However, the volatiles that cause aroma are present in such minute quantities that most of them are still unknown and those that are known generally require the most advanced chemical and spectroscopic techniques to quantify them.

Although the methods of chemical analysis that define a quality grape will continue to develop and improve, there is another approach, sensory analysis. This involves the determination of quality attributes using methods from the sciences of behavioural psychology and sensory perception. These methods relate the human perception of quality to food components. Instead of using chemical reactions and physical measurements, sensory analysis uses human subjects as tools to determine quality by measuring their behaviour when they are subjected to the food. A review of sensory methodology as it relates to the optimization of quality attributes is given by Moskowitz.

1. Carbohydrates
Carbohydrates are the most abundant component in grapes. On average, grapes have per 100 g, 6.2 g glucose, 6.7 g fructose, 1.8 g sucrose, 1.9 g maltose and 1.6 g of other various mono and oligosaccharides. Pectic substances, which act as the intercellular cement, are a mixture of numerous long chain carbohydrates and related compounds, which occur in solution and/or colloidal dispersion in grape juice.

2. Acids
Tartaric acid is the predominant acid in grapes and accounts for the tartness of the juice. Tartaric acid is present as the D isomer and malic acid as the L isomer. Other acids present in minor amounts include citric, lactic, succinic, fumaric, pyruvic, a oxoglutaric, glyceric, glycolic, dimethyl succinic, shikimic, quinic, mandelic, cis and trans aconitic, maleic and isocitric acids. The resulting pH of grape juice can range typically from pH 3 to pH 4 depending upon variety, climate and soil conditions.

3. Mineral content
Although differences among varietals in mineral content are not typically noted, differences during maturation have been studied. Mineral anions and cations are taken up at a relatively constant rate and distributed throughout the system resulting in a relatively poor concentration in the berry compared to other parts of the wine. During maturation heavy metals increase by as much as 50%. Phosphate content increases in both the peel and the pulp.

4. Phenolics
The color of Concord grapes is due in large part to the anthocyanin pigments located in and adjacent to the skin. These pigments are extracted by heat and/or fermentation. Seven individual color components have been identified in Concord juice, the major contributor being delphinidin monoglucoside. The phenols typically found in grapes include benzoic acids, cinnamic acids, flavonols, anthocyanidins as well as various flavans, which constitute the tannin precursors.

5. Volatiles
Maarse listed 500 volatile compounds in grapes but most of these compounds occur at levels well below their detection threshold. Only a very few seem to evoke sensation and affect perception. Furthermore, The
odor active molecules have no identifiable chemical features that distinguish them from the more prevalent odorless volatile compounds. The odor active volatiles in Lubruscana grapes come from different metabolic pathways. 2,5 Dimethyl 3 (2H) 4 furanone, a sweet strawberry smelling compound, is produced from carbohydrate metabolism. Ethyl 3 mercapto propanoate, with a foxy smell, methyl anthranilate with its Concord smell and the floral smelling 2 phenylethanol are formed from amino acids, while beta damascenone with a rose like aroma and linalool with the aroma of orange peel oil are derived from terpenoids. The green leaf like smelling (E) 2 hexenol is a lipid oxidation product.

This diversity results in a variety of processing effects on the aroma of grape products. For example, the heat treatments used in color extraction, depectinization, juice concentration and pasteurization cause beta damascenone, vanilin, and/or methyl anthranilate to dominate the aroma of certain cultivars.

Modern grape juice processing

1. Harvesting/ripening

Grape juice consists of a natural aqueous mixture of various carbohydrates, organic acids, anthocyanins and flavor compounds. In the soluble solids of grape juice, the primary sugars are glucose and fructose. In unripe grapes, glucose accounts for as much as 85% of the sugar content. As the grape approaches full ripeness there is generally a slight excess of fructose. Sugars are manufactured in the leaves via photosynthesis and translocated to other organs, particularly the berries, as needed. It is the sugar content of the grapes, which often is the basis for purchase and a primary indicator of optimal harvest time for grape juice production.

A typical level of acidity at time of harvest in Concord grapes is 1.3 g/100 ml as tartaric acid. This acidity generally starts quite high in the grapes and decreases as ripening takes place. Optimum ripeness is often associated with balanced levels of sugars and acids. On occasion, tannins, color and aroma are also considered. Although acidity levels of Concord grapes at harvest are very high, cold temperature storage (32°F) of the grape juice extracted from these high acid grapes will induce a detartration and reduction of total acidity to more acceptable levels. Degrees Brix, a refractive index based measurement of soluble solids, is the primary method used in grading grapes at harvest, which are scheduled for juice production.

Mechanical harvesting has greatly improved the efficiency and speed of bringing grapes from the vineyard to the processor. Mechanically harvested grapes are handled in bulk boxes (47 x 42 x 38 inch) equipped with polyethylene liners. These boxes will hold approximately 1 ton of grapes. Studies have shown that mechanically harvested grapes actually contain fewer stems and trash than hand harvested grapes. This is important due to the detrimental effect of materials other than grapes on the quality of expressed grape juice. These boxes can be expected to have approximately 21 inch of free run juice in them because of mechanical damage, vibration and weight of grapes from depth of load.

The Chisholm Ryder grape harvester is a self propelled system that straddles the rows of vines and is one of the most commonly used harvesting units. This harvester bats off the grapes and grape clusters with metal or rubber like strips as it moves down the length of the row. The grapes fall onto a series of collector leaves located on either side of the unit underneath the vine being harvested. These rotating leaves then transfer the grapes to conveyers, which carry them to the top of the harvester unit and dump them into a transfer chute for filling of a bulk bin separately transported by truck.

