The Soft Drinks Companion

A Technical Handbook for the Beverage Industry

Maurice Shachman

CRC PRESS

The Soft Drinks Companion

A Technical Handbook
for the Beverage Industry

Maurice Shachman

Visit the CRC Press Web site at www.crcpress.com

Preface

With this handbook, I am not attempting to compete with the numerous textbooks available on the subject of beverage manufacturing technology. These books, whether written in simple layman's language or in elaborate technical jargon, generally cover adequately, in detail and in scope, the technical processes of beverage manufacture. All the relevant issues involved, from water treatment through ingredients, syrup making, filling, and packaging, are usually aptly dealt with in a systematic step-by-step manner. Ancillary matters such as quality, hygiene, inventory control, costing, and general troubleshooting are often added in appropriate dedicated chapters.

Also, I do not aim to compete with the sophisticated in-house technical manuals compiled by large international beverage manufacturing conglomerates for benefit of their technical management teams and operational staff. These chunky tomes aim to cover in minute detail and in sophisticated orderly fashion every technical aspect of the beverage manufacturing process, and indeed, they do not miss much. So then, what is my companion handbook all about?

Basically, it is an anthology of items relevant to technical and sometimes general issues I encountered in the 30-odd years of my association with the beverage industry. I think that these issues have either not been specifically mentioned in the textbooks and manuals or that they have not been sufficiently elaborated upon in them. This is not due to any fault of these books and manuals. By their nature and function, they must necessarily be prescriptive and authoritative and, as such, do not allow for theoretical discussion or academic debate.

The chapters included in this anthology are presented in seemingly haphazard fashion, in no specific sequential order. They are of subject matter that most production and quality personnel encountered or could eventually encounter at one stage or another of their careers. This anthology attempts to elaborate on some of the technical concepts that in the rush and turmoil of routine working hours are accepted by technical and other staff at face value, without probing into their real significances and meanings.

Also, this handbook, in accordance with its description as a *Soft Drinks Companion* endeavors to supplement the knowledge and expertise of technical staff members of not-so-big organizations, who have not been fortunate enough to receive the training afforded to their equivalents in large international conglomerates. They do not always enjoy the advantages of having a head office technical center at their beck and call.

Furthermore, this *Soft Drinks Companion* handbook hopes to assist the individual, new, would-be beverage-manufacturing entrepreneur who is usually clueless as to what is technically involved in such a venture. The anthology will, in one form or another, give such a person a basic idea of the technical issues involved, albeit these are not presented in as methodical and systematic a format as found in general textbooks and manuals.

I also attempted, by means of this handbook, to cater to the general curious public and to convey the message that making soft drinks is not, as often described, a simple matter of putting some sugar, bubbles, and flavor into a bottle of water. Okay, it is not as complicated as sending a space mission to Mars, but then — read on.

Contents

Appendix 7 Glossary of Technical and General Terms Used in this Handbook

Introduction to Soft Drinks

SOME STATISTICS

Soft drink is the name commonly given to a nonalcoholic beverage that is consumed cooled or chilled, as opposed to a hot beverage, like tea or coffee. Soft drinks fall into several categories distinguished by the industry as carbonates, still drinks, juices, dilutables, and bottled waters. A carbonate, also called a carbonated soft drink (CSD), is a fizzy drink containing gaseous carbon dioxide, commonly called soda pop in the U.S. Still drinks are noncarbonated soft drinks, and they consist of a

Main types of soft drinks:
Carbonates
Still Drinks
Bottled Water
Dilutables
Juices / Nectars

plethora of varieties, such as fruit drinks, energy and sports drinks, and health beverages, just to name a few. In the last decade or two, bottled waters have become very popular, whether still or carbonated, flavored or nonflavored, with or without natural sugars. Usually, these are prepared from natural spring waters or from other subterranean water sources and have high mineral contents, either naturally or added during manufacture. Dilutables is the name given to concentrated syrups, squashes, and cordials that are reconstituted with water by consumers to prepare beverages in ready-to-drink (RTD) forms.

Juices and nectars are beverages made mainly from natural fruit juices, the content of which is prescribed by local food law regulations. Roughly speaking, juices contain pure, 100% juice, whereas nectars have around 50% natural juice content. Juices may or may not be sweetened, but nectars are always sweetened,

Carbonated soft drinks make up almost half of the global soft drinks market.

in one manner or another, to make up for the nonjuice portion of the beverage. Figure IN.1 gives an idea of the split of these soft drinks categories in terms of global consumption in year 2001.

The global consumption figure of 412 billion liter is, in any terms, a stunningly high quantity and is presented here for the sole purpose of impressing upon you the magnitude of the soft drinks industry. For an idea of this quantity, imagine a lake that is 10 km long, 4 km wide, and about 10 m deep. The 6 billion people living on earth would empty this in 1 year.

The magnitude of the soft drinks industry has a profound impact on the world economy and on our lives in general. For instance, a simple statistic would indicate that each person on earth consumes about 70 liter of soft drinks in a year. For a family of five persons, this means an annual consumption of 350 liter per family, which in turn, means a purchase of almost 1 1liter of soft drink every day of the year. Of course, this is

The average global per capita consumption of soft drinks is about 70 liter per year. There are about 6 billion people on earth.

merely a statistic. In reality, in the densely populated areas of the world and in the highly industrialized nations, these figures could well be tripled or even quadrupled.

Take another statistic — sugar utilization in the soft drinks industry. Sugar makes up about 10% of soft drink content. This would mean about 40 million t of sugar is used for the global production of soft drinks. This is roughly one third of the global annual sugar production.
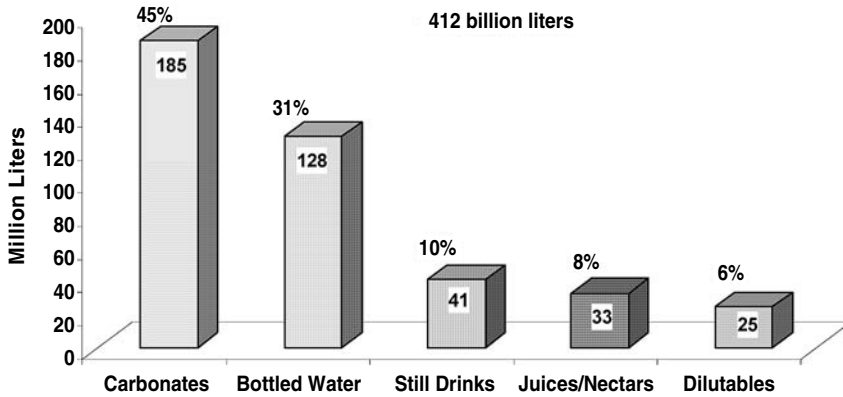
FIGURE IN.1 Total global soft drinks consumption (2001).

The soft drinks industry is a megabucks business involving huge volumes of raw materials and a multitude of service industries

Again, this statistic is not completely true, as sugar has been replaced by other natural sweeteners (e.g., high fructose corn syrup [HFCS]) and other artificial intense sweeteners, such as saccharin, cyclamate, aspartame, etc. But, the magnitude of sugar utilization in soft drinks gives you an idea of the megabucks business impact the soft drinks industry has on world producers, importers, exporters, and industrial users.

I could go on endlessly, supplying astronomical figures in volumes and monies that the soft drinks industry involves, from glass and plastic bottles, metal cans, manufacturing equipment, food additives, carbon dioxide gas, transport and cargo, through marketing and media advertising, employers and employees, consumer spending, and governmental taxation. I will not do so, but I will merely state that this industry is an immense global business entity that impacts very heavily on our lives in many ways.

Shown in Figure IN.1 is that the CSDs make up almost half the total soft drinks consumed in the world. It is upon this category of beverages that this companion book mainly focuses. There are many technical aspects common to CSDs and the other soft drinks, but there are also some specific differences between the various categories. Such differences will be addressed in applicable chapters.

WHAT IS A SOFT DRINK?

All soft drinks have a basic compositional structure. First, there is the water that makes up about 87 to 92% of the beverage volume. The water used is normally separately pretreated to remove impurities, microorganisms, and other undesirable attributes, such as off-tastes, odors, and turbidity. It is also treated to regulate alkalinity and hardness. Make no mistake about the fact that water used in soft drinks made by the more reputable bottling companies is much more purified than what comes out of the common tap in your house.

All soft drinks have the same few components. Other specialty ingredient combinations give us the diversity we see on the shelves.

Next, we have the sweetener, which is usually refined white sugar, though other natural or artificial sweeteners are being used as alternatives. In a naturally sweetened soft drink, the sugar makes up about 8 to 12% of the beverage by mass.

Another ingredient common to almost all soft drinks is the acidulant. This is the term used for any inorganic or organic acid that contributes to the sourness of the beverage. The balance

between sweetness and sourness is what gives it the basic typical taste profile of all flavored soft drinks. Without this sweetener and acid balance, the beverage would taste totally wishy-washy and unexciting.

To this basic taste background, a flavorant, or a flavorant combination, is added. Flavorants may be natural, nature-identical, or completely synthetic. They are usually in very concentrated forms and give beverages their characteristic tastes. Flavorants can be compared to perfumes inasmuch as they also contribute to the smell of the product, which plays an important role in the general overall sensory perception of the drink.

To round off the taste of the soft drinks, colorants are added to the composition when such coloring is considered essential to the visual impact the drink has on the consumer. Colorants may be natural ingredients but are more commonly synthetic food dyes. They are used in minute quantities individually or in combinations that give us the rainbow spectrum of soft drink colors we see in the marketplace.

A soft drink may be crystal clear in appearance, such as the common lemonade and cream soda. Or a soft drink may be cloudy, such as with citrus fruit-flavored drinks. Thus, we divide all soft drinks into clear or cloudy drinks. The cloudiness is achieved either by the inclusion of a natural cloudy juice or by means of a clouding agent. The latter is usually an oil-in-water emulsion from which fine globules of citrus or other natural oils are suspended in the liquid of the drink and give it the characteristic cloudy appearance. Emulsion technology involved in preparation of these clouding agents is complex and will be elaborated upon in one of the chapters of this companion manual.

In CSDs, of course, an essential ingredient is carbon dioxide gas, which gives the fizziness to such beverages. In some listings of ingredients, this gaseous additive is sometimes referred to as carbonic acid, which forms when carbon dioxide is combined with water. The gas also then contributes to the acidity of the beverage and, as such, plays an auxiliary role as a preservative against spoilage.

This is the basic composition template on which most soft drinks are based. All other items that you may see on the ingredients list of a soft drink label, and there may be many, are mainly auxiliary components that are deemed necessary for the particular type of beverage.

Thus, we may have to include preservatives to prevent microbiological spoilage (just another term for "going off") and increase the shelf life of the beverage. Commonly used preservatives in soft drinks are sodium benzoate and potassium sorbate and, to a lesser degree, sulfur dioxide. The soft drinks industry, and indeed the entire food-processing industry, has one continuous battle against the ever-present hazard of microbiological spoilage when the product stands on the shelf. These preservatives are not bug killers — if they were, they would kill us as well. They are called bacteristatic agents, meaning that they can, selectively, and to a certain extent, prevent further growth of any microorganisms that are, for some reason or other, still present in small numbers in the drink when the packages are filled.

Long shelf-life soft drinks need to be resistant to spoilage. Preservatives or a suitable preparation process can achieve this.

