Carbonated Soft Drinks: Formulation and Manufacture

Edited by

David P. Steen
and
Philip R. Ashurst

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Editorial Offices:
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Blackwell Publishing Professional, 2121 State Avenue, Ames, Iowa 50014-8300, USA
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List of Contributors

Dr Philip Ashurst	Dr P. R. Ashurst & Associates, Unit 5, Gooses Foot Estate, Kingstone, Hereford, HR2 9HY, UK
Dr Bob Hargitt	British Soft Drinks Association, 20–22 Stukeley Street, London WC2B 5LR, UK
Mr Ray D. Helliwell	A.G. Barr plc, Mansell House, Aspinall Close, Middlebrook, Horwich, Bolton, BL6 6QQ, Lancashire, UK
Mr John Horman	Diessel Metering Systems Ltd., Cross Edge, Green Haworth, Accrington, Lancashire, BB5 3SD, UK
Mr John Medling	Krones UK Ltd., Westregen House, Great Bank Road, Wingates Industrial Park, Westhoughton, Bolton, Lancashire, BL5 3XB, UK
Mr David Rose	Britvic Soft Drinks Ltd., Widford, Chelmsford, CM1 3BG, UK
Dr David P. Steen	Casa Davann, Las Rellanas 26-F, Arboleas 04660, Almeria, Spain
Mr David Syrett	Britvic Soft Drinks Ltd., Widford, Chelmsford, UK
Mr Walter Tatlock	CBJ Service Ltd., 17 Kirkfell Drive, Astley, Tyldesley, Manchester, M29 7GB, UK
Mr Barry Taylor	Dansico Ingredients Ltd., Denington Estate, Wellingborough, NN8 2QJ, UK
Mr Andrew Wilson	Krones UK Ltd., Westregen House, Great Bank Road, Wingates Industrial Park, Westhoughton, Bolton, Lancashire, BL5 3XB, UK
Mr Philip A. Wood	A.G. Barr plc, Mansell House, Aspinall Close, Middlebrook, Horwich, Bolton, BL6 6QQ, Lancashire, UK

Preface

The market for carbonated beverages has grown dramatically in most countries, for example, by 128% in the UK since 1984. This growth has required changes in the way factories are run. Soft drinks are now classified as food products and are produced under stringent hygiene conditions. Twenty years ago this was not always the case – carbonated drinks were often produced in old buildings where cross-contamination could easily occur. Filling technology has progressed rapidly to meet the needs of manufacturers and consumers alike. Whilst the basic counter pressure filler is still the main work horse, new generations of electronically and pneumatically controlled filling machines have been developed that allow production under much more hygienic conditions and to much higher standards of filling accuracy and repeatability.

Primary packaging for carbonated soft drinks in most countries appears to have settled on PET bottles, with 500 ml and 2 l sizes predominating. The returnable glass bottle business is in decline and single-trip glass bottles are now mainly used for specialist products. The growth of can use appears to have stabilised. The 'lightweighting' of PET bottles over the last decade appears to be reaching its limits. Work on this will inevitably continue though at a slower rate as a consequence of the high cost of oil. Developments in barrier technology and new resins mean that shelf life in small PET bottles is not the problem it once was for carbonated products, although the much higher bottle cost restricts the use of such materials to premium product. Closure technology has also improved over the last 10 years with the advent of new neck finishes for PET bottles and improvements in closure design.

After an introduction to carbonated soft drinks, this volume considers the specifications and treatments for water, the main ingredient of any soft drink. A chapter on the other ingredients and formulation of carbonated drinks then follows (Chapter 3). Chapter 4 considers how ingredients are blended together to an agreed specification, and includes sections on sugar dissolving and batch and continuous syrup production. The predominant philosophy now is to manufacture the finished product as ready to drink (RTD), and prove that it is within specification prior to carbonation. In this way losses are minimised, uniformity of product is guaranteed and there is tight cost control of production.

A chapter on carbon dioxide production and the physics of carbonation then follows (Chapter 5). Modern carbonation techniques and feedback control are considered, with a discussion of different carbonation methods. The physics of filling carbonated beverages is included, followed by a consideration of the latest generation of filling machines (Chapter 6).