Bulk bins of grapes are transported to a grading station where core samples are taken from each bin and combined to form a load sample. This is used to measure the soluble solids (Brix) upon which payment for the load will be based. Grapes are typically processed within 4 6 h of picking.

Most grape juice processed in the United States is made from Concord grapes. A significant volume of literature can be found concerning grape juice processing and some reviews of the technology are also available. A typical process outline is described below and shown in Figure 2.
2. Stemmer/Crusher Operation
Grapes at the plant are first conveyed to a stemmer/crusher, which removes residual stems, leaves and petioles from fruit. This unit is designed around a rotating perforated drum. The perforations are approximately 1 inch in diameter and generally cover the entire drum. In the process of traversing the rotating drum, grapes are caught by the perforated drum and knocked from the stems. The individual grapes are broken open or crushed in the process and drop through the drum. Stems and leaves, etc. continue on in the center of the drum and are discharged at the end for waste.

3. Hot break process
Once the stemmed/crushed grapes are separated from the vines they pass through a large bore tubular heat exchanger where they are heated to 140ºF. This is known as the hot break process and it is primarily designed to extract a large amount of color and assist in maximizing the yield of juice. To the hot grapes is added a pectolytic enzyme and in the case of the typical process shown here, Kraft (wood pulp) paper (actually spent filter media from the rotary vacuum juice filter) is added to serve as a press aid. The addition of press aid to the mash provides firmness and exit channels for the juice. Sterilized rice hulls, bleached Kraft fiber sheets or rolled stock and ground wood pulp are common press aids used commercially. Ideally, a rotary filter press aid should have relatively long fibers and it should be able to be separated with a minimum breakage of those fibers for maximum effectiveness.
Soluble pectin is found in the juice and is a result of pectolytic enzymes which are primarily located in the cell wall of the grape. This soluble pectin causes difficulties in pressing due to the lubrication it affords the press cake and the consequential reduction in screw press effectiveness. Typically, 50-100 ppm of a pectinase enzyme is sufficient for the depectinization process at this stage. Depectinization is designed to reduce the slippiness of the pulp and thus permits the effective use of a screw press when combined with wood pulp bulking agent. Enzyme treatment is allowed to continue for about 30min prior to pressing. Several depectinizing tanks are employed so that a continuous flow may be maintained to the presses.

4. De juicing/pressing operation
The mash is generally hot pressed in order to maximize yields and color extraction. Hot pressed juice is higher in total solids, tannins, anthocyanins and other matter. Control of the combined hot break/hot press procedures is important because the extraction of astringent materials (i.e. tannins) will increase with time and temperature of these two unit operations. Phenolic compounds contribute to both the color and the astringency of grape juice. The extraction of both the phenols and the anthocyanins is greatly affected by the degree of heating used in the hot break process. In general, the longer and hotter this process, the more significant the extraction process.
The dejuicing or pressing operation can utilize a number of different equipment variations. These include screw, hydraulic, belt and pneumatic presses. Selection of the equipment can depend on production capacity, juice yield, desired level of automation, availability of manpower, operating cost and required capital investment.
The hydraulic rack and frame press was the mainstay of the grape juice pressing operations for many years. Heavy cotton or nylon cloths were filled with a set amount of mash and then folded to produce what is called a cheese. The individual cheeses were stacked and separated by a wooden or plastic lattice work. The combined stack was then compressed using a hydraulic ram during which the juice was expressed. The Bucher Guyer Press is a highly automated pressing system used in a batch pressing operation. Generally this system requires no press aid. The system consists of a rotatable cylinder with a hydraulic ram used for juice expression. Within the cylinder are fabric covered flexible rubber rods. The rods have longitudinal grooves, which allow the juice to transport easily to the discharge port. The wilmes press is a commonly used system for grape juice pressing. It is a pneumatic based system consisting of a performed, rotatable horizontal cylinder with an inflatable rubber tube in the center. The
cylinder is filled with grape mash through a door in the cylinder wall, which is rotated to the top position. After filling, the press is rotated to ensure even filling. During this rotation the air bag is filled, creating the mash compression action. The bag is then collapsed and the cylinder is rotated. The rotation and pneumatic compression of the mash is repeated many times with increasing air pressure.

The depectinized mash produced in the hot break process can be passed over dejuicing screens where 50-60% free run juice is removed. With this low technology step, the mash to be pressed is reduced by approximately half. The dejuiced pulp is then pressed in (horizontal or vertical) screw presses. The typical screw press consists of a reinforced stainless steel cylindrical screen enclosing a large bore screw with narrow clearance between the screw and the screen. Breaker bars are typically located between the screw intervals in order to disrupt the compressing mash. Backpressure is provided at the end of the chamber and is usually adjustable. Typical capacities for screw presses with a 12 inch and 6 inch diameter are 5 and 15 tons/h, respectively.

The Serpentine belt press, the Ensink and other belt presses are effective for grape juice processing. In belt presses, a layer of mash is pumped onto the belt entering the machine. Added press aid is usually required for improved yield and reduced suspended solids. The belt is either folded over or another belt is layered on top of the one carrying the mash. A series of pressurized rolls compress the enveloped mash. Expressed juice is caught in drip pans. The cake is discharged after the last pressure roller.

The waste pomace from any of these systems may be repressed for improved yields of an additional 3-5 gallons of juice per ton leading to a total juice yield of 200-205 gallons per ton. Extraction of the pomace using hot water, in a plant equipped with concentration equipment, can recover additional soluble solids in the juice. This secondary extraction, when handled with care, will produce a low soluble solids liquor which will have no odor or taste defects. This low flavour impact, low soluble solid extract can be recombined (in natural proportions) with single strength juice intended for concentration.