Soft drinks that do not contain preservatives are usually processed under sophisticated hygienic conditions and treated in one manner or another, such as by pasteurization, hot-filling, or ozonation, so that any microorganisms present in the beverage are killed before or during filling. Some soft drinks may contain ingredients to give them a characteristic mouthfeel, that is, a thicker sensation on the palate. These ingredients usually natural plant gums or synthetic thickeners. Still other ingredients may be included for specific brand profiles, such as added vitamins and minerals, as well as gimmicky items, such as energy boosters, isotonic or hypotonic salts, antioxidants, and a plethora of alleged medicinal, nutritional, and health boosters. This then is what soft drinks are made of — looks simple, one would say.

A food technologist gets involved in many activities and discussions while working for a soft drink company.

For a short period during my career, I moved around in an "arty" crowd of television and advertising types. In the inevitable philosophical discussions that abounded in such a social group, I was often challenged as to how I could waste my life in such a mundane and simple profession as "putting bubbles into some sweetened water."

When the mood was upon me, which was not too often, I met such challenges by explaining that to get a soft drink onto a supermarket shelf, fit for consumption for several months, attractive to both the eye and the palate, and at a profit to my employer, was no less an art than that in which they were dabbling. I explained that this art was more complex than meets the eye and involved knowledge and skills covering a broad spectrum of science, technology, and art.

I would then rattle off a volley of subjects, such as the chemistry and physics of water, sugar, flavors, and emulsions; the science of microbiology and living organisms; the art of sensory evaluation; and the concepts of quality assurance, Hazard Analysis Critical Control Points (HACCP) accreditation, International Organiziation for Standardization (ISO) marking, and food legislation. This could possibly be followed by a short dissertation on hygiene, safety, and good manufacturing practices. If I felt that my message was getting over to somebody in the crowd, I would continue on the art of new product development, the innovative ideas involved, and the problem of beating cost restrictions. I would also add some examples of the gremlins and "ghosts in the machines" one encounters in production and how these are eliminated in troubleshooting escapades, by disciplined rational thinking or by pure hunches. Last, but not least, I would talk about cost-savings ideas and innovations, stressing that this was always one of the main criteria for a successful career with an employer.

Such discussions sometimes ended with a show of gaping mouths from my listeners and sometimes a bit of gained respect from them.

So, though soft drink technology is no "rocket science" matter, it is still not as simple as may appear to the uninitiated. It is the aim of this companion manual to deal with some of the interesting and not-so-simple technical matters of this industry.

WHY SOFT DRINKS?

There are many detractors of soft drinks that warn us of the harm that they can cause.

In spite of the abundant consumption of soft drinks all over the world, there is a large lobby of detractors of these beverages. And it is growing from year to year. Soft drinks are blamed for a multitude of health and general well-being problems of modern society. From contributing to obesity and dental caries, through allergy problems and heart ailments, and ending with a multitude of issues from the ever-flowing studies by respected scientific bodies covering numerous human health defects — soft drinks have been blamed for most of these.

I have no real arguments against such detractors, other than to state first, that all of these problems are not restricted to the domain of soft drinks. They apply to many other foods and the eating habits of our modern society.

Second, much like alcoholic beverages and gambling, for example, the detrimental effects of which are even more evident and widely known, millions of people indulge in soft drink consumption for the simple reason that they enjoy them. This enjoyment seems to outweigh the dangers about which detractors warn us. Further on, I will nevertheless endeavor to challenge the anti–soft drinks lobbyists with some facts about these beverages that they seem to ignore or perhaps are not aware.

The human body requires, for its well-being and proper maintenance, a daily intake of between 1 and 2 liters of water. This is a biological truth that cannot be disputed. We either drink water or we die. Water is required for a multitude of reasons to sustain life. It serves as a major building material of our bodies and is the medium in which the chemical reactions vital to life take place. Water is required to flush our bodies of impurities and even toxins that are life threatening. Water regulates our precarious body temperature control systems. It is essential for digestion of food and is the carrier of minerals and micronutrients indispensable to the body. Water is refreshing and uplifting and, as such, has a major psychological impact on our lives, even if we are unaware of its physical function.

A person requires about 1 to 2 liters of water a day for good health and basic survival.

In prehistoric times, Man would establish his communities near a river, lake, or stream, or if he were of the nomadic type, he would make sure he knew where the springs or wells were located. He had to get his few liters of drinking water per day, or he would perish. As civilization grew, Man devised water conduits to convey this precious liquid to the nearer surroundings of home and then into his home — this for the convenience of not having to trek every few hours to the nearby river, stream, or well for a sip. He also designed and created vessels of all sorts to contain water for trips or for storage at home. I would hazard a guess that all the pottery and ceramic artifacts found and so treasured by archeologists in their digging sites were created from this original need to store water at home, at work, at army camps, or to take along with on travels.

So why am I going on about all this? It is simply to state that in our modern times we are no different. We need the convenience of having drinking water available at all times, at work or at play, at home or while traveling, during the day and at night. In our overpopulated world, in our highly industrialized areas or rural communities, in our many poverty-stricken populations, in the crime-ridden streets of our cities, can you imagine us running around looking for streams, springs, wells, fountains, and taps in order to take the needed drinks of water? Can you imagine us lugging around buckets, plastic pails, and what have you, to keep water nearby and on hand? I think not.

Having a soft drink in a bottle, can, or carton is the modern, handy way of having that drink of water when you need it.

So, how did we find the solution to having water in convenient containers, in quantities easy to handle, near at hand when needed, and above all, in potable quality at all times? I submit the theory that it was the early soft drinks industry, of not much more than 100 years ago, that provided the solution. I also submit that it was the CSDs industry in particular.

Any respectable encyclopedia will give you the details of how the CSDs industry developed to fulfill the need for a convenient, handy, refreshing drink in modern societies. I will not go into this history here. But it is perhaps not arguable that the wide variety of soft drink containers we now find prevalent in every niche of daily lives, the glass and plastic bottles, the metal cans, the cartons, and the other packs we are familiar with, are all derived from the crude glass bottles that held the first mass-produced CSDs.

But then you will ask: why soft drinks and not straightforward water? Why all the flavors, the carbonation, and the colors? Why all the sugar and all the other ingredients? One answer could be that now, and for the last decade or two, bottled water is the second largest segment of soft drinks consumption in the world. But why did it not start out as such in the beginning? I will leave the answer for a bit later. I first would like to discuss another issue connected to this entire question.

It is true that simple potable water is the best thirst quencher and refreshing drink available. Ask any weary infantry rookie what he would prefer after a 30 km forced march — a huge canteen of cold water or a bottle of cola drink? Ask the same of an exhausted backpacker or mountain climber. What would be the choice of a dehydrated miner surfacing from his underground work? I am confident that the majority of such people would go for the water. (I suppose

that there would be quite a few who would choose neither and opt for a beer, but that is another story.)

If we need to have our daily water, why not add some zing and tang to it, and have some fun at the same time?

Why then do the usual soft drink consumers at most times prefer these beverages to plain water? I think that the answer simply lies in the inherent hedonistic nature of Man. People are pleasure-seeking creatures. If we have to continuously drink water, why not add a few gratifying elements to this practice? Why not add some exciting flavor sensations and some fizz to tickle the palate? Even add some color for fun. All of these additions appeal strikingly to three of our five senses — taste, smell, and vision. We tend to be self-indulgent when it comes to pleasing sensations. Perhaps even our sense of hearing could also be added to the list. The sound of fizz and bubbles popping from a poured CSD may well be linked to the primordial pleasure of a thirst-quenching drink from a gushing stream of water. And it is, therefore, no wonder that the entire advertising industry is geared to conveying these pleasure-giving sensations in the barrage of images it bombards us with day and night.

The first mass-produced bottled soft drinks were the carbonates of the late 19th century and not bottled waters. Why was this?

This hedonistic factor is possibly the reason why bottled water was not the start of the mass-produced soft drinks industry. The industry started out in the late 19th century in the U.S. in the local drugstore, where people came to drink exciting-tasting syrups mixed with soda water into glasses of fun beverages. These drinks became a fad and a rage, and soon enough, entrepreneurs recognized the business opportunities of mass producing them in specialized bottling factories. Over the following 100 years, the industry slowly but surely developed the complex procedures and sophisticated equipment involved that we are familiar with today: water treatment, sanitation procedures, raw materials handling, bottle washing, carbonation, high-speed filling and packing machines, quality control, and distribution fleets, to name just a few.

It is only recently, in the last 20 years or so, that bottled waters climbed on the bandwagon of the CSD industrial technology and engineering — and this to supply the market of the CSDs detractors and the overly conscious health lobbyists. But even this bottled water industry has not escaped the hedonistic factor mentioned. A large portion of the bottled waters market consists of sweetener-containing, mildly flavored, and carbonated variants.

The paradox of the up-market bottled waters market is that, in spite of the fact that their raw materials and production costs are way below those of most other soft drinks, they cost much more in the shops. I suppose this is a perfect example of the supply and demand principle in economics — many people want what they perceive as a healthier product, and they are willing to pay for it.

I am not at all knocking the bottled waters industry that is currently growing at great leaps and strides. There are many very good products and they deserve the popularity that they are enjoying. I am only trying here to clarify why and how bottled waters did not originate first, or at least parallel to, the CSDs and other soft drinks categories. I am attempting to explain why, despite the essential biological need for a continuous intake of water, CSDs other than bottled waters seem to be the consumers' preferred category.

BENEFITS OF SOFT DRINKS

It is possible that some of the alleged accusations leveled at soft drinks have some truth to them, against which I cannot argue with here. But what I can argue is that soft drinks have certain socioeconomical values and benefits.

At the head of such a list would be that they are a main source of the required body water intake in geographical areas where either there is not enough or no potable-quality water. Such areas could be, on one hand, in densely populated and highly polluted industrial first-world countries. Here it must be pointed out that most soft drinks manufacturers adhere to the principles of treatment and purification of water for their products, and thus, indirectly rendering the locally available polluted water as potable by humans.

Soft drinks can be sources of clean water, carbohydrates, and other nutrients in many parts of the world where these drinks are unavailable.

On the other hand, these areas may be in underdeveloped countries where natural drinking water sources are either far removed or, again, the available water is too polluted. Of not much less importance is that, in our world in which millions of people suffer and die of starvation, soft drinks are simple and immediate sources of carbohydrate nutrition — one glass of naturally sweetened soft drink supplies about 20 g of sugar, which interprets into 320 kJ (76 Cal). A glass or two of a soft drink can therefore supply a small but significant portion of essential nutrition to such unfortunates.

In addition, not only do soft drinks supply the drinking water but also the natural micronutrients it contains. The treated water in soft drinks retains most of its original natural minerals content. In underdeveloped countries, where local water sources are polluted or are far removed from the community, soft drinks thus supply some of the micronutrient minerals that would have normally been unavailable.

Furthermore, many soft drinks are, for marketing purposes, specifically enriched with minerals and vitamins and other nutrients. Once again, soft drinks serve a nutritional function, especially in poverty-stricken and undernourished communities and countries.

Apart from these human health and nutrition factors, let us briefly consider a few socioeconomical and even political aspects of the global soft drinks industry. The 412 billion liters of soft drinks consumed annually are produced in thousands of bottling plants scattered around the world, providing employment for millions of workers. The support industries, such as bottling and canning equipment manufacturers, raw material

The soft drinks industry has a profound economical, social, and even political impact on peoples' lives and on world affairs in general.

producers, transport and cargo fleets, and many others, in turn, provide gainful employment to still more millions of workers. Whenever an "Iron Curtain" or "Berlin Wall" collapses, one of the first new industries providing an immediate economic boost for the countries on the other side is one or more of the international soft drink conglomerates.