Chapter 7 deals with primary packaging – the concepts of containing, protecting, identifying and marketing are considered in the light of environmental, legislative and cost factors for the three main containers: glass bottles, PET bottles and cans.

Chapter 8 is on secondary packaging, explaining its importance during the development of a new or existing product. The function of secondary packaging is to ensure that the primary container is delivered to the consumer in prime condition, at the same time as satisfying the ever increasing demands of the trader.

A further chapter deals with production systems, applying the topics of previous chapters to the production line and factory, discussing glass, PET and can lines and describing principles and inspection systems (Chapter 9). This chapter also considers plant breakdown characteristics, line control and management systems. An introduction to the requirements for factory layouts and design is then followed by considerations of performance measurement and benchmarking.

Chapter 10 deals with the increasingly important subject of production planning and distribution. As a consequence of the high weight and comparatively low value of carbonated soft drinks, this topic is receiving much more attention than previously. Supply chain management is discussed in relation to soft drinks, highlighting its importance. It is no longer enough to just produce soft drinks, they must be produced uniformly every day and be distributed to the customer at the lowest possible cost if the producer is to stay in business. Chapter 11 is on quality, environment and food safety; completing the picture by providing the framework within which manufacturing and distribution must now exist.

The aim of this volume is to provide an overview of carbonated soft drinks production in the early part of the twenty-first century, presenting the latest information on carbonation and filling methods. Detailed references provide opportunity for further reading in more specialised areas. Certain topics, such as ingredients and packaging, are not included in great depth here because they are covered in detail elsewhere in the series. The book is aimed at graduates in food science, chemistry, microbiology and engineering who are considering a career in the soft drinks industry, as well as technical staff already employed within the industry and associated suppliers.

The editors are greatly indebted to the contributing authors: without them this book would not exist. All are experienced in their particular fields and, for most of them, the work involved in writing their chapters was a significant extra burden on top of their already heavy workload.

David Steen

Philip Ashurst

1 Introduction

Bob Hargitt

The aim of this introduction is to provide a brief perspective on the historical development of carbonated soft drinks from their first appearance in the late eighteenth century to the present day, and also to consider their future path.

1.1 Early history

The consumption of soft drinks in their various forms has taken place for many centuries in order to meet the body's fundamental requirement for hydration. The most obvious source of hydration is water, but in earlier times the consumption of water was very hazardous as it was frequently contaminated by micro-organisms. Outbreaks of cholera, dysentery and other waterborne illnesses were common in many European cities prior to the twentieth century. The consumption of 'small beers' – drinks which had been boiled, flavoured with, for example common herbs, and slightly fermented – was widespread. Barley waters, flavoured drinks containing pearled barley, were recorded as early as 1320 and the earliest English reference to lemonade was published in 1663. The drink contained lemon juice and was sweetened with sugar or honey and is thought to have originated in Italy. Orangeade was also recorded in the 1660s. All these early drinks were, of course, not carbonated.

Production of effervescent alcoholic beverages, that is, beers and wines where the carbon dioxide was derived directly from fermentation, is recorded as beginning at the latest in 1693, when Dom Perignon is credited with the invention of champagne. However, references to sparkling wines are found in English literature well before this date. Several spas were also known where the water was naturally effervescent and during the seventeenth century scientific interest and study grew in the gas which caused this effect, particularly at Spa in Holland and Pyrmont and Seltzer in Germany. There was considerable scientific investigation across Europe of the gas we now know as carbon dioxide (CO_2) by the middle of the century. In 1741, Brownrigg termed the gas 'mephitic air' and produced effervescent waters from bicarbonate salts. By 1767, Richard Bewley was selling effervescent 'mephitic julep' for its medicinal properties. In 1764, Macbride in Ireland demonstrated the medicinal uses of effervescent waters and their antiseptic properties.