All pressing operations must be able to deal with free run juice and in some cases handle it with special care to give the highest possible product quality. In comparing the different press types, the screw press is probably most popular, however, this is highly dependent on required yields, available capital at purchase and smoothness of integration into current operations.

5. Coarse filtration
The pressed juice is merged with free run juice and accumulated in slurry tanks where the press aid, usually paper or wood fiber is added at the rate of about 15 lb/ton of grapes. The paper, which typically comes in 1 lb sheets, requires very heavy agitation to break it up and disperse it throughout the juice. Alternatively this paper may be shredded first. Having been dispersed, this paper serves as filter media for the rotary vacuum belt filtration that follows.

Prior to filtration, the insoluble solids (ISS) content of Concord juice pressed with paper (measured volumetrically by centrifugation) can reach 10-12%. Without paper, pressing is extremely difficult and produces juice containing up to 30% ISS. After filtration through the belt and paper, insoluble solids will be 1% or lower. The spent paper discharging from the belt is then re slurried into the fresh hot grapes entering the system just prior to the treatment tanks, thus the paper serves the dual function of filter media and press aid.

The importance of achieving low ISS cannot be overemphasized for two reasons: (i) high efficiency heat exchangers used for pasteurization have very small clearances between plates and tend to plug over a period of time with high levels of insolubles (ii) any insolubles remaining will ultimately settle to the bottom of the storage tanks. The actual volume of bottoms is dependent primarily on the level of insolubles in the initial juice and the filtration of bottoms juice containing high levels of insolubles is difficult and costly.

6. Bulk storage and tartrate precipitation
A common practice is the storage of single strength grape juice in bulk storage tanks. The tanks
themselves are pre cleaned and then filled with clean municipal ice water for periods of 1-4 weeks prior to use. This water is then used for cooling processed juice during the periods of highest process demand thereby dramatically reducing the immediate refrigeration needs. Air inlets at the tops of these tanks are generally fitted with absolute sterile air filters in order to ensure no airborne contamination.

In the actual process, filtered juice is pasteurized at 185-190°F for a minimum of 1 min. The heat exchanger system utilized in this step, cycles through a cleaning every 24 h. Hot caustic, followed by 200 ppm chlorine solution, followed by 185°F hot water rinse is the usual sanitizing method. By proper flow design this cleaning approach can be used for not only the heat exchangers but also for all the feed lines to the storage tanks. Once the juice is properly pasteurized it is immediately cooled using a regenerative heat exchanger, to 30-32°F prior to storing in refrigerated tanks.

The entire system is treated much like an aseptic process. Special care is taken to avoid any dead ends or other such areas for contamination buildup. Use of heat exchangers for the cooling process is required in order to deliver juice at proper temperature to the storage tanks. Failure to reach storage temperature prior to delivery of juice to the tank will cause the tank to remain above proper storage temperature excessively long.

These tanks, which typically are either stainless steel or Food Grade epoxy lined cold rolled steel, are not truly aseptic but nevertheless are carefully sterilized prior to introduction of any new juice. Design of the tanks allows for complete filling up to a top manhole. The manhole top is usually equipped with an ultraviolet lamp to preclude the growth of mold. Tank capacity varies typically in a range of 150,000-320,000 US gallons but can range over 700,000 gallons. Juice processed in this manner and held at 28-30°F is very stable and has been held for over 1 year without any evidence of fermentation. Obviously, stringent sanitation requirements are necessary.

### Processing of citrus juices

#### Introduction

The citrus growing areas in the United States are located in the States of Florida, California, Texas and Arizona. The largest crop is harvested in Florida where over 90% of the oranges and approximately 55% of grapefruit are processed into juice products. Brazil's crop is larger than Florida's, where even larger percentages of oranges are processed for juice. Other citrus growing areas in the Western Hemisphere include Mexico, Central America, Puerto Rico, Jamaica, Dominican Republic and countries on the northern part of South America. The machinery used for the processing of citrus juices in these countries and in other regions, such as Spain, Italy, Israel and around the Mediterranean is quite similar.

Most of this chapter deals with the processing of oranges in the State of Florida, USA, with which the author is most familiar. The handling of grapefruit, tangerines, lemons, limes, etc., is quite identical in most ways to that of oranges, though some of these citrus varieties require additional process equipment for certain byproducts.

The basic unit in Florida for describing the size of the orange crop is the fruit box. A box of oranges, by definition, weighs 90 lb and a box of grapefruit weighs 85 lb. The harvesting season crosses over the New Year and has a duration of 7-10 months, depending on varieties. 123 100 000 boxes of oranges (61 550 US tons) were harvested during the 1986-1987 season of which 92% went to processing, the balance going to the fresh fruit market. In the same season, 49 800 000 boxes (2116 500 tons) of grapefruit were harvested with 56% of the crop processed for juice. Of the approximately 113 million boxes of oranges processed in the 1986-1987 season, the juice from 96 million boxes was concentrated to make frozen concentrated orange juice (FCOJ).

By products resulting from the processing of citrus fruit include dried peel for livestock feed, molasses
concentrated from liquid pressed from the peel, commercial d limonene, which is distilled peel oil, and cold pressed oil, the processes of which are discussed later in this chapter. The production of livestock feed from the processing of all varieties of citrus in Florida for the 1986 1987 season was 600 626 tons of dried peel and 27 811 tons of molasses. d Limonene production was 13 483 000 lb.