This reminds me of a story I heard many years ago. A government leader of a very highly populated and poverty-stricken Asian country made some ridiculous politically motivated demand of an international soft drinks company. It threatened to close the company's numerous bottling operations if it did not comply. The soft drinks company responded to this leader by saying: "Okay, we close, but what will you do with the several hundred thousand jobless people and their families you will have on your hands?" The leader immediately retracted the demand.

I mention these last few items about the benefits of soft drinks in this introduction because I am weary of fielding explanations arguing against the derogatory claims made by the anti–soft-drinks lobbyists, the medical scientists, the nutrition experts, and every other Tom, Dick, and Harry. These people usually all come from the middle to upper levels of society, working in the comfort of their professions, and sitting in the

Soft drinks of all sorts are here to stay. Millions of people need them, enjoy them, and want them. That is an undisputable fact.

luxury of their relatively lavish homes. They carry on in a cloud of ignorance of the soft drinks industry's benefits and profound socioeconomical impacts in today's world. They are unmindful of the millions of people living in poverty, hunger, and disease who benefit from this industry.

1 Brix — The Basics

THE BRIX CONCEPT

I chose this subject for the first chapter in the handbook because Brix is one of the most pivotal technical topics encountered in the soft drinks industry. Generally, Brix (pronounced "bricks") is used to indicate the amount of dissolved solids in a solution. In the soft drinks industry, it is used specifically to quantify the sugar in a beverage, syrup, or juice.

The Brix scale of measurement was established by a 19th century German chemist, Professor A.F.W. Brix, in whose honor the system is named. He found that by immersing a hydrometer in a fruit juice, he was able, from its density, to calculate the percentage of sugar in the juice. The Brix hydrometer was designed with a measurement scale from which fairly accurate sugar content was immediately readable. This was a boon to the European winemakers of the time, as they could assess the sugar content of grape juices and, thus, judge ahead the quality of the wine these could yield.

For the purpose of this handbook, Brix is defined as the percentage of dissolved sugar in a water solution on a *weight for weight* basis and is expressed in degrees Brix (°B). Thus, for example, a 10°B solution implies that in 100 g of solution, there are 10 g of dissolved sugar.

For Brix purposes in soft drinks technology, all dissolved solids are considered as sugar.

Note: The term "mass" is often confused with "weight." Though there is a clear subtle scientific difference between these two terms, "weight" is loosely used when "mass" is intended. In this handbook, "weight" will occasionally also be loosely used, as it is the preferred term in parlance on the floor of a soft drink manufacturing facility.

Special note must be taken of the following fact: In a soft drink, there are, in addition to the sugar, other dissolved solids. They are in extremely small quantities compared to the sugar content but, nevertheless, contribute slightly to the Brix measurement. For pure convenience sake, we consider these to be "sugar" as well, that is, as far as the Brix reading is concerned. The very small error that can be introduced individually by a variety of different dissolved ingredients in different formulations is accepted on a universal basis and is ignored most of the time.

So then, in the soft drinks industry, all products, beverages, syrups, juices, etc., are considered as pure sugar solutions as far as Brix measurements are concerned. There are instances where this error must not be ignored, and these will be dealt with in specific sections of the handbook.

DENSITY

Brix is nothing more than the measurement of the density of a liquid. Density is defined as the weight of a specified volume of the liquid.

$$\text{Density} = \frac{\text{Weight}}{\text{Volume}}$$

It is common to measure the weight in kilograms and the volume in liters. Therefore, as an example, if 1 liter of a sugar solution S weighs 1.034 kg, then it will have a density value of 1.034. (This, by the way, is equivalent to a Brix of about 9.20°B).

Though the Brix hydrometer in the soft drinks industry has been replaced by more sophisticated electronic and optical instruments, the manner in which it measures sugar content will help to understand the relationship of Brix to density.

Figure 1.1 describes the structure of a Brix hydrometer. The Brix hydrometer works on the Archimedes principle of buoyancy, which, simply stated, says:

> A body immersed in a liquid will displace a volume of the liquid equal in weight to the weight of that body.

Now imagine two sugar solutions in water, *A* and *B*. Let us say that in 1 liter of solution *A* there are 100 g of dissolved sugar. In 1 liter of solution *B*, there are 200 g. Sugar is heavier than water. Having more dissolved sugar and less water, solution *B* will be denser than solution *A* — it is "heavier" than solution *A*.

When the Brix hydrometer is placed in solution *A*, it will displace a volume of solution equal to its weight, which we will call *W*, and will sink to a certain level until this volume of solution is displaced. The hydrometer is so designed that a portion of its graduated stem will stick out of the liquid surface. The surface of the liquid will be level with a Brix graduation mark.

The same will happen when the hydrometer is placed in solution *B*. But in this case, the volume of solution equal to the hydrometer's weight *W* will be less, because the solution is denser. The hydrometer will, therefore, displace a smaller volume of solution — it will sink less than it did in solution *A*. The graduated stem will protrude more out of the liquid surface, at a higher Brix graduation mark. Figure 1.2 illustrates the experiment.
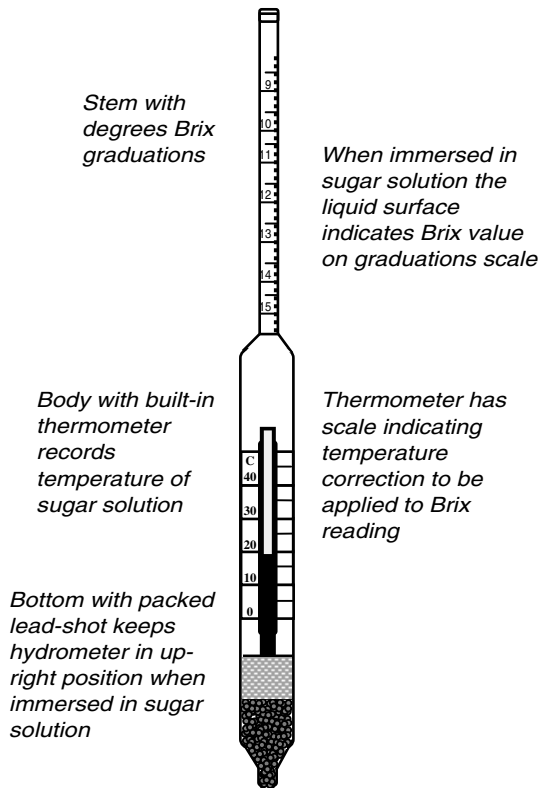
FIGURE 1.1 The Brix hydrometers.
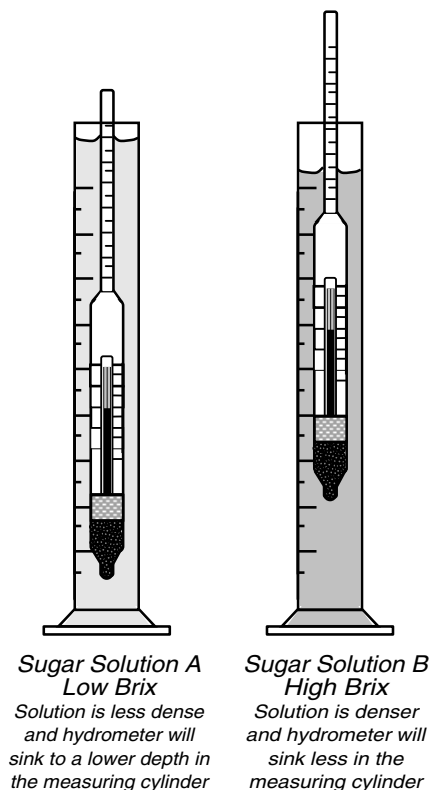
FIGURE 1.2 The Brix/density relationship.

So, in fact, all that the immersed Brix hydrometer is doing is responding, according to the simple law of buoyancy, to the density of the solution. It is the calibrated graduated stem of the hydrometer that is interpreting this density into a Brix value, i.e., the amount of dissolved sugar in the solution. Solution *A* will have a lower Brix reading than solution *B*. This Brix/density relationship is not as simple as it would appear from the above demonstration. Temperature now comes along and throws a spanner in the works.

Elementary physics teaches us that liquids expand with an increase of temperature and contract when cooled. This applies to sugar solutions as well. So, let us take for example the 1 liter of solution *S* (mentioned previously, with a weight of 1.034 kg and Brix of 9.20°B) and place it in the refrigerator for a while. It would cool and contract somewhat — it will no longer occupy a 1 liter volume but less than that. Let us say that the new cooled volume is now 998 ml (0.998 liter). The density would be calculated as follows:

$$\text{Density} = \frac{\text{Weight}}{\text{Volume}} = \frac{1.034}{0.998} = 1.036$$

The density of solution *S* is now 1.036 and not 1.034 as it was before the solution was cooled in the refrigerator. This difference in densities, only in the third decimal place, may seem insignificant, but this is not the case. If the cooled solution had been measured with a Brix hydrometer, the new higher density would reflect an increase in Brix by about 0.6°B. This represents an apparent increase of about 6.5% sugar in the solution. There is, of course, no increase in sugar in the solution. What happened is that the change in temperature increased the solution's density and would "fool" the Brix hydrometer if it were used to measure the sugar content.

Professor Brix was no fool. All Brix determinations are based on a standard temperature of 20°C. The Brix hydrometer has a built-in thermometer that records the temperature of the solution. This thermometer also has a graduated scale of precalculated standard temperature correction units. When the temperature is below 20°C, a correction is indicated as a subtraction from the Brix hydrometer reading. When above 20°C, a correction is added. In the above example, the Brix hydrometer would indicate a subtraction of 0.6°B from the actual reading — resulting in the original 9.20°B value.

20°C is the standard temperature at which Brix values are determined.

As I said previously, the Brix hydrometer is not used much any more — new sophisticated instruments and techniques are employed to determine Brix in the soft drinks industry. The hydrometer was discussed here mainly to demonstrate the relationship between density and Brix, which is still applicable in the new instruments.

DENSITY VS. SPECIFIC GRAVITY

Density and specific gravity are two ferent creatures altogether.

Density is often confused with specific gravity (SG), and as such, these two terms are sometimes incorrectly used. For liquids, SG can be defined as the ratio of the weight of a volume of the liquid to the weight of an equal volume of water at 4°C or other specified temperature.

The "weight of a volume" of a liquid is the liquid's density. Therefore, SG is a ratio that merely compares the density of the liquid to the density of water and tells us how much lighter or heavier the liquid is than water. It does not give us an absolute weight of the liquid. Water at 4°C is at its highest density. At this temperature, 1 liter of water weighs 1 kg. Its density is, therefore, 1.000.

When referring to the SG of a liquid, the temperature of this liquid and that of the water need to be stated. This is normally accomplished by placing a two-temperature annotation following the SG term, such as "SG 4°C/4°C." The first temperature is that of the liquid, the SG of which is being calculated. The second is that of the equal volume of water. This annotation is sometimes presented as:

$$SG_4^4$$

It is well known that water has a SG = 1.000. This is because, by definition, this SG is calculated as follows:

$$\text{Water SG 4°C / 4°C} = \frac{\text{Weight of one liter water at 4°C}}{\text{Weight of one liter water at 4°C}} = \frac{\text{1 Kilogram}}{\text{1 Kilogram}} = 1.000$$

You may ask why I needed to show this calculation — one does not need to be a math genius to know that any number divided by itself will result in the value 1.000 (excluding zero, of course). The reason it is shown is that "later on" I wish to make a point using this same calculation format.