The discovery of the means of artificially carbonating water by dissolution of CO_2 under pressure is attributed to Dr Joseph Priestley in the late 1760s, though there were many other workers active in this field at the same time who probably deserve equal credit. He published his work, *Directions for Impregnating Water with*

Fixed Air in 1772 and Dr John Mervin Nooth developed an apparatus for preparation of effervescent waters, which he reported in the *Philosophical Transactions of the Royal Society* in 1775. Torbern Bergman, Professor of Chemistry at Uppsala University in Sweden, published his work on preparation of artificial mineral waters in 1773. His treatise on Bitter, Seltzer, Spa and Pyrmont Waters has been termed the world's first textbook on the manufacture of mineral waters. In 1780, Duchanoy in France published a treatise on the art of imitating naturally occurring mineral waters. The initial commercial development, deriving from all this scientific work, was that of selling imitation mineral waters, that is, waters to which were added minerals in the proportions found in naturally occurring mineral waters and then artificially carbonated. Hence the term in English of 'aerated mineral waters', which became synonymous with all carbonated drinks. The commercial development of carbonated waters took off very rapidly following the initial scientific and technical discovery.

Thomas Henry, a Manchester apothecary, is generally credited to have been the first commercial manufacturer of artificially carbonated water in the late 1770s. He improved and developed Nooth's design to make an apparatus capable of carbonating batches of up to 12 gal (54 l). The product was sold in tightly corked glass bottles. Henry recommended consumption of lemon juice and soda water for the stomach but did not state whether the two were combined. By the late 1770s he was also selling artificially manufactured Pyrmont and Seltzer waters, that is, imitations of the naturally occurring spa waters. Thomas's son, Dr William Henry, was the inventor of Henry's Law of Gases (1805). The storage of fresh water on board ships during long sea voyages, which could last many months, was a serious problem and the antiseptic effect of carbonation and hence its long 'shelf-life', made an immediate impact upon the British Admiralty. It was also claimed (wrongly) that soda water cured scurvy and one of the first uses of carbonated water was on board a ship. Bottles of soda water have been salvaged from the wreck of the 'Royal George' which sank in 1782. Early effervescent drinks, similar to Bewley's Mephitic Julep, were manufactured by mixing sodium bicarbonate solution with lemon juice or lime juice, which would of course cure scurvy. This was probably the cause of the misconception that CO_2 was a cure for scurvy.

The manufacture of carbonated drinks also rapidly became popular across Europe. Paul, Schweppe & Gosse established a successful business in Geneva, before Jacob Schweppe moved to London in 1792 to set up a factory-scale operation there. The production of mineral waters was well established by 1800, and J. Schweppe & Co opened another factory in Bristol in 1803. His former partner, Nicholas Paul also moved to London in 1802 and set up in competition with Schweppe. Paul is credited with the first commercial use of a high pressure gas pump to aid dissolution and achieve high levels of carbonation, his mineral waters were famous for containing several volumes of CO_2.

Carbonated waters were imported into the USA from the UK prior to 1800. The first commercial production is attributed to Benjamin Silliman, who was professor of chemistry at Yale College. He had seen carbonated waters on his travels to England and had met Joseph Priestley, who had emigrated to the USA. In partnership

with a Mr Twining, he began selling carbonated waters in 1807 in Newhaven. Joseph Hawkins established an enterprise in Philadelphia the same year and operations rapidly sprang up in other cities in the north-east, for example, New York, Baltimore and Boston.

An excellent account of the development of the soft drinks industry in the USA was written by John J. Riley.

1.2 The growth of carbonates – production

The carbonated soft drinks industry continued to grow steadily as the nineteenth century progressed. By 1840, there were at least 50 manufacturers in London. At the Great Exhibition, held in London in 1851, J. Schweppe & Co paid £5000 for the concession to sell 'soda and other mineral waters'. They sold in excess of 1 million bottles during the course of the exhibition. Throughout the nineteenth century the popularity of carbonated soft drinks increased steadily and the number of flavours expanded likewise, driven by the popularity of the temperance movement. This growth of carbonates coincided with the industrial revolution through the nineteenth century. Production of soft drinks became more industrialised and a process of continuous improvement soon developed. The *Mineral Water Maker's Manual for 1885* lists over 80 patents, which were registered in the previous year, related to the manufacture and packaging of bottled soft drinks. It also lists approximately 300 trademarks which had been approved between the passing of the Trade Marks Act in 1875 and 1881, including that for the Buxton Mineral Water Co., Fairfield Works, Buxton, in 1876.