Fruit harvesting and transport
The harvesting of citrus fruits in Florida begins when the fruit reaches maturity standards set by the United States Department of Agriculture (USDA) and the Florida Department of Citrus. For juices, these regulations have to do with Brix acid ratio color, oil content, etc. and in general are set to ensure quality products.

The picking of fruit for the orange juice market begins in September with most of the juice going to the single strength market. There are four main varieties of oranges growing in Florida for the juice (and fresh fruit) market. The earliest oranges consist of Hamlin and Parson Brown varieties. These early fruits are harvested mostly from October to December. Mid season fruit (called Pineapple oranges) mature during the first 3 months of the year. Late season fruit (Valencia oranges) are harvested from March to June.

The production of FCOJ usually begins early in December when the soluble solid (sugars) content is around 12% (12°Brix). With evaporators operating at full capacity, concentrate production drops by 5% if infeed Brix is 11.5° instead of 12°.

Hand picked and mechanically harvested fruit are brought from the groves to the roadside and loaded into trucks (tractor trailer type), which hold 500 550 boxes of fruit. The trailers are then trucked to the processing plant.

Unloading and storage of fruit
These operations are shown diagrammatically in Figure 1. The trailers are approximately 8 ft wide x 40 ft long. Trailer sides extend approximately 5 ft above the bed of the trailer. After weighing, the trucks are hauled to the unloading ramps where they are inclined and unloaded through a gate at the rear of the trailer. There are various types of unloading ramps used, the most historic of which is a fixed back over or fixed back down ramp. As the crop size grew and processing plants became larger, a need for quicker unloading became necessary and the trend now is to convert to hydraulic ramps for lifting and tilting the trailers. Of these, there are two types, the back into and the drive through arrangement.

The older fixed back into ramps are concrete slabs with a 10° slope from horizontal. Because of the fixed slope of the incline and associated clumsy traffic patterns, a good average unloading rate for one ramp is about three loads per hour. This would allow an infeed fruit flow of 1500 boxes h or 65 70 tons raw oranges per hour. Other disadvantages include the varying height of different trailer beds above the road, which sometimes requires manual fixing of fill in ramps or wheel elevating shims before the back gate of the trailer can be opened.

The drive through type hydraulic ramp allows for the most favorable traffic patterns, adjustable tilting to accelerate the rolling of fruit near the end of the unloading cycle, and an adjustable hydraulic back stop and fill in ramp which can be completely lowered to facilitate driving through. Unloading ramps of this design can handle up to six trailers per hour (3000 boxes of oranges per hour).

One of the problems facing the unloading staff is the accumulation and disposal of leaves, stems, dirt and even small branches that arrive with the load. The amount of trash has increased over the years as plants grew and as the percentage of mechanically harvested fruit increased. In the path of flow from the trailers to the storage bins, the fruit may travel over a gravity bar grate, roller spreaders, belt conveyors, chutes, elevator, etc., and in each of these transitions, leaves and stems must be contended with. Bar grates and roller spreaders will drop some of the small, loose pieces through their open spaces to a collection pit, which needs periodic sweeping and shoveling. Conveyor transfer gates and elevator chutes sometimes
become clogged. The clean up and manual disposal of this trash requires considerable man hours throughout the production day. Many attempts have been made to reduce the labor required for this clean up by mechanically conveying the trash from under bar grates and roller spreaders. Screw conveyors are not completely suitable for elevating the trash out of the pit as the longer stems will wind their way around the shaft, accumulate other pieces and stop the flow.

The latest solution to the trash problem is the installation of machinery similar to that used in the corn industry for husking corn. These units consist of feeder and distribution belts, which put the fruit in single file through a belt and roller arrangement that not only drops out the loose trash but will pull off stems that are attached to the fruit. The use of this type of equipment requires 10 12 ft headroom to complete all the gravity transfers of fruit and trash through it to other conveyances.

Layout of this type of equipment depends on availability of plant space. Florida surface water tables are not too far below ground level so deep pits are not always feasible and careful attention needs to be paid to the type of conveyors, elevators and transfer points. Dirt and small pieces of trash will pass through transfer points, especially under the fruit wipe off on belt conveyors and on the bottom of bucket type elevators, so there still needs to be access under these conveyors for periodic clean up.

On its path to the storage bin the fruit passes through a sampler, a device which takes an on line sample of the incoming fruit. The sampler is usually located after the fruit is elevated, and the fruit drops through chutes to the State Test Room. An approximate 40 lb sample of raw fruit is run through a state test room extractor and tested for yield, soluble solids content, Brix and acidity.

Next in the path of fruit flow is a grading station, where unsuitable fruit is culled out and attached stems that have passed through the trash removal equipment are removed. The grading stations consist of roller spreaders with grading personnel picking out the culls and dropping them through a chute to a conveyor (usually a screw conveyor) that transfers them to the cattle feed production part of the citrus plant, referred to as the Feed Mill.

An unloading station that can handle six loads per hour requires a grading station capable of removing culls (unsatisfactory fruit) from fruit that passes at a rate of fifty 90 lb boxes of oranges per minute. One box of oranges lying single height requires approximately 13 ft² of area on a conveyor belt and grading table. A grading table consists of a roller type conveyance that spreads the fruit across the table and conveys them forward at about 60 ft/min. The widest tables are 52 inch across the rollers with grading personnel on each side. Grading personnel are spaced about 48 inch apart with drop chutes between them. A single 52 inch wide grading table x 10 ft long with six people will ideally handle 20 boxes of oranges per minute. However, since the fruit will be graded again on its path to extraction, the unloading grading tables are pushed harder, allowing for two tables per unloading ramp, each handling approximately 25 boxes per minute. After grading, the fruit travels through belt conveyors and elevators to the fruit holding bins.