This SG of 1.000 often leads people in the industry to use this figure as the "universal" density of water. They therefore assume that 1 liter of water weighs 1 kg. This is incorrect — it is only true for water at 4°C.

The density of water at 20°C is 0.99717 kg/liter.

In our industry, we mostly deal with product water that is at ambient temperature. It is closer to 20°C, the standard temperature at which Brix is determined, than it is to 4°C. At 20°C, 1 liter of water will weigh less than 1 kg, because it is less dense than at 4°C — it will weigh 0.99717 kg. Therefore, it is erro-

neous to assume that water has a density of 1.000 as many people do — the correct factor to use for water volumes to weight conversion calculations is 0.99717. This is the first point in the confusion of density and SG that I want to highlight.

The second area of confusion between SG and density occurs with sugar solution calculations. These calculations involve, among others, the need to convert beverage, fruit juice, and syrup volumes to weights, from milliliters to grams or from liters to kilograms and the reverse, to convert weights to volumes.

Density is the factor to be used in weight/volume conversion calculations — not SG.

Standard Brix tables are available in which Brix values are given corresponding values of density at 20°C and SG values at 20°C/20°C. We often use these tables to find the factors of sugar solutions at different Brix values in order to calculate volume/weight conversions.

In such tables, at 9.2°B as an example:

> The density column has a value of 1.03379
> The SG column has a value of 1.03672

Which of these figures must we use to convert a liter of the 9.2°B solution to its weight in kilograms? In much the same way as was mentioned above for water, many people opt for the value in the SG column of the table. This again is an error. We must use the density value and not the SG figure. This is because the SG figure is based, by definition, on the ratio of the solution's density at 20°C to the density of water at 20°C.

I will demonstrate this with the previous SG calculation format used for the SG calculation for water:

$$\frac{9.2°B \text{ sugar solution}}{\text{SG } 20°C / 20°C} = \frac{\text{Weight of one liter sugar solution at } 20°C}{\text{Weight of one liter water at } 20°C} = \frac{1.03379 \text{ kg}}{0.99717 \text{ kg}} = 1.03672$$

This simple math equation is presented to once more drive the point home that density should not be confused with SG. It also shows that the SG column figures in the Brix/density tables are nothing more than the corresponding density figure divided by the density of water at 20°C.

So why include the SG values in this table? I suppose the answer lies in the need for scientific completeness by the compilers of such tables — the SG value tells us at a glance how much heavier than water 1 liter of the sugar solution is at 20°C. This could, for instance, tell an engineer how much extra stress will be imposed on a pump, which normally transports water, when it is converted to pump a high-Brix syrup, or something else of that nature.

Using the SG value as the factor in conversion calculations instead of the density is a common error that should be avoided. The difference between SG and density values (only in the third decimal place) may appear to the casual observer as negligible, but when this difference is, for example, involved with Brix readings or calculations, it is significant. This is also true when it is used in cost or yield calculations relating to thousands of liters or tons of sugar solutions.

All of these last notes on the density/SG issue may have been a bit too much to comprehend. If so, let me summarize this issue in a simpler manner, as follows:

> Density is not the same as specific gravity. SG is a ratio that compares a liquid's density to that of water at specified temperatures. Density gives us the absolute weight of a volume of liquid at a specified temperature. When using these terms, it is necessary to state what temperature basis is being used. For this purpose, in the soft drinks industry, the temperature 20°C was established as a universal standard. Because confusion and errors can come about when calculating and dealing with figures for water and sugar solutions such as beverages, syrups, and juices, I have in my career elected to use only the density values at 20°C. I have totally discarded the SG concept in this respect.

The reader is advised to do the same and to especially take note of the magical number *0.99717* — the density of water at 20°C — the weight of 1 kg of water at 20°C. It will reappear in many parts of this handbook.

BRIX/DENSITY TABLES

A Brix/density table is a must for anyone involved with soft drinks technology work.

There are various Brix/density tables for sugar solutions that may be used in the soft drinks industry. These were compiled by different scientific or technical organizations based on empirical data obtained in the laboratory and tabulated in different manners. The density values listed in the different tables may not always be identical for given Brix values. This could be due to experimental technique, rounding off of decimals, and scientific sophistication. The differences are usually minute and not too significant. The rule is to consistently use the same table in all your calculations and thus standardize the differences, especially when comparing with calculations done by another person or organization that used different tables from your own.

I have, for all these years, consistently been using an original table published by the U.S. National Bureau of Standards in 1942. This is the Circular of the National Bureau of Standards C440, *Polarimetry, Saccharimetry and the Sugars,* U.S. Government Printing Office, Washington, D.C., 1942. Since its printing, it has possibly been amended and updated, but basically it has been very reliable. Throughout my entire career, I have never ceased to be repeatedly amazed each time when, based on this table, I have in calculations and laboratory work achieved actual Brix results, with volumes and weights at or very close to the theoretical values expected. This table in simplified form is presented in Appendix 1 of this handbook. I invented my own abbreviated term for "density at 20°C," D20, and will use it from now on in this handbook.

WHY IS BRIX USED IN THE SOFT DRINKS INDUSTRY?

Brix monitoring is the key factor in quality and sugar costing controls.

Apart from the water, sugar is by far the largest component of naturally sweetened soft drinks. It can make up to about 13% of the drink content and gives the beverage its characteristic sweetness level. Interacting with other ingredients, the sweetness determines the overall characteristic taste profile accepted by the consumer. In a particular brand of beverage, any serious deviation from the target sugar content could result in loss of consumer acceptance, the ultimate nightmare of any marketing organization.

Brix is a measure of the sugar content in a beverage and is a major process and product control standard. It needs to be continuously monitored and controlled on line during the production processes involving huge syrup quantities and high-speed fillers packing hundreds of bottles or cans per minute.

A large deviation from the Brix specification can impact negatively on the quality of the drink.

The control measures of Brix have to be frequent and precise — and deviation from target specifications must be minimized. Such deviations could not only impact negatively on the quality of the products but can also be very costly to the business. For the purpose of this discussion, let us use an example of a soft drink that has a target Brix specification of 11.00°B. I think it would be fair to state that some regular consumers would perceive a drop or increase in 0.50°B from this 11.00°B specification.

First, such a consumer would notice a significant change in the sweetness. In addition, the disturbed balance between the sweetness and sourness could be noticed. The overall taste typical to the flavor of the beverage that the consumer has become used to will be suspect. Some discerning

consumers may even interpret the Brix deviation as a change in mouthfeel due to the thickening effect the sugar has on the product.

For the purpose of maintaining the sugar content of the drink at the target Brix, the quality control (QC) standard of most Soft Drinks companies allows for a tolerance of only 0.15°B above or below this target. In our example, therefore, the factory is required to produce and fill the beverage between 10.85 and 11.15°B. This tolerance is allowed to accommodate any acceptable "experimental errors," in actual production processes and in laboratory testing procedures. These could be weight or volume measurements, visual readings, equipment calibrations, and, of course, plain and simple "human error."

This narrow ±0.15°B tolerance range in Brix specification seems to take care of the organoleptic factor — the consumer is not expected to notice the deviation in sweetness and overall taste of the drink within this range.

Now let us look at some cost implications related to Brix. Table 1.1 demonstrates how bottling or canning at the upper limit of the Brix specification would impact on sugar usage and costs. Figures in column *A* are for a small independent plant producing 20 million l per year. Those in column B are for a fairly large plant or for a group of plants within a single-business company that produces 200 million l per year.

The price of white sugar given is in US$ equivalent as supplied to a South African bottler during 2003 in local Rand currency (1US$ = ZAR7.50). The density (D20) values for the two Brix values were obtained from Brix/density tables.

Note: The calculations indicated in Table 1.1 can serve as a typical example of how Brix and density values are used to convert the liters of beverage to kilograms of sugar, as discussed in the previous section of this chapter.

The calculations indicate that producing beverage at the upper limit of the Brix specification would result in a giveaway of about US$15,000 per year for the small bottler and about US$150,000 per year for the larger company. The respective bottlers would not easily ignore these avoidable extra costs in the form of sugar overusage.

TABLE 1.1
The Effect on Sugar Costs by Producing Beverage at 0.15°B above Target Brix

Beverage Production		A		B	
		Small Plant (20 million l/yr)		Large Plant/Franchise Group (200 million l/yr)	
		11.00°B	11.15°B	11.00°B	11.15°B
Annual liters of beverage	a	20,000,000	20,000,000	200,000,000	200,000,000
D20 (from Brix/density tables)	b	1.04123	1.04186	1.04123	1.04186
Brix (expressed as % w/w)	c	11.00%	11.15%	11.00%	11.15%
Annual beverage (kg) — (a × b)	d	20,824,600	20,837,200	208,246,000	208,372,000
Sugar content (kg) — (c × d)	e	2,290,706	2,323,348	22,907,060	23,233,478
Price of white sugar in U.S. dollars	f	0.47	0.47	0.47	0.47
Annual sugar cost in U.S. dollars (e × f)	g	1,068,996	1,084,229	10,689,961	10,842,290
Extra sugar cost at 11.15°B		US$15,233		US$152,328	

The corollary of this simple study is that if the beverage could be ideally produced at the lower allowed Brix specification, yet another US$15,000 and US$150,000 could be saved by the respective bottlers, thus doubling their annual cost avoidances. In practice, it is difficult to consistently maintain a constant beverage Brix at the lower specification figure. Not only is it difficult to do so, but also this would imply that the target specification is actually being "unofficially" lowered. By doing so, out-of-spec low Brix values below the allowed tolerance range will invariably and inevitably be expected. This is where the QC manager will come into the picture and cause havoc with production.

Maintaining the target Brix of the beverage in the lower tolerance range will save a company a lot of money.

The ideal situation in practice is where both QC and production work together to maintain the target filling Brix in the lower range permitted, thus achieving a large portion of the potential cost savings in sugar usage. It goes without saying that producing beverage completely above the Brix specification tolerance range is to be avoided at all times from both quality and sugar cost aspects.

As discussed, the control of sugar content in the ready-to-drink (RTD) beverage for quality and cost purposes appears to be the key technical aspect of the Brix concept in the soft drinks industry. There are, however, more areas in which Brix is of vital importance. I will touch on these only briefly in this chapter, as they will be dealt with in greater detail elsewhere in the handbook.

Most carbonated soft drink operations use the principle of water/syrup proportioning for final beverage filling.

Most if not all carbonated soft drinks (CSDs) operations are based on the principle of blending concentrated syrups with treated water at the filling machines. The filling machines have a piece of equipment called a syrup proportioner or syrup blender. This device may be of different designs. Basically, what it does is feed a high-Brix beverage syrup at a precise specified ratio to water so that a solution at the target Brix of the final beverage is obtained. This solution is then carbonated and dispensed into the bottles or cans at the filler as the final RTD product.

The principle of using bulk concentrated syrups (instead of bulk dilute RTD product) allows for many practical advantages, such as reduction of bulk storage tank sizes and tank storage areas. In addition, high-Brix syrups offer greater resistance to microbiological spoilage on standing. They also allow for quality checks before actual RTD beverage filling starts. There are possibly some other advantages that will be discussed elsewhere in this handbook.