Continuous improvement in production and packaging of carbonated soft drinks meant that by the middle of the nineteenth century a manual bottling line was capable of filling 100 dozen bottles per day, but the introduction of steam power increased that to 300 dozen per day. By 1900, it was estimated that 70,000 people were directly employed in the UK soft drinks industry and 22,000 horses were used for product delivery. Total UK production was estimated by Bratby & Hinchcliffe to be almost 300 million dozen half pints (ca. 900 million litres). For comparison, in 1990, government statistics show that almost 18,000 people were employed in the soft drinks industry (manufacturing, distribution, sales and marketing) producing 6717 million litres of drinks. In 1899, there were 2763 soft drink bottling plants in operation in the USA.

The industries of the UK, Europe and USA progressed along slightly different paths owing to the differing circumstances found in those regions, although three types of beverage were found in each region. The industry in the UK, which was becoming more industrialised with large factories supplying products to the masses, progressed along the path of industrial production of soft drinks in returnable bottles sold through shops. In continental Europe the soda siphon type device (i.e. the gasogene or seltzogene) became popular for home use. These were used for the dispensing off of flavoured drinks, not just soda water. The common soda siphon which we would recognise today was patented by Charles Plinth in 1813. However,

he used a stop-cock to dispense the contents and the use of a lever-operated device was patented by Deleuze and Dutillet in Paris in 1829. The use of a small metal bulb filled with CO_2 to re-charge a siphon of water was patented by Arthur Marescot in 1874.

In the USA, soda fountain equipment, where drinks were produced in shops for consumption on site, also became very popular. Some carbonates were consumed purely as a source of refreshment but many retained their medicinal pedigree to a greater or lesser extent. The most notable was probably quinine tonic water, which was consumed in tropical regions as a cure for malaria. Dandelion and burdock was obviously of herbal origin, and another popular drink in late nineteenth-century Scotland and in London during the 1890s was Kola Tonic. Kola (or cola) was a nut from West Africa, which was used by Nigerians as a symbol of hospitality. In 1886, Dr John S. Pemberton combined cola with coca (an extract from the S. American coca leaf) to produce his coca-cola 'brain tonic' sold in the soda fountain of his store in Georgia. In 1892, Asa G. Candler took over the business and incorporated the Coca-Cola Company in Atlanta with an aggressive marketing campaign for his 'nutrient beverage and tonic'. The company granted the rights to bottle the product under licence. The first such plant opened in Chattanooga in 1899, followed rapidly by many more. Around the same time Dr Pepper was launched by R.S. Lazenby in Waco, Texas (ca. 1888) and Pepsi-Cola was launched at New Bern, North Carolina by Caleb D. Bradham (ca. 1896, although the name Pepsi-Cola was not coined until 1901).

By the close of the nineteenth century most of the common carbonated soft drinks of today were already on sale, for example, soda water, ginger beer, ginger ale, lemonade, orangeade and other citrus drinks, cherryade, quinine tonic water, bitter lemon, colas, sarsaparilla, root beer, cream soda etc. These would all have been well known to consumers in the late Victorian era.

There is a difference between the American and British definitions of soda water. In the USA, soda water is defined simply as carbonated water, but the UK legislation still requires that soda water must contain a minimum of 550 mg/l sodium bicarbonate. Interestingly the only other legal compositional standard for a soft drink in the UK is for tonic water, which currently must contain a minimum of 57 mg/l quinine (as sulphate).

1.3 Technological development

1.3.1 Carbon dioxide

It had been recognised by many scientists in the early 1700s that the gas produced by brewery fermentation, combustion of wood and addition of acids to chalk/marble was one and the same. It was given several names including artificial air (Boyle 1685), mephitic air (Brownrigg 1741), fixed air (Black 1754), gas acide carbonique (Lavoisier 1782) and finally gaz oxide de carbon (Fourcroy 1805).