The holding bins are constructed with steel columns, beams and braces with either wood slats for siding or flat mesh expanded metal. They are usually constructed in parallel rows with each bin having a capacity to hold one truck load. Each bin has approximate dimensions of 10 x 10 x 25 ft high and the succeeding bins have common walls. The two rows of bins are fed with a bell conveyor equipped with manually set wipe offs and gates for feeding the individual sections. The fruit enters the bins through inclined ramps that more or less cause the fruit to roll down in a spiral motion so that dropping and bruising is minimized. The inclined ramps are located so that the total weight of the load is distributed throughout the height of the bin to prevent squashing of the fruit at the bottom.

Fruit transfer from storage bins to extractors

The introduction of fruit into the processing plant begins with the bin operator opening gates at the bottom of the bins where fruit rolls onto a conveyor belt in the center of the bin rows. The rate of flow out of the bins
is manually controlled by the bin gate opening and by an adjustable vertical gate at the end of the bin take out conveyor. The processing buildings are located at some distance from the fruit bins in order to be away from the flies and other insects that tend to inhabit the bin area. Belt conveyors and bucket elevators bring the fruit to a height suitable for gravity flow through washing, grading, sizing and extractor feed. The elevated fruit usually drops into a fruit surge bin located just outside the extractor room with a volume capable of holding 5-10 min of fruit. The surge bin is equipped with level switches which send signals to the fruit bin operator and extractor operator, for purposes of regulating flow. The surge bin take out conveyor has a variable speed drive that is controlled by the extractor operator so that fruit flow rate coincides with juice demand.

From the surge bin, the fruit is discharged onto a roller spreader and from there it enters a brush washer. The washer consists of a series of rotating cylindrical brushes turning in the direction of the fruit flow. Detergent is added at the fruit inlet end and water is sprayed over the spinning fruit. Most Florida citrus processors use evaporator condensate (the water removed from the juice in the concentrate process) for washing fruit.

Just downstream from the washer are located further grading tables where unsuitable fruit is graded out by personnel on each side. The culls are dropped through chutes and conveyed to the feed mill. After grading, the fruit travels through another roller type device similar in design to the grading tables but used to spread the fruit into a pattern feeding the total width of the fruit sizer. The sizer consists of several narrow belts running in parallel and tilted so that the fruit travels in single file along the low edge of the belt and against a rotating roller that can be adjusted up and down. Juice extractors require larger and smaller cups for different size ranges and the actual construction of the sizer depends on type and number of juice extractors. Each roller bay of the sizer is adjusted to suit the size variations of the incoming fruit. Extractors have constant speeds and only meet maximum capacity when their feed chutes are kept full. The extractor room people must make periodic checks and adjustments of sizer roller spacing, gates and lane dividers to ensure that the extractor room is not the bottle neck of the process.

The sized fruit drops through chutes to a distribution belt that feeds the extractors. This belt conveyor travels the full length of a row of extractors plus a few more feet to accommodate the drive and drop for overflow fruit. The top belt is tilted toward the extractors and separated into lanes for conveying the larger fruit past the smaller cupped extractors as the sizer above is not as long as the total row of extractors. The distribution belt is equipped with gates and wipe offs that can be set to maximize the extraction efficiency. The return side of the distribution belt is usually a few feet lower than the top or feed side of the belt. Along the feed flow between extractors that change cup size, is a wipe off and an overflow chute that drops fruit to the return side of the distribution belt. The overflow fruit travels back towards the front end of the system, is wiped off, conveyed and elevated back to the fruit surge bin. Fruit sizing must be set to ensure that the fruit surge bin does not accumulate too many of one size, which would limit the capacity of the extraction operation.

Juice extraction and finishing

1. Extractors

There are two types of extractors in common use in the Citrus Processing industry, both originating in the United States. One type is manufactured by FMC and the other by Brown Citrus Machinery. Extractors are leased on a royalty basis and the equipment is owned and serviced by the extractor manufacturer. In Florida there is about an even split between the two types and the advantages one has over the other are best extolled by the respective suppliers. Both types produce a juice yield and quality sufficient to meet high technical standards and profitability.

Extractors are lined up along the length of the distribution belt on a platform 8-10 ft above the room floor.
The maximum number of machines per row is ten (maximum of eight preferred) on the FMC extractors and eight on the Brown. Additional in line extractors would require wider and more unwieldy conveyor belts. The FMC extractor is equipped with a feeder that runs fruit into the extractor cups in five rows on the five head machine. Eight head machines are used for small fruit such as lemons, limes and tangerines and three head machines are used for larger oranges and grapefruit. A five head FMC extractor, operating at 100rev./min with 90% of the cups full, will handle 450 fruit/min. During the Florida Valencia orange picking season (March to May) most of the fruit will be of a size range that averages 250 fruit per 90 lb box with a yield of 6 gallons of 12º Brix juice when finished. This is 10.8 US gallons/min per extractor. However, not all the cups will always be 100% filled (or even 90% filled), especially the larger cup machines on the end of the line.