The syrup, often referred to as final syrup, contains all the beverage formulation ingredients, including the sugar, and is nothing more than a highly concentrated beverage (without the gas, of course). It is concentrated about four or five times more than the RTD product. Preparation is at a specified high Brix so that when proportioned with five parts of water, the target Brix of the beverage will be obtained. For our example of beverage at 11.00°B, we would use a final syrup at 54.70°B in a ratio of one volume syrup to five volumes water to achieve the 11.00°B target RTD beverage. (How I arrived at the required 54.70°B value of the final syrup will be explained in Chapter 6 — I do not wish to confuse the reader with other issues.)

The actual target beverage Brix during filling must be set according to the final syrup Brix.

As was the case for the beverage, the Brix of the final syrup must also be controlled accurately for the same purposes of quality and sugar costs control. There is another important factor to mention: The resultant 11.00°B of the RTD tells us that the 54.70°B final syrup has been correctly proportioned with the water. This also tells us that all the other ingredients, particularly the flavors, have been proportioned correctly.

Now consider the following: When preparing the 54.70°B final syrup, an allowed QC Brix tolerance of ±0.20°B is usually applicable in the final syrup quality specification. Thus, a batch of syrup may have a Brix value of between 54.50 and 54.90. At a 54.90 Brix value, syrup mixed in

the prescribed 5:1 water/syrup ratio will yield a final beverage of 11.07°B and not the specified 11.00°B. At what Brix value should the bottling line supervisor target the filling operation — 11.00 or 11.07?

It would seem natural to say keep to the 11.00 official specification. But in order to do so, the operator must necessarily change the syrup/water proportioning device setting by decreasing the syrup volume slightly in the syrup/water ratio. By doing so, he will reduce the sugar content in the drink. He will also reduce the content of all the other formulation ingredients. Of particular concern would be the decreased flavor component that may well negatively affect the taste of the beverage. Therefore, the operator must leave the 5:1 syrup/water ratio intact, and fill to the 11.07 Brix target.

This may seem a case of "splitting hairs." After all, how much can a difference of 0.07°B have on the taste of the drink? I will not debate this point here, as Chapter 17 is dedicated to this issue, and there is more to it than meets the eye. The point

The prescribed syrup/water ratio should never be changed.

that I am trying to make here is that the Brix QC parameter also serves the purpose of ascertaining that the prescribed syrup/water proportioning ratio is strictly maintained. This is to ensure that drops or excesses of flavor and other key ingredients in the soft drink do not occur.

This same principle setting the beverage target Brix according to the final syrup Brix would also apply to final syrup that is at the lower end of the Brix specification range. You may ask why final syrups of the same product should vary in their Brix values. First, as with any quality specification, a leeway tolerance must be allowed to accommodate standard allowable errors in processes and quality testing. There is another reason that has to do with the phenomenon of sugar inversion, which is a subject complex enough to warrant a dedicated chapter in this handbook, and this will be addressed there (see Chapter 6).

Another area in which the Brix concept is important is in that of fruit juices. These juices are often prepared by the process of concentrating the extracted juice of the fruit. The degree of concentration is controlled by the Brix value of the concentrated product. Thus, for example, lemon juice 30 Brix

The Brix of a fruit juice is a key control parameter in juice processing.

indicates that the single-strength natural lemon juice, which is attributed with 7.5% solids content (7.50°B), has been concentrated four times its natural strength ($4 \times 7.5 = 30$). In fruit processing technical jargon, this is sometimes referred to as "fourfold" or "four-times concentrated" lemon juice.

The Brix value that describes a particular juice concentrate also indicates to a user how much sugar it contains and would contribute to a soft drink to which the user intends to add the juice as a formulation component. This value is also a factor in financial respects — the user is paying for the solids content and not the water in the fruit juice concentrate. Downward deviations from specified Brix values will cost the user money.

Still on the Brix and fruit juices subject, occasionally, unscrupulous fruit juice suppliers add extra sugar to the concentrates and thus elevate the Brix values. This can sometimes be detected by a concept called the Brix/acid ratio of the fruit juice. In nature, there is usually a somewhat fixed relationship between the sugar and acid contents of a fruit species. If a juice has been adulterated by the addition of sugar, this ratio of Brix to acid will be noticeably upset, regardless of the concentration level of the juice. Then you could say that extra acid could also be added to maintain the Brix/acid ratio in an adulterated product to avoid detection. Well, this is a never-ending story. It will suffice to say that when such juice adulteration is suspected, there are other ways and means to detect it, so do not try it.

Use of the Brix concept is involved in many other technical aspects of the soft drinks industry. These uses will be addressed in other parts of this handbook, in specifically dedicated chapters.

HOW IS BRIX MEASURED?

The Brix hydrometer —— out-dated but still in use as an inexpensive item.

I already mentioned the use of the Brix hydrometer as the basic classical instrument of measurement. Though it can still be used for Brix measurements, it has some practical disadvantages. The first disadvantage is that it is made of glass and is often easily broken, as is the case for most laboratory glassware. In addition, each hydrometer needs to be periodically and accurately calibrated to prevent inherent potential error due to "wear and tear," such as slight shifting of the internal Brix scale in the glass stem.

The procedure of testing Brix with a hydrometer is cumbersome and time consuming. Also, the visual reading of the Brix value on the graduation scale is subject to individual operator error. Many times, three or four individuals cannot agree on a reading. The Brix hydrometer is, however, not a costly item. For this reason, it is still used in cash-restricted outfits. Brix hydrometers have long since been replaced with more sophisticated and costly instrumentation. Among these are two main types — Brix refractometers and density meters.

Refractometers are accurate optical instruments for measuring Brix by refraction of light passing through a solution.

Refractometers operate on the principle of light refraction. When a beam of light passes from one medium to another, it is bent at a certain angle. As most of us are aware, as we know that an object at the bottom of a swimming pool or a goldfish in a pond, is not exactly where we think it is. This bending of light is called refraction.

The refraction angle of the light depends on the density of the medium through which it passes. If light is passed from the air through a sugar solution, the angle of refraction will depend on the sugar concentration, which as we have learned, determines its density and hence the Brix value. The higher the density, the greater is the angle of refraction of the light. This angle of refraction is referred to as the refractive index of the solution.

In operation, a drop of the sugar solution is placed between two glass prisms. By observing a light source through the lenses of the instrument, a dark line is seen against a background scale of refractive index graduations. The manufacturers of refractometers for the soft drinks industry have made life easy for us — this scale has been converted directly into Brix values. The reading is almost instantaneous, and this is the great advantage over the cumbersome hydrometer.

A correction is required if the Brix is not read at 20°C.

Because the refractometer is actually measuring density, the reading is temperature dependent. As Brix measurements are standardized to 20°C, a temperature correction must be added or subtracted from the actual reading, much the same as is done with the hydrometer. Tables of these temperature corrections for refractometer Brix readings are given in Appendix 2.

The manufacturers of refractometers again have made life easy by designing all types and models of instruments to meet the required needs of the users. These types and models include variations and combinations thereof as follows:

Handheld portable models
Bench models
Digital displays of Brix values
Built-in automatic temperature correction to 20°C

The user will choose the type to use based mainly on a compromise between the available budget allowed versus precision required and convenience desired.

When a refractometer is used for Brix determinations of sugar solutions with high acid contents, such as fruit juices, another correction must be added to the reading. This is the acidity correction, which will be addressed in Chapter 7 of this handbook.

A more sophisticated type of instrument for Brix determinations is the density meter. This instrument operates on highly complex physics and chemistry principles involving U-tube oscillation and sound velocity factors, the details of which I will not attempt to describe as these are simply out of my league. This I would leave to the actual suppliers' representatives, should you need more information.

Special density meters for the soft drinks industry are highly sophisticated instruments — and are very expensive.

Again, the suppliers of these instruments, aware of the lucrative business opportunities in the megabucks soft drinks industry, designed models dedicated to Brix determinations of sugar solutions. They give almost instantaneous, four-digit, temperature-corrected Brix displays and printouts, with facilities for multisample testing. Suppliers have even gone so far as to design models that give simultaneous readings of fresh Brix, inverted Brix, and degree of inversion (subjects that I will deal with in Chapter 6 on "advanced" Brix matters).

These density meters are considered the "Rolls-Royces" of Brix-determining instruments and are very high priced, well into the tens of thousands of dollars category. Still, companies that appreciate the cost factors of "over-Brixing" their huge volumes of soft drinks produced annually will not hesitate to invest in these density meter types.

CHAPTER REVIEW

In this chapter, I attempted to demonstrate the importance of the Brix concept to the soft drinks industry and to briefly explain some of the basic technical factors involved. Most of this chapter's contents are probably well known to many experienced technical readers of this handbook. If, however, even one little item has shed some new light on Brix matters to such readers, then the aim of the handbook has been achieved.

There are a few additional, more complex aspects of the Brix in soft drinks that I will return to in later chapters. I chose to do this, as I suspect that the less knowledgeable reader may already be overwhelmed with the few technicalities of the Brix concept described in this first chapter.

I will end this chapter with a Brix anecdote I never tired of telling to technical people in the soft drinks industry, especially over a beer or two.

Many years ago, when I joined a bottling company as a factory chemist, I was sharing an apartment with my brother, in whose room resided the single telephone we had. At the time, my bottling plant was engaged in the preparation of syrups using a novel process that involved a particular critical Brix determination problem. Night-shift supervisors were instructed to call me out if the problem occurred, regardless of time of night, and not to continue with the process until I had arrived to sort it out.

"Of Bricks and Bricks...."

For about a few weeks, every second or third night I received a callout, mostly in the early hours of the morning. Obviously, the phone rang on the bedside table in my brother's room, and he, in dazed half-sleep mode, would handle the call as follows:

Brother: Yes?
Plant supervisor: Mr. Shachman?
Brother: Yes! What is it?!
Plant supervisor: The BRIX is wrong!!!
Brother: What??!!

Plant supervisor: The BRIX is wrong!!!
Brother: The BRICKS are wrong??!!
Plant supervisor: Yes, damn it! The BRIX is wrong!!! Come quickly please!
Brother (calling out to me in my room): Maurice, the BRICKS are wrong again!
Me (muttering to myself): Oh no! This damn Brix business!

With that I would get up, get dressed, and drive to the plant. I would do my thing at the factory and return after some time to the apartment and go back to sleep.

This was the standard routine for a few times, until after one early morning callout, I returned to the apartment to find my brother sitting half asleep in the kitchen sipping a cup of coffee. With a look of total incredulity, he asked me what was going on at my factory. Was I working as a food chemist in a soft drinks factory, or was I working as a builder? What is with all this "bricks" nonsense?

Needless to say, I postponed my explanation until later in the day. I did not rag on my brother about it, because even I, a university science graduate, had never heard of the Brix expression prior to joining the soft drinks industry.

2 Taste Testing — Theory and Practice

THE SENSE OF TASTE

In physiological terms, the sense of taste can be described as the sensations we perceive in the mouth when a food or drink is consumed. This is basically accomplished by chemical interaction of food components with taste sensory tissues on the tongue and other areas in the mouth. We commonly call these the "taste buds."

Taste testing a food means evaluating the impact it has on all of our senses.

However, the overall sensory impact experienced when a food is tasted involves more than just the actual individual taste sense. It is often more of a combination of taste with several additional senses — olfactory (smell), visual, touch, and sometimes, even sound. Think about it this way.