The most practical/economic means of commercial production was by the action of sulphuric acid on marble chippings (known as whiting) or, at a later date, on sodium bicarbonate. Crushed marble (or chalk or limestone) was cheap and readily available in large quantities. However, the purity of the marble was critical to the quality of the CO_2. Impurities (particularly organic ones) would cause noticeable 'off flavours' in the finished drink. This forced manufacturers to introduce filters and scrubbers to remove taints. Bubbling the CO_2 through olive oil was a commonly used method of removing organic taints. The purification of CO_2 introduced complexity and hence cost to the production process. Although more expensive than marble, sodium bicarbonate could be obtained in commercial quantities at consistently high purity and was preferred by some manufacturers. The product of the action of sulphuric acid on marble is calcium sulphate, which is insoluble in water. Large quantities of the resulting sludge were difficult to dispose of, particularly when the UK municipal authorities introduced controls in the 1890s. Problems of effluent emissions are not new. The liquification of CO_2 by means of high pressure was reported by Michael Faraday in 1823 and the first practical manufacturing equipment was patented by Dr Henryk Beins in Holland in 1877. The commercial manufacture and use of liquid CO_2 for the carbonation of drinks began in Germany and in the USA in the 1880s. The production of solid CO_2 was discovered by Thilorier in 1835, and a patent for the production and use of solid CO_2 was granted to Dr Samuel Elworthy in 1897. The handling and transportation of solid blocks of CO_2 was much easier than for heavy metal cylinders containing liquid CO_2. Though use of liquid or solid CO_2 increased in the late nineteenth and early twentieth century, it was not until the 1950s that transportation of liquid CO_2 by low pressure bulk road tankers became commonplace.

Production of carbonated drinks was traditionally carried out by means of adding concentrated syrup to the bottle and then topping up with carbonated water. A considerable improvement in speed was achieved in 1937, when the Mojonnier Brothers Corporation of Chicago introduced a continuous blending/cooling/carbonating system. Such continuous systems have gradually replaced the syrup dosing systems, though some of the latter remained in operation into the 1980s.

1.3.2 Sweeteners

One of the major drivers of growth in carbonates has been the development of sweeteners and consequent improvement in the quality of low calorie soft drinks, particularly in the USA and UK. Saccharin was invented in about 1874 and very rapidly became popular as a sweetener for soft drinks, usually blended into sugar to reduce cost. Figure 1.1 shows an advertisement for saccharin, which was published in 1890, by which time it was already widely used. A modern supplier may have difficulty substantiating all of the claims made for it. However, it proved to be a popular sweetener in the UK, particularly when sugar was in very short supply during the First World War. A blend of sugar and saccharin (50 : 50 by sweetness) became the standard sweetener system for common soft drinks, for example, lemonade.

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5. AN appreciable saving per ton over Sugar; should the latter rise in price the economy would of course be proportionately greater.
6. A SAVING of half the carriage on the Sugar.
7. A SAVING of about 20 per cent. on the Acid bill.
8. A GREAT saving of steam, trouble and labour. Eight lbs. of Saccharin replace one ton of Sugar, consequently instead of the labour and steam necessary to handle and melt a ton, sufficient for manipulating eight lbs. need only be employed—a very pronounced advantage, especially in a busy season.
9. ECONOMY of storage room—a very material desideratum in many factories.
10. THE flavour of the essences employed is more fully developed, whilst the "body" of the finished beverage cannot be distinguished from that of one made wholly of Sugar.

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Figure 1.1 Advertisement for saccharin, 1890.

Low calorie soft drinks (containing <10 kcal/100 ml) began to gain popularity in the 1960s and a blend of 1 part saccharin to 10 parts cyclamate produced a good tasting low calorie sweetener system. However, the use of sodium cyclamate came to an abrupt end in 1969 when it was banned in the USA and UK (from 1 January 1970) due to evidence suggesting that it caused bladder cancer. Cyclamate was not banned elsewhere and it remained a very popular sweetener until recent severe restrictions in the EU. The original work was later discredited but it resulted in saccharin being the only permitted sweetener in the UK and this severely limited the growth of low calorie drinks because of the unpleasantly bitter aftertaste of saccharin when used as a sole sweetener. The growth resumed again in the mid-1980s following the approval of aspartame and acesulfame K in the UK in 1983. This growth in popularity of low calorie (or 'light') drinks has been a massive driver of volume growth in the USA and UK, but to a lesser extent in mainland Europe. In the UK, in 1981, only approximately 4% (84 million litres) of the 2040 million litres of carbonates produced was low calorie. By 2003, low calorie represented 32% of the carbonates market of 6500 million litres (see Table 1.1) and a further 25% was reduced sugar (usually for reasons of cost).