Fruit is deposited by the feeder into the bottom cup of the FMC extractor. The upper half of the cup descends and presses down on the fruit, and as contact is made, the sharp end of a round stainless steel tube, located inside the bottom cup, is inserted in the bottom of the orange, cutting a plug. As the fingers of the top and bottom cup halves mesh, the fruit is pressed inward forcing the juice into the tube which is perforated with small holes in the cylindrical section and has a restriction in the bottom to prevent loss of juice. The resulting internal pressure forces the juice and some pulp through the perforations in the tube wall and strains out the seeds and larger pieces of pulp. Through precise timing and as the upper half of the cup is in the pressing position, the strainer tube containing the restriction, plug, pulp and seeds, rises to further press the contents of the tube and to eject the pressed plug.

As the two halves of the FMC cups come together, the oil cells in the skin of the fruit are ruptured, forcing the oil out of the skin where water sprays can be mounted which wash the oil and small pieces of skin (crumb) down the outside of the cups and via a screw conveyor to a cold pressed oil recovery system. The extracted juice drops into a juice manifold connected to the line of extractors, which is sloped in the direction of flow toward the final finishing. Ejected peel drops through chutes to a screw conveyor located under the extractors, which conveys the peel to the Feed Mill.

The extractors manufactured by Brown Citrus Machinery use a reaming action to extract juice from citrus fruit, except for the model 1100 machine which is described later. Of the reaming type, there are three models, the most used of which are models 700 and 400. Of these two types, the model 700 machines have the highest speed and will handle up to 700 fruit/min. In a line of these extractors, most will be model 700 when processing oranges, with one or two model 400s at the end of the line to handle large fruit. The model 400 can be equipped with larger cups and reamers and is also used on grapefruit lines. The Brown model 500 extractor has cups and reamers of a smaller size for handling limes and lemons.

The model 700 extractor has a rotating feeder wheel with a horizontal shaft and paddles spaced apart on the perimeter of the wheel. Fruit rolls from the feed chute into the spaces between the paddles, which are timed to rotate and feed fruit cup halves that are connected to traveling chains. The cups accept the fruit from the feeder wheel and pass over a knife that halves the fruit. The fruit then passes across a slider plate, which holds the halves in the cups as they spread apart to feed the reamer wheel.

The reamer wheel also has a horizontal shaft and is equipped with reamers at its perimeter that are spinning through gear action in the rotating wheel. The cups are so spaced on the chains to match the position of the reamers on both sides of the reamer wheel. As cups and reamers rotate around, the juice is extracted along with pulp, rag and seed and it drops down into a juice trough that feeds the juice finishers. The peel is ejected from the cups as the chain returns to the feeder wheel and is dropped to screw conveyors to transport the mass to the Feed Mill.

The Brown model 1100 extractor has a feeder that places the fruit into three single lanes as it enters the extractor. As the fruit drops into the extractor it is caught by a series of rotating discs with wide angle nearly flat conical shapes on horizontal shafts. The fruit is wedged between pairs of discs which forces the fruit
across a knife and cuts the fruit in half with the skin side of the halves against the discs. As the discs rotate the open sides of the halves are forced across a stationary screen. Juice, pulp, rag and some seeds pass through the perforations down to the juice trough that feeds the finishers. Peel is ejected by the rotation of the discs after about 320º of circular path.

2. Finishing
From both FMC and Brown machines, the extracted juice needs finishing to separate cloudy but otherwise clean juice from pulp, rag, seed and pips. Extracted juice enters the finishers from headers or troughs that are sloped toward the direction of flow. The finishers separate the pulpy matter from the juice by the action of a rotating auger inside a cylindrical screen. The spinning auger forces the pulp out the end of the finisher through a valve which is either spring loaded or loaded by use of an air cylinder. The valve seat or clearance area is conical and is about the same diameter as the screen cylinder (approximately 14 inch in diameter). Screen hole sizes range from approximately 0.020 inch to 0.030 inch in diameter, depending on the condition and softness of the fruit.

The tightness of the finish results from the force applied by the auger against the pressure of the valve. Correct juice yields are controlled by adjustable pressures applied in both the extractors and finishers. Higher pressures give greater juice yields, however excessive pressure can result in off flavors by forcing too much peel and pulp matter into the finished juice.

Two finishers are often placed in series at the end of the extraction line, the upstream finisher referred to as the primary finisher and the downstream called the secondary finisher. The primary finished is not set as tight as the secondary unit and so will have a higher flow capacity. Sometimes large plants require two secondary finishers in parallel, as they will have higher finishing pressures thus less throughput capacity.

The juice from the primary finisher will be lower in pulp matter and its juice stream can be directed to a process that may specify low content of insoluble solids.

The amount of pulp allowable in the final processed juice is set by plant quality standards and the maximum is set by USDA and Florida regulations. Pulp content is tested using a clinical centrifuge, which spins a sample placed in a graduated glass tube. Sinking pulp is forced to the bottom of the tube and floating pulp appears at the top. The target is to achieve 12% or lower total pulp, but the measurement is by volume, not weight, as the cellulose matter on a dry basis is only a very small fraction of the total weight of the sample.

The pulp discharge off the finisher is transferred to the Feed Mill drying operation, or to a pulp wash operation which yields further soluble solids by the action of counter current water leaching. Washed or unwashed pulp is also sometimes directed to pulp recovery systems, which through further equipment removes seeds and reject material. The clean portion of the pulp is pumped through heat exchangers, pasteurized, cooled and chilled by refrigeration. This product is packed in 40 lb containers and stored in freeze rooms for future use.

Juice processing for pasteurized single strength
The canning of pasteurized juice begins in Florida in August and September and coincides with the harvesting of fruit for the fresh fruit market. Overflow from the packing houses is sent to processing plants, and some fruit is delivered directly from the groves. Blending of fruit varieties and control of ratios is usually accomplished by the fruit storage bin operator. Juice is pumped from finishing to process receiving tanks that are equipped with agitators to keep the pulp suspended. These tanks can also be used for adding sugar or other ingredients when canning sweetened or fortified juices. From the tanks the product is pasteurized by hot filling at 195 200ºF.