Would freshly squeezed orange juice taste like orange without the aromatic impact of the volatile citrus oils in the peel and the juice itself on our sense of smell? Would it taste like orange if, for some absurd reason, it was deep purple in color? Would we not think something was wrong if we did not feel and sort of "hear" the small little juice sacs pop in our mouths as we swirl the liquid around our tongues? What if the juice was as thick as porridge? Or it was as thin as water? Or it was slightly warm? Then there is the psychological factor: Would it taste the same if presented for tasting in an ornamentally cut crystal-glass goblet instead of in a polystyrene cup? I think the accumulated answers to these questions would indicate that the overall taste of the juice would be an intricate combination of several senses and psychological factors.

As a result of this, food technologists tend to think in terms of a drink's "sensory properties" when evaluating it for taste. These are the different sensory perception factors that impact on our brain: sweetness, sourness, flavor, mouthfeel, color, clarity, etc. In a carbonated soft drink, the gas content or its "fizziness" is a critical factor as well. In addition to the sensory factors, the temperature and presentation of the tested product would also play a significant part in the test results. Therefore, for our purposes, a "taste test" would not only mean how does it taste but would also refer to a general evaluation of its sensory properties.

Taste testing is evaluating all the interacting sensory properties of the food.

WHY TEST FOR TASTE?

This is really a ludicrous question to ask of anyone in the food business. The answer is monumentally simple: A soft drink may adhere to all of its other quality specifications — Brix, acidity, color, turbidity, preservative level, microbiological specification, nutritional values, etc. — but if it does not taste like it is supposed to, it will be rejected by the consumer. It will not sell. You do not have to have an MBA degree to know this simple fact. There is no need to elaborate any further on this subject.

Taste is king when it comes to consumer acceptance.

WHEN DO WE DO TASTE TESTS?

Taste tests are either for routine or for special purposes.

Taste tests are performed at variable levels of sophistication and on different occasions. From the simple, routine, repetitive online tasting to confirm that what is being filled is what it should be, through the periodic troubleshooting tests when taste defects are suspected online (in the warehouse or in the trade), to sophisticated taste testing for new product development and consumer research surveys.

Whatever the occasion for a taste test, two main principles must be considered:

- The type of test to be used
- Absolute, nondeviating adherence to the basic rules of the science of taste testing

These will be elaborated upon in the ensuing sections of this chapter.

TYPES OF TASTE TESTS

Only a few basic types of tests are needed.

Most textbooks on sensory evaluation (taste testing being such) describe and prescribe a multitude of types of tests for, again, a multitude of occasions and purposes. The same can be said of sensory evaluation courses and seminars. I have no argument with such book writers and course presenters — that is their professional specialty, and all respect is due to them.

However, during my entire career, I found the need for no more than a few basic test types and would be bold enough to say that they have adequately met the requirements of the day and successfully served the purposes targeted.

ONLINE TASTE TESTING

Online taste tests during filling are a must.

Tasting soft drink product coming off the filling line is not a special type of test, insofar as the procedure and result evaluation are concerned. It is usually a frequent (half-hourly?), prescribed, periodic routine quality control (QC) test involving no more than a sip of the product being filled to confirm that it is what it is supposed to be and meets the basic taste expected.

These tests are usually performed by QC operators who routinely collect samples off the line and bring them to the laboratory for other online tests as well, such as Brix, carbonation, net content volume, package inspection, date coding, etc.

Suspected taste defects often lead to more sophisticated taste test methodology.

Online taste testing by the filling machine operators is also a possibility. This is often practiced by companies with operators who have been well trained not to return bottles or cans from which they have tasted product back onto the line. In most cases, product can be tasted from reject packages, such us under-filled bottles or cans, bottles or cans with faulty labeling or sealing, etc. These packages should, in any case, not be returned to the line and can serve as samples for taste testing, as there is usually nothing wrong with the contents.

The online taste test consists merely of a quick check of a small amount of product by the operator, QC, or line worker, who, by virtue of having tasted the particular product so many times before, has developed a "memory" of what the taste should be like. He or she is able to immediately detect if something is wrong with the product, such as the sweetness and flavor levels, carbonation, fermented taste or odor, and any other distinctive off-note taste. When such occur, the operator will usually seek confirmation from a colleague or supervisor before QC or production managers are

brought into the picture. If managers are convinced that there is a taste defect, then the fun starts: what, where, when, how, and usually above all — who?

This simple type of taste test already brings to the fore one of the basic rules of any taste-testing procedure: With taste issues, you should never make an outright decision entirely on your own. It is always better to have a consensus of opinion. This will be elaborated upon later in the chapter.

THE EXPERT TASTE PANEL

The expert taste panel type of taste test is performed by a group of people the test convener considers as experienced and skillful in taste testing, especially in the particular type of product being tested. Such people may have acquired these skills and experience from specific familiarity with the product or years of practical taste-testing know-how, or simply may have proven to have a keen sense of taste in previous testing sessions.

An expert taste panel type of test may be used for the following purposes:

- When a taste problem is suspected and a satisfactory consensus of opinion has not been achieved in first stages of the investigation
- When in new product development, the formulator requires guidance as to his or her progress in the project
- When the newly formulated product is submitted for final approval
- When a competitor's product is examined for general evaluation purposes
- When any other taste test requires individual opinions of skilled and experienced taste judges

The expert taste panel taste test is a sort of "brains trust" meeting in which an informal group discussion is conducted under the guidance of the convener. The latter may throw in questions in an ad lib manner and make notes of the responses. Alternatively, preprepared blank questionnaire sheets may be submitted to the panel, in which specific issues are to be focused on by the individual participants with or without group discussion. The manner in which the session is conducted depends on the convener's aims and expectations. It is up to the convener to analyze the results of the session input, submit recommendations, or make decisions, as the case may be.

There is no prescribed rigid format for the expert taste panel taste test.

The tasting session may be conducted in a group or with each panelist separately. For the best results, the discussion should be held in group format. The expert taste panel is an excellent in-house means of obtaining information on a taste issue, whether it is one of quality problem solving, new product development, or other matters. It is often a preamble to further taste tests of one of the other three main types still to be discussed.

It should be noted here that the expert taste panel is the only type of taste test for which the format and the manner in which it is conducted are not prescribed in any strict and rigid set of rules. This all depends on the convener's aims, skills, and ability to draw information based on which actions and decisions are to be taken.

THE TWO-SAMPLE PREFERENCE TASTE TEST

This taste test is also sometimes referred to as the paired comparison test. For convenience sake, I will call it the two-sample preference taste test in this handbook. Each judge is presented with two different samples and is requested to state which one is preferred. (See Figure 2.1.)

This test aims to determine whether a known difference between two samples will result in a significant preference for one of them.

Two tasting cups A and B

A   is test sample

B   could be the reference
     sample or a different test
     sample

FIGURE 2.1 Two-sample preference taste test.

The aim of the two-sample preference test is to determine if a significant preference is displayed for one of two samples, between which a distinct and definite difference exists. Preference simply means that the taster likes one more than the other. The difference (or differences if there are more than one of these) may be minute or substantial. The primary purpose of the test is to measure the extent to which the known difference may impact the tasters' preference, if any at all, for one sample or the other. Two simple scenarios are given to demonstrate how and why this type of preference test is used.

In the first, imagine the following scenario:

You have reformulated a new lemonade to replace your company's standard product. The new product has been requested for the following reason: The flavorant of the standard product has become unavailable and needs to be substituted.

Your brief from marketing states that the new product's taste profile should not deviate too much from the standard lemonade in order to avoid tampering with the present favorable consumer acceptance of the current product.

You have, after numerous trial formulations (and perhaps even several expert taste panel sessions), come up with a suitable candidate product and want to put it to the test.

In this scenario, the two-sample preference taste test is called for. You will now perform it using the standard lemonade as your second sample, the one to which the first will be compared. This may be first performed as an in-house taste test with 20 to 30 judges (we call the tasters involved in the test the "judges"). Depending on the results, you may want to do the test with consumers in the marketplace — about 200 to 300 judges.

If performed strictly to the basic set of rules of the two-sample preference test, still to be discussed, the results of the taste test will tell you one of the following:

- There is no significant preference for either one of the two samples. Therefore, it would be reasonably safe to replace the standard lemonade with the new formulation. Both the marketing manager and you can sleep well at night.
- There is a very significant preference for the standard lemonade sample. In this case, you would not recommend substituting the current product with the new one. It is back to the drawing board for you.
- There is a very significant preference for the new lemonade. At first, this may seem to be a good thing — the new lemonade is better than the standard. However, what does this actually mean? The test is telling us that the preference for the new lemonade is probably due to its difference factor, the new flavorant being used. This difference must be striking to cause a very significant preference for the new product. This is not in accord with the original marketing brief that stipulated a not-too-big deviation from the standard lemonade's taste profile so as to avoid any fiddling around with the currently established consumer acceptance of the company's lemonade brand. It would now be up

to marketing management to decide whether to take a risk in launching the new lemonade or to formulate another product that will not be too different in taste profile.

This scenario showed that though the desired result, a "no significant preference," is aimed for in the lemonade two-sample preference test, other results may be obtained that could throw the proverbial cat among the pigeons. The second scenario is as follows:

Your company does not have lemonade in its range of products. It wants to launch a product that could compete well with competitor Company X's lemonade, which is the current market leader. The marketing brief to you, the new product development manager, stipulates that the new product can be of any formulation that equals or improves upon the taste profile of the competitor's lemonade (provided, of course, that its ingredients cost is within limits stated in the brief).

For this purpose, you juggle around the specifications of the new lemonade, the Brix, acidity, carbonation, and flavorant combinations until you come up with what you think is a good candidate formulation.

In this scenario, the new lemonade is totally different than that of the competitor's product. You made it less sweet, tarter, and fizzier, and added a hint of lime to the overall lemon flavor.

Will it compete with the competition's lemonade brand leader? A two-sample preference taste test is again most suited to this scenario. It is performed with the two samples — the competitor's product and your newly developed lemonade. The following are possible results:

- There is no significant preference for either one of the two samples. Therefore, it would be reasonably safe to assume that the new lemonade could fare well against the competition product. Further action needs to be thought about.
- There is a very significant preference for the new lemonade sample. The road is clear to confidently launch the new product.
- There is a significant or very significant preference for the competitor's sample. It is back to the drawing board for you.

These two scenarios sum up the general way the two-sample preference test is chosen and what the results could mean. There are many variations on this theme, but generally it can be said that with a two-sample preference test, you are looking for either a nonpreference situation or a significant preference result. It all depends on the aim of the test. Later in the chapter, I will describe how the two-sample preference test and other types of tests are performed, how the results are evaluated, and how conclusions are determined.

THE TRIANGULAR TASTE TEST

This test, commonly known as the triangular taste test, gets its name from the fact that three samples are used in the taste test. The aim of the test is to establish whether one sample is significantly different than a second sample. We are not trying to establish any sort of preference for one or the other sample, as was the case in the two-sample preference test. We are trying to establish the probability of the consumer being able to detect a significant difference. This difference may have unwittingly been imparted to a product, or it may be a deliberately introduced difference.

This test aims to determine if the tasters can detect a suspected or known difference between two samples.

In the triangular taste test, the tasting judge is presented with three samples of product, but they only represent two products. Two of the samples are of the same product, and the third sample is of another product. Sound confusing? Let me put it in simpler terms: Two samples are the same,

Three tasting cups in samples set.