1.3.3 Flavours and colours

As previously mentioned the original carbonates were artificial imitations of naturally occurring mineral waters. Manufacturers blended mineral salts in the same proportions as found in the natural spring waters and added carbonated water. A large range of such waters was available during the early 1800s. Early attempts at producing flavoured products were limited by a lack of stable flavourings and spoilage problems. The flavouring materials used consisted mainly of herbal/botanical extracts, for example, ginger, nettle, nutmeg, horehound, lemon oil, vanilla etc., but the technology for manufacture of soluble stable flavouring extracts developed rapidly during the middle of the century with the establishment around this time of many speciality flavour companies (such as W.J. Bush and Stevenson & Howell in London). An early recipe for lemonade consisted of citric acid, essential oil of lemons and sugar syrup, the mixture being topped up with water and impregnated with carbon dioxide – instantly recognisable as the forerunner of today's lemonades. In 1858, Mr Erasmus Bond patented 'an improved aerated

Table 1.1 Growth of low calorie carbonates.

Year	Low calorie carbonates (million litres)	Total carbonates (million litres)	Percentage
1980	84	2040	4
1990	941	4129	23
2003	2099	6560	32

liquid, known as Quinine Tonic Water' and, following the development of a clear soluble ginger extract, ginger ale was first manufactured in Belfast in the 1870s.

By the second half of the century, carbonate manufacturers could buy a very comprehensive range of flavours to use in their products and the science of flavour chemistry was well under way, as demonstrated by the development of artificial vanillin by Tiemann and Wallach in 1872. This reduced the cost of vanilla flavour by a factor of more than $\times 30$ (from \$300/lb (\$555/kg) to less than \$10/lb (\$19/kg)). As mentioned above, many of the popular drinks of today were on sale before 1900. The quantity of CO_2 added to a drink has a pronounced effect upon its character and flavour impact. The solubility of CO_2 in water decreases as temperature increases but increases with increasing pressure, that is, a given level of carbonation will generate a higher pressure as the temperature increases. Ice cold water (0°C) will dissolve 1.7 volumes (3.4 g/l) of CO_2 at atmospheric pressure. At CO_2 levels and at temperatures above this, increased pressure must be applied to retain the CO_2 in solution. In some of his early highly carbonated waters Nicholas Paul used carbonations of up to eight volumes of CO_2 (16 g/l); however, the usual carbonation levels now range from about two volumes for a slightly sparkling fruit drink to around five volumes for a mixer drink such as tonic water (see Table 1.2). Mixers require higher levels of carbonation because they are intended to be diluted with spirit before consumption.

In the early 1800s, colours were restricted to mainly variants of brown and red, that is, those which could be produced from caramel or cochineal. This remained the case until the introduction of synthetic aniline dyes around 1880. The *Mineral Water Maker's Manual for 1885* described the manufacture of some colours from vegetable extracts but stated that there was a trend for these to be replaced by the new aniline-based dyes, even though these 'are considered objectionable by many'. It also strongly warned manufacturers not to use colours such as arsenic sulphate, lead chromate, mercury sulphate and copper arsenite, which it claimed were sometimes used to colour confectionery.

1.3.4 Packaging

Waters from natural springs were recognised as being safe (even healthy) to drink from earliest times and were transported by whatever means that were available.

Table 1.2 Typical carbonation levels.

	Volume	(g/l)
Lightly sparkling	2.0	4
Fruit juice carbonate	2.5	5
Lemonade	3.0–3.5	6–7
Cola	4.0	8
Mixer	4.5–5.0	9–10

Naturally carbonated waters were collected into earthenware containers, which were tightly sealed with cork and wax, usually not very successfully. The use of earthenware bottles proved to be unsatisfactory for the more highly carbonated aerated mineral waters and they were soon replaced by glass bottles. Many of the early glass bottles had round bottoms ensuring that they were stored on their side, thereby keeping the corks moist and so preventing leakage from corks drying out. The manufacture of glass bottles was a skilled job as they were hand blown. Although some semi-automation had been introduced earlier, the first patent for an automatic glass bottle blowing machine was granted to Michael J. Owens in the USA in 1904.