Peel oil enters the juice in the extraction process. Higher extraction pressures yield more juice but also force more peel oil into the juice stream. Too much oil gives off flavors to the juice and in the early days the amount of oil could be controlled by extractor pressure only. Since then de oilers have been developed as
an integral part of the pasteurizing process. In the de oiler the juice temperature is elevated above the can filling temperature. The juice is then flashed into a vacuum chamber controlled by a flash condenser and vacuum system to the can filling temperature. As a rule of thumb, a flash of 10ºF, say from 205ºF to 195ºF will remove approximately 1% of the mass as evaporated water vapors. This flash evaporation strips out some of the oil and the greater the difference between the heater and flash chamber, more evaporation occurs and more oil is removed. Since the oil has a higher boiling point than the juice, the removal of oil is an example of steam distillation or steam stripping. Some lower boiling constituents in the juice, which contribute to the juice essence, are also removed in the de oiling process. This is not considered objectionable in processing hot pack canned products. The juice entering the can must be hot enough to pasteurize it (about 195ºF). However, there is a limiting high temperature for taste reasons which, therefore, limits the amount of oil which can be removed by flashing and has an influence on extractor pressure settings.

Some de oilers use heat exchangers to bring the juice up to filling temperature and heat the juice further by direct injection of live steam. The condensing of steam adds water to the juice but in the vacuum chamber an equal amount of water is flashed off. It is the authors opinion that there is a danger of adding essence of boiler or essence of steam pipe to the juice with the use of this type of de oiler. An advanced design uses indirect heating only. The flash chamber is connected to a stripping condenser through which the water and oil vapors pass. The water phase is condensed and returned to the juice and the oil exits through a vent line connected from the condenser to an oil recovery system.

The heated juice is pumped from the pasteurizer, de oiler to the can filler bowl, which has a demand float that regulates the juice flow through the system. Can fillers rotate and accept empty cans through mechanical timing devices driven by the filler which space the cans to synchronize with the filler valves. Under the rotating filler bowl, the cans are lifted by cam action and forced upward toward the bottom of the bowl. The cans contact the valves located in the bowl, push the valve stems up, opening the valves and the hot juice flows by gravity into the cans.

Filled cans exit the filler and enter the can closing machine, which is driven by the filler and thus synchronized. A small stream of live steam is injected into the head space at the top of the can to expel air that would otherwise be trapped between the lid and the juice. Lids are applied and seamed and the cans exit the closer into a can twist, which inverts them so that the hot juice pasteurizes the lid. The cans are then fed into a water spray can cooler. Cans enter the cooler at about 195ºF and exit the cooler at about 100ºF. They are stored in warehouses at ambient temperature.

Single strength orange juice is also filled into glass containers at 190 195ºF, after which they are cooled first by warm water to avoid thermal shock, followed by chilled water. The coolers in this type of operation carry the bottles on a wire mesh belt (as compared to the spinning of the cans) with recirculating water sprays in sections along the length of the cooler, the warmest water at the inlet end. The outlet section uses chilled water (about 35ºF) and cools the product to around 50ºF after 1 h residence time in the cooler. This product is stored and distributed at cool temperatures and given a shorter shelf life than the canned product due to the inevitable colour and taste changes with age.

Juice processing for concentrate
The obvious advantages of making concentrate from fruit juices are: (1) reduced volumes for storage and shipping, and if enough water is removed from the juice, the concentrate can be kept at ambient temperatures without spoiling. The most widely used technique is to apply heat to the product in order to evaporate water by boiling, though other processes, such as removing the water by freezing or ultra filtration have been tried on citrus juices without any wide acceptance. Citrus juices are quite sensitive to heat and if exposed to elevated temperatures or even kept at ambient
temperature for too long, flavor and color changes will occur. With high temperature short time (HTST) pasteurizers orange juice may be heated quickly to 185-200°F, held for 30s and quickly cooled without any color change. This process stops enzymatic reactions, which would otherwise cause cloud separation, flavor and color changes.

There is, however, a non enzymatic reaction that takes place in juice and concentrate that in time causes browning due to sugars reacting with proteins. This reaction is retarded at low temperatures. For this reason all orange juice concentrate produced for reconstitution into juices is stored at temperatures of 20°F or lower. This allows for holding inventories of concentrate for more than 1 year if necessary.

The earliest orange concentrate in Florida and California was produced on steam driven evaporators, sometimes only open kettles. The concentrate produced was not suitable for juice, but was used for drink bases and confections. By 1935 several processors were producing concentrate on vacuum evaporators designed by various equipment manufacturers originally for use on other products. These were medium to high temperature evaporators, which by todays standards produced an inferior product. The concentrate was then heated and hot filled into cans. The canned product was cooled by water spray and stored at ambient temperatures. The market for this product was in Europe and England and for the armed forces during World War II.

It was during the period between 1935 and the middle 1940s that considerable research and development was done on producing concentrate by using high vacuum low temperature evaporators. Research and development showed that by the use of a low temperature (below 160°F) concentration process followed by frozen storage a much fresher tasting concentrate could be produced. The trade name for this product became Frozen Concentrate Orange Juice or FCOJ.