X is sample being tested
A is reference sample
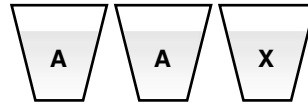
The set of samples can either be:

Two test samples and one reference
sample
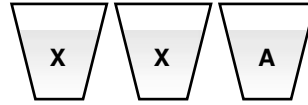
OR

Two reference samples and one test
sample

FIGURE 2.2 Triangular taste test.

and one sample is a second product — it is often called "the odd man out." The tasting judge is told this fact. Figure 2.2 illustrates this three-sample issue.

Each judge is requested to taste all three samples, one by one, and then is required to indicate the one sample that is different than the other two, the odd man out. The number of "correct" choices made in the total tasters' population is the key to the triangular taste test.

To demonstrate the principle of how and why the triangular taste test is used, I will again use a hypothetical scenario (only one this time), as follows:

You are the quality assurance manager of a bottling plant.

One of the QC inspectors, on a new shift, reported a strange off-taste in the soda water. You establish that during the course of the day, when converting from a raspberry flavor to soda water, the lines to the filler were inadequately rinsed out. You suspect that some of the soda being bottled may have a trace taste of raspberry. Numerous tasting sessions with your staff in the laboratory did not result in an unanimous opinion regarding the presence of a faint raspberry note in the soda. Some thought it was there, while others could not detect any off-taste.

By this time, about 1000 2-liter cases have been filled. You stop the bottling line, isolate the suspect cases, and call an urgent production management meeting to discuss the matter. The production manager, on tasting some suspect product, is adamant that there is no raspberry off-taste in the soda. He insists that the 1000 cases are okay and must be released to the company warehouse. His production supervisory staff members support his opinion.

The marketing manager is brought into the meeting and cannot make up his mind if the faint raspberry taste is there. He looks at you and asks, "What next?" Do you think that this faint "there and not there" raspberry note would be picked up by consumers? Would it be picked up by many consumers? Would it be picked up by all consumers?

You say that the only way to decide this is to conduct an in-house triangular taste test with at least 30 judges.

The triangular taste test is the most reliable way to handle this type of scenario.

You perform the test within 3 h, and the results show that 19 of the 30 tasters correctly chose the odd man out sample. This indicates a very significant difference between the suspect sample and a standard-quality product from a previous bottling run. The result implies that the probability of consumers picking up the raspberry note is significantly high. No one argues when you recommend dumping the 1000 cases.

Had no significant difference been detected, it would be reasonable to assume that the majority of consumers would not detect the suspect raspberry note in the soda water. It would, however, be wise to repeat the test again with perhaps more and other tasters, with the same result, before releasing the product into the trade. This scenario demonstrates when a triangular taste test, and not another type of test, should be used. An expert panel taste test in the form of the QC staff and production meeting was used, but to no avail. A unanimous consensus could not be arrived at.

A two-sample preference test session would be pointless, because a preference is not being searched. (For all we know, the suspect defective soda may have been preferred.) Admittedly, we could modify a two-sample preference test session by telling the judges that one sample is defective and asking them to try picking it out. However, the triangular taste test is more suitable. The "two the same and one different" setup heightens the tasters' sensory awareness and increases their searching efforts to find the odd man out.

This "triangular" setup makes statistical evaluation of the "correct" sample choices more stringent in establishing the significance level of the difference in samples. It also reduces the chance factor. This will be explained in detail later.

The triangular taste test is commonly used in such scenarios where a defect in a product is detected. Then, it is questioned whether it is serious enough to warrant dumping the product or if the product could go into the trade without seriously affecting consumer acceptance. This, of course, is applicable to defects in quality that endanger only the brand's image, not the consumer's health. Such defects are usually minor (e.g., a slight color difference or slight carbonation or Brix deviation) but can be costly to the bottling company in dumping of stock or product recall. The triangular taste test that results in a nonsignificant difference result usually indicates that most consumers will not pick up on the suspected defect.

> Remember that consumers, unlike the judges in the test, are not told about the suspected harmless defect and are not being asked to search for it.

The use of the triangular taste test is handy when company management (marketing, production, or even the managing director) challenge a QC manager's recommendation for product rejection. A very significant difference result from the triangular taste test will usually quickly change their minds.

The triangular taste test can be used for purposes other than defect detection. One example that comes immediately to mind is that of launching a new formulation for a current product that is doing extremely well in the market.

The new product could be, for example, a revamped, less costly modification of the existing one. The key criterion is that it must match the current product's taste profile. The consumer must not be able to detect a difference.

When trying to establish a good match of one product with another, the triangular taste test is the most suited. A "no significant difference" result will say it all.

Matching a product perfectly is not an easy task at the best of times. To match and reduce its ingredients cost is extremely difficult. If a close approximation is achieved that can be demonstrated by a preference test (with a no significant preference result), then a further triangular taste test session with a no significant difference evaluation could put the "cherry on top of the cake" of confidence in launching the new-formulation product.

THE HEDONIC RANKING TASTE TEST

Hedonic is derived from the Greek language and means "pleasurable." This test can involve several different samples at one session. I would not recommend more than four, because the taste buds tend to get confused after some time (Figure 2.3).

This taste test is based on the judges rating their like or dislike of the sample by means of a ranking scale.

Up to maximum 4 samples per tasting session.

Samples A, B, and C are samples being tested.

D may be a reference sample or different test sample itself.
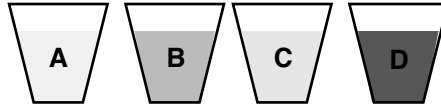
FIGURE 2.3 Hedonic ranking taste test.

The hedonic ranking test measures the tasters' levels of liking a drink based on a ranking scale. This scale enables the taster to communicate the feeling of like or dislike for the sample tasted. The test is simple. The taste judge is asked to taste the sample and rate his or her like or dislike by checking one of the levels of the scale presented in the test questionnaire. This scale usually contains nine categories ranging from "like extremely" at the top to "dislike extremely" at the bottom. Each category, from the top downwards, is attributed a score from nine down to one. After the taste test, the scores are evaluated statistically by rank analysis, and the sample is rated as to its overall like or dislike by the tasters participating in the test.

In my career, I simplified the hedonic ranking scale to five categories. In addition, I used the simple arithmetic average of the sum of all the scores as the sample's final score of the test. Pure sensory evaluation scientists and experts may shudder at these simplifications, but they served me well on the occasions I used them.

I also used different scale categories, depending on the aim and nature of the test performed. Figure 2.4 gives some examples of such categories and their scores. The test is simple as far as the taste judge is concerned. All that is asked is sincerity in ticking off on the ranking scale how much the sample is liked or disliked — nothing more.

Purposes for the use of this type of taste test may vary, some of which are as follows:

• Evaluating several new product development samples
• Comparing company brands against competitors' products
• Choosing a new line extension from an array of different potential flavors

In an hedonic ranking test using the five-category scale "very good" to "very bad" as an example, I considered a sample with an average rank score of 3.5 to 4.0 (fair to good) as a reasonable candidate for further action or decision making. A sample with an average score of over 4.0 should be considered as very favorable.

TASTE-TESTING TECHNIQUES AND RULES

It is far beyond the scope of this handbook to elaborate on taste-testing techniques and rules for valid and meaningful taste tests. For this information, it is suggested that company staff charged with critical taste-testing activities attend basic sensory evaluation courses. At least one standard textbook on sensory evaluation should be on such a person's bookshelf.

Below, I will offer a brief overview of basic salient taste-testing principles of the three main types of tests described above. Most of the techniques and rules are common to all of these tests. Where one type of test has particularly relevant aspects, these will be specifically indicated.

Application	Score	Category
Can be used for rating a newly developed product to match a reference benchmark sample.	5	A very good match
	4	A good match
	3	A fair match
	2	A poor match
	1	A very poor match

Application	Score	Category
Can be used for a straightforward general appraisal of the sample.	5	I like it very much
	4	I like it
	3	I neither like nor dislike it
	2	I dislike it
	1	I dislike it very much

Application	Score	Category
Can be used to rate a single attribute of the drink, e.g., color, sweetness, tartness, etc.	5	Very good
	4	Good
	3	Fair
	2	Poor
	1	Very poor

This graphic hedonic scale could be used for kids (or just for fun!).

5 I like it very much

4 I like it

3 I don't like or dislike it

2 I dislike it

1 I dislike it very much
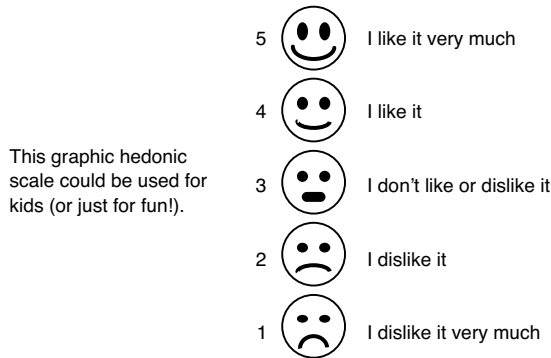
FIGURE 2.4 Examples of some hedonic ranking scales and relevant scores.

BALLOT SHEET

The document presented to the taste judge for completion is sometimes called a ballot sheet, as a kind of "vote" is required from each taster, be it a preference, odd sample choice, or a rank rating. The ballot sheet should be designed to meet the aim of the taste test. It should be simple and not intimidate a taster. Instructions must be brief and precise.

The taste test document is called a ballot sheet. It is the key to a successful taste test.

Examples of such ballot sheets are given in Figure 2.5, Figure 2.6, and Figure 2.7. Note that these are examples of ballot sheets for a taste test designed to take place in-house at a dedicated taste test station, where there are no time restrictions. These ballot sheets contain short but precise instructions for the test. The judges can then be left alone to do the test and complete the sheets individually.

For mass consumer tests, such as in a busy shopping mall, people passing by are approached by an assistant and requested to take part in the test. The assistant gives brief verbal instructions

TWO SAMPLE PREFERENCE TASTE TEST

LEMONADE

You have been presented with two samples of lemonade beverage marked with the following code numbers:

| **527** | | **693** |

Taste the two samples, starting with the one on your left. Compare the taste of the two samples and indicate the one you like best by writing its code number in the blank block below:

Please remember that this taste test requires that you must state you choice of one of the samples even if you do not have a clear preference. This means that even if you find it difficult to chose which one you like best you are requested to choose one even if you have to make a guess.

If you wish you may make a short comment of why you like the one you have chosen:

_____

_____

_____

_____

Name : ....   Date: ....

FIGURE 2.5 Example of ballot sheet for two-sample preference taste test.

on how to perform the test and then also checks the sheet with the judges' feedback regarding preference and the reasons for it. The assistant also fills in other data regarding age, gender, demographics, etc.

The hard-copy completed ballot sheet is a "priceless" piece of paper, for it has all the information and data from the test that will be required for analysis, decision making, and possible future action. Treat it with respect, and do not lose it.

Tasters

The tasters, who I prefer to call "judges," must be people who are willing to participate in the test. It is meaningless to persuade a person who is not interested in doing the taste test. Such a person can only skew the end result if he or she is not sincere and honest with the taste test feedback. The judge must not have any tasting or smelling problems such as can occur when having a cold or the flu (also just after consuming some hot curry dish). If language or literacy difficulties are anticipated with some judges, then an interpreter or guide will be required.