High pressure generated inside bottles by the carbonation caused frequent leakage and, although improved by wiring-in-place, corks were generally unsatisfactory. Many alternative forms of seals were patented over the years and these fell broadly into three main categories:

1. Wire and rubber sealing devices were especially popular in the USA until the early 1900s. The wire could be either an internal spring form, which held a seal in place on the inside of the neck, or of the external 'swing' type, in which an external wire frame was used to hold a ceramic plug in place against a rubber seal. First patented by Charles de Quillfeldt in 1874, this latter type is still currently in use for some speciality beers.
2. Variations on the theme of using an internal ball made from rubber, ebonite or glass were developed and used with varying degrees of success. The ball was held in place by the internal pressure. The most successful of these was patented by Hiram Codd of London. His bottle was widely used in the UK from the 1870s until the 1930s. A similar bottle, but with a floating rubber ball acting as seal, was patented in the USA by S. Twitchell in 1883.
3. The third popular alternative was the internal screw top bottle. Unlike today's bottles, the thread was on the inside of the bottle neck and an ebonite or wooden stopper screwed into the neck, with a rubber washer being used to improve the seal. These types of stoppers were in common usage well into the 1950s in the UK. Ebonite, an early type of plastic resin material soon replaced wood, which had a tendency to absorb moisture, causing it to swell and crack the bottle neck.

A major step forward in sealing development was made by William Painter, who in 1892 patented the 'Crown Cork', founding the Crown Cork and Seal Company on 1 April 1892. Although initially slow to gain acceptance for two reasons: (a) the existing large capital investment in returnable bottles and bottling plant, and (b) the need for a tool to remove the crown, the crown cork eventually became popular, especially for small single serve and beer bottles. Screw stoppers retained their popularity for the larger bottles where re-sealability was important.

Except for some speciality earthenware ginger beer containers, glass bottles were the only form of packaging for carbonates for over hundred years until the introduction of cans in the 1960s. Then, just as the second half of the nineteenth century had been 'boom-time' for product development, the second half of the twentieth century became 'boom-time' for packaging and distribution development.

1.4 Recent technological development

Technology certainly played a large part in the growth of soft drinks in the second half of the twentieth century. The development of cans, plastic bottles, high speed packaging lines and improvements to distribution systems have been largely responsible for the increase in availability, the decrease in real-term cost and the resultant increase in consumption.

The advent of railways and large steam ships in the 1800s made transportation feasible and indeed drinks were exported from the UK to the USA as early as 1800. The export trade continued to expand and by the mid-1800s significant trade was being done with the far corners of the Empire. This must have involved considerable cost and on a domestic basis the trade was on a much more local scale. The industry evolved as a multitude of local businesses operating in a small geographical area, though some larger companies operated several production plants in different parts of the country. The UK *Bottler's Year Book 1933* listed more than 2000 soft drink manufacturing companies but by 1983 the list had shrunk to less than 400, and the number is now down to less than 100. Likewise the number of bottling plants in the USA grew to reach a peak of 7920 in 1929, remaining fairly constant until around 1950 and then halved to 3727 by 1965 as improved productivity and distribution started to have a significant effect. This halving of the number of bottling plants took place over a period in which per capita consumption rose by over 60%. More recently, the growth of cans and PET bottles at the expense of returnable glass has played a significant part in this continuing productivity improvement, which has been truly amazing. As recently as 20 years ago a typical returnable glass bottle line producing, say 300 bottles/min, required about 25 operating personnel. Highly automated high speed production lines now fill up to 2000 cans/min using three operators. Likewise, integrated PET bottle blowing and filling operations have also improved production efficiencies significantly. Other factors contributing to improved operational/distribution efficiencies (both in time and cost) include:

- use of shrink wrap in place of crates or boxes
- micro-processor controlled equipment, for example, for palletisation
- automated syrup room operations
- centralised computer-controlled warehousing systems
- automated bar-coding and traceability systems.

1.5 The growth of carbonates – consumption

The growth of carbonates worldwide has been a remarkable phenomenon, not only in the USA and western Europe, but also in Mexico, Brazil, eastern Europe, China and India. In the USA especially, carbonates have dominated the soft drinks market and the carbonates market has been dominated by cola. This worldwide growth in carbonates can be attributed in large part to the two major American cola companies