By 1950 equipment manufacturers had successfully developed commercial low temperature high vacuum evaporators, some of which used refrigeration heat pump designs and others, which used large recompression jets. Concentrate was pumped out at 58º Brix at temperatures around 55-60°F. Unpasteurized, single strength cut back juice was blended in to make 42º Brix for canning, which partly compensated for the loss of volatiles in the concentrate process.

The concentrate produced by this low temperature technique was of very good quality and was packed mostly in 6 oz cans, which were sent through a blast freezer and stored at –10°F.

It became apparent after some time that heat treatment was necessary to stabilize the canned product, as frozen storage temperatures could not always be guaranteed after leaving the plant refrigeration facilities. Microbial spoilage and/or cloud separation due to pectolytic enzyme action would sometimes occur. Around the mid 1950s, high temperature short time pasteurizers were added to the concentrate process which would bring the temperature of the juice to around 195°F with enough holding time to kill the microorganisms and deactivate the pectin esterase.

1. Characteristics of 1950s evaporators
To understand the significance of the advance taken by later designs, it is necessary to examine these first commercially successful evaporators. These early low temperature evaporators were of the recirculating type, shell and tube falling film design. Stainless steel tubes were installed vertically in, a configuration referred to as a tube nest or evaporator body. Juice entered the top of tubes and flowed downward as a film against the inside wall of the tubes. Evaporated vapors traveled downward through the center of the tubes and exited with the juice through a vapor liquid separator. The juice was pumped back to the top of the tube nest and into the tubes through some sort of distribution device. On the outside of the tubes, referred to as the shell side of the tube nest, steam condensed under vacuum giving up its heat to the boiling juice on the tube side of the tube nest.

Tube nests were arranged in stages and effects and each stage held a considerable amount of product. When the correct concentration was reached in the final stage, concentrate was pumped out and replaced...
from earlier stages under liquid level control. Brix control of the product from these evaporators was good because of the large stabilizing effect of the bulk of product in process.

Maximum evaporator operating temperatures varied with manufacturers design, up to 120°F for steam driven types with recompression jets. Refrigeration heat pump evaporators highest process temperature was around 75°F (not including the pasteurizer).

These evaporators required considerable heat transfer surface because of low temperature difference across the tube walls and because of high resistance to heat transfer caused by cold thick product inside the tubes. Vapor liquid separators were large as were vapor transfer ducts by virtue of the large volume of the evaporated water vapors. These large spaces were almost impossible to clean in place (CIP) and after 30-40 h of operation the separator man ways and top distribution chambers needed to be opened and manually cleaned. Cleaning required a considerable amount of down time and man hours. Recharging these evaporators with juice, restarting and reaching steady operation at 58° Brix pump out, also added to loss of production time.

2. Modern evaporators for citrus fruit

The low temperature evaporators had been designed on the basis that low evaporation temperatures would compensate for the long residence time in the process and avoid heat damage. The successful use of high temperature short time pasteurizers demonstrated that no significant heat damage was done to the product provided the time of elevated temperatures was kept short.

This experience along with the aforementioned deficiencies of the low temperature evaporator design gave rise to the development of the thermally accelerated short time evaporator (TASTE), which at the present time is used almost exclusively in the world wide citrus industry. These evaporators are of the multi effect, multi stage, single pass design and the first one was installed in Florida in 1958.

For the reader who is not familiar with evaporator terminology it might do well here to explain the difference between the evaporator effect and evaporator stage. Effect defines the heat flow through an evaporator, the first effect always the warmest which receives the energy for driving the evaporator. In refrigeration low temperature heat pump evaporators, which were usually double effect units, the first effect received heat as the condenser side of a refrigeration system. The water vapors from evaporation inside the tubes of the first effect traveled through vapor lines to the shell side of the second effect, condensed and gave up its heat to the boiling liquid inside the tubes of the second effect. The water evaporated in the second effect entered the shell side of a vapor condenser, condensed and transferred its heat to a boiling refrigerant inside the tubes. The refrigerant vapors were boosted by the compressors and the refrigeration condensing heat was absorbed by the first effect, completing the cycle.

The TASTE evaporator is driven by boiler steam directed to its first effect shell side. For each pound of steam condensed, an equal amount of water vapors are evaporated and sent to the next (second) effect, from the second to the third and so on, with the evaporated vapors from the last effect condensed by cool water, usually recirculated from a cooling tower.

The stages of an evaporator define the product flow the first stage receiving the single strength feed juice. Any effect of an evaporator can be designed to receive feed liquid. A forward flow evaporator feeds the first effect and product flows parallel with the heat flow through the effects. Reverse flow feeds product to the last effect and pumps out of the first effect. Mixed flow loosely defines an evaporator, which is staged as neither of the above.

The number of effects used determines the energy efficiency of the evaporator. A single effect steam driven evaporator will evaporate approximately one pound of water for each pound of boiler steam condensed. In a two effect unit, the first effect is the boiler for the second, thus two pounds of evaporation per pound of steam is achieved, and so on. This pound for pound ratio does not exactly apply to citrus evaporators as it does not include the heat required for preheating (heating the juice to the first effect temperature). Other
forms of evaporator design have been offered to the citrus industry, such as the use of vapor recompression, in order to reduce the steam and/or energy requirements. However, the evaporation to steam ratio for a seven effect TASTE evaporator is 6.1/1. That is, 1 lb of steam will cause 6.1 lb of evaporation (including the preheating load). This energy efficiency is more favorable than that achieved with recompression, especially when considering the greater capital investment for the recompression plant. Multi effect steam driven evaporators are much more forgiving to upsets caused by infeed flow and Brix variables and are thus easier to control. They may also be operated at lower than design capacities simply by throttling the steam valve.

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