TRIANGULAR TASTE TEST

SODA WATER

You have been presented with three samples of soda water drink coded as follows:

| 186 | 623 | 594 |

Two of the samples are <u>of the same drink</u> and the third is a <u>different one</u>.

Please taste the three samples, starting with the one on your left, and try to identify which sample is the different one. In other words try to determine which sample is the odd one out.

If you cannot identify this different sample you are requested to make a guess.

When you have identified the different sample write its code number in the block below.

If you wish you may comment below on why you think this sample is different to the other two samples:

_____

_____

_____

_____

Please fill in your name:

Name…………………………………………………   Date………………………..

THANK YOU

FIGURE 2.6 Example of ballot sheet for triangular taste test.

Presentation of Samples

Samples should be contained in identical, neat-looking cups filled to the same levels with the beverage to be tasted. They must be presented in the sequential order for tasting as stipulated in the ballot sheet and coded accordingly.

A critical factor in taste testing is temperature. The samples must be at a pleasant cool temperature — there is nothing worse than a warm soft drink.

It is of paramount importance that all samples in a tasting set are at more or less the same temperature. This is true for all three types of tests described. A difference in temperature between samples in a set will skew the results and render the entire taste test meaningless:

A discernable difference in temperature between samples in a taste-testing set will render the entire test as meaningless!

COLA - RANKING TASTE TEST

You have been presented with three cola beverage samples. These are coded as follows:

| 634 | | 781 | | 295 |

as listed in the Ranking Table below.

Please taste each sample, in the order as listed above, starting from the left. After tasting each sample enter your rating of the sample as a cola beverage in the Ranking Table below by placing an X in the applicable block

RANKING TABLE

Place a cross (X) in the applicable column to indicate how you rate the test sample as a cola beverage.

	Test Sample Code	634	781	295
5	I like it very much			
4	I like it			
3	I neither like nor dislike it			
2	I dislike it			
1	I dislike it very much			

If you have any comments please list them below:

....
....
....
....

Print Name : ………………………………………..   Date: ………………………….

FIGURE 2.7 Example of ballot sheet for hedonic ranking taste test.

- In an hedonic ranking test, the cooler sample will invariably be rated more favorably based on temperature alone and regardless of its other attributes.
- In a two-sample preference taste test, the cooler sample will usually have a preference advantage over the warmer one.
- In a triangular taste test, a difference in temperature between the reference sample and the test sample would be disastrous for the taste test — identifying the odd man out would be child's play.

Differences not related to the actual test must somehow be nullified.

As for temperature, differences between samples in a taste-testing set, other than those differences being tested for, will also make a mockery of the taste test. Let me explain this a bit further.

In a two-sample preference taste test, where, for example, two samples are being compared for overall taste, if one sample has gone flat, that is, lower in carbonation than it should be, it could skew the preferences of the tasters in either way. Judges who naturally like low gas content will favor the flat sample, and those who like their drinks very fizzy will favor the other sample.

In a triangular taste test, again, the identification of the odd man out will be easy, for the wrong reason. Another typical difference to be avoided in a triangular taste test would be in color or cloud intensity (turbidity). If the samples are different in these respects, even slightly, the visual difference must somehow be masked. This can be done by tasting in "darkroom light" or by covering the cup in aluminum foil and having the judge sip the hidden beverage from a straw — anything that will hide the visual difference.

Sample Coding

Samples should not be coded with simple one-digit numbers or alphabet letters. It was well established that such coding can subconsciously bias a judge's decision in any type of taste test. People have "lucky numbers" and favor or shun different alphabet letters (especially if they turn out to be the taster's initials or those of his or her boss). I hope the reader does not consider this as nonsense. I will relate a short story about it at the end of the chapter.

Coding samples must be without any possible bias for the judges.

In sensory evaluation, a common method of coding samples to avoid any tester's subconscious bias toward a sample in a taste-testing set is to use random three-digit numbers for the samples, e.g.:

The "random three-digit numbers" system is the acceptable coding method.

164
852
296
370

The person conducting the taste test has the cups labeled with these three-digit numbers and has a method, in his or her head (or on a piece of paper in a pocket), whereby he or she and assistants can instantaneously identify the sample by merely looking at the numbers. (To give examples of such tricks would be giving the game away.) They would always be able to identify the odd man out in future triangular taste tests (or be barred from being judges in such tests).

How does it work?

One clue will give you an idea of how to identify what sample is which product: choose the middle digit as your identifier — got it? Or choose an even number as the reference sample and an odd number as the test number. The identification method is up to you as the organizer of the taste test. Remember not to allocate the two identical samples in a triangular taste test the same three-digit number (for what I hope are obvious reasons).

Where does one find a list of random three-digit numbers? Well, in the "old days," we used to look up the last three digits of five-digit logarithm tables, which are considered by mathematicians as satisfying the randomness principle. But, who uses these tables nowadays? In our modern computer-ruled times, we can download random number generators from the Internet.

Tasting Sequence

When tasting several samples in one test, the first sample tasted may have a slight dominant impact on the judge's senses. Therefore, it is standard practice to alternate the first sample tasted between the different judges. One should aim at achieving a fifty–fifty split between the first tasted sample in a two-sample preference taste test and as much rotation of the first sample as possible in an hedonic ranking test. In a triangular taste test, half of the sets should be comprised of two reference samples and one test sample, and the other half, the reverse, two test samples and one reference sample.

Tasting sequence is of paramount importance.

In order to control this first-tasted sample system, you will need to establish a rigidly adhered to methodology of tasting the left-hand sample first or the right-hand one — the choice is yours. In a triangular taste test, never instruct the judge to taste the middle sample first. This will invariably make him think that it is the odd man out — trust me.

Significance Level

Previously, I often mentioned "significance level," "significant difference," or "preference significance." What is all this about?

Caution: This issue is somewhat complicated. If you want to be brave, carry on reading. If not, simply skip over to the summary at the end of this section and accept the fact that significance tables are required to determine if a taste test result is significant and to what degree.

Establishing the significance of a preference or a difference requires statistical math.

This section deals with the evaluation of taste test results using statistical analysis methods involving probabilities, chance, etc. As I am no statistics genius, I will try to explain this in the simplest terms possible.

Let us take the two-sample preference taste test as an example. Assume that we had 100 judges in the test who were completely taste blind (yes, such people do exist), and we "forced" them to guess which samples they preferred. According to laws of probabilities, ideally, we should get a fifty–fifty split in the preferences for one or the other of the two samples (just as we expect a flipped coin to land on its head or tail at a fifty–fifty split).

Likewise, if we presented two identical samples in the two-sample preference taste test to 100 people with normal tasting abilities and again forced them to choose preferences, the fifty–fifty split should ideally occur. So, in a regular two-sample preference taste test with two different samples, we must expect a fifty–fifty split only if within the population of 100 tasters, there is an inherent and genuine equal preference for either of the samples. This would mean there is really no significant preference for either sample in the 100-judge population in that test.

If, however, there is a 55–45 split in preference for sample A over sample B, then we could conclude that in this population of judges, there is a significant preference for product A. But this is not necessarily true. Just like with the coin flipped for 100 times, there will hardly ever be an exact fifty–fifty head to tail split result. This is because "chance" comes into play in the matter. The same is the case with taste testing in a two-sample preference taste test — chance plays its part, as well — and a 51–49 or even a 55–45 split in preference cannot in all confidence be taken as a significant preference result.

At what split do we start assuming that there is some significance in the preference ratio? This is where the statisticians come into the picture. They have mathematical methods and tables to use to calculate when this preference split is significant and at what level — is it slightly significant or highly significant?

The number of judges participating in the taste test is critical in determining the significance level.

It does not end here. They say that the split in preference and its significance level depend on the number of judges participating in the test. The more judges in the population of tasters, the lower the split ratio required for a significance factor. This is demonstrated in Table 2.1.

This table shows that as the number of judges increases, the percentage of preferences for one sample required for a significant preference decision decreases. Thus, with 10 tasters, we need 90% preferences for the one sample to render it significantly preferable to the other; for 100 tasters, we need 60%; with 10,000 judges, we need only 51% preference judgments for the same purpose.

Basically, what does this tell us? Simply that we need significance tables to interpret whether an apparent preference result in the two-sample preference taste test is significant, and how high or low this significance is. There is still one more hurdle.

TABLE 2.1
Preference Significance in Two-Sample Preference Taste Test

Number of Judges	Number of Choices for Sample A Required for Preference Significance	Preference Split Expressed as a Percentage Ratio	Preference for A Expressed as Percent of Total Number of Judges
10	9	90/10	90%
100	60	60/40	60%
1000	531	53/47	53%
10,000	5098	51/49	51%

The significance tables used in evaluating taste test results will use another statistics term, "confidence level." Basically, if there is a significant preference, this tells how high this significance is — marginal, moderate, or very high. The confidence level tells us how much the result is due to chance alone. These levels are explained as follows: (Note that *P* means the probability that the preference is due to chance alone.)

The confidence level tells us how significant a preference is — marginal, moderate, or very high.

P = 5% level: Marginally significant; 95% confidence that it is not due to chance alone
P = 1% level: Very significant; 99% confidence that it is not due to chance alone
P = 0.1% level: Extremely significant; 99.9% confidence that it is not due to chance alone

To demonstrate this, in Table 2.2, I extracted a few rows from a two-sample preference taste test significance table for the different judges' numbers. In practice, using 100 judges as an example, if the taste test was conducted to evaluate replacing product B, which is experiencing drops in sales, with a new and better product A, the gist of how to use the table is as follows.

If there were less than 60 preferences (e.g., 58) for sample A, then there is no significant preference for either sample. Do not launch product A as a substitute for product B, as there could very well be a continuing decrease in consumer acceptance if you did.

The established level of confidence in the preference significance guides us in how to act on the taste test results.

If there were 60 to 62 preferences for sample A, then the preference is marginal (5% confidence level). Again, there will be no mileage in substituting product B with product A. There is still a small risk involved.

If there were 63 to 66 preferences (1% confidence level) for sample A, then the preference is very significant. You can definitely consider product A as more preferred than B. But perhaps it would be wise to repeat the test (with similar results) at another site or with another taster population, just to be certain.

If there were 67 or more preferences for sample A, then the preference is extremely significant (0.1% confidence level). You can recommend launching the new product (and sleep well at night).

With a triangular taste test, the principles are the same, only the "statistics" are harsher in determining the significance of differences found. This is because three samples are involved in the test. ("Chance" has a better chance of skewing the results.)

Significance tables for the two-sample preference taste test and the triangular taste test can be found in Appendix 3 and Appendix 4 of this handbook, respectively.

The summing up of this section is simple. Accept that the mathematicians know what they are doing, and therefore, significance tables must be used in order to determine the correct evaluation of results of preference tests and triangular tests. Critical decision making and actions may be needed based on this evaluation.

TABLE 2.2
Preference Significance versus Number of Judges in Two-Sample Preference Taste Test

Number of Judges	Number of Preferences for Sample A Required for 5% Confidence Level	Number of Preferences for Sample A Required for 1% Confidence Level	Number of Preferences for Sample A Required for 0.1% Confidence Level
10	9	10	Need more judges
100	60	63	67
1000	531	541	553
10,000	5098	5129	5165

Forced Decision

The forced decision principle should be applied to all preference and triangular taste tests.

The two-sample preference taste test and the triangular taste test apply the principle of forced decision to the judges. This means that if a taster cannot determine which sample is preferred or is different, a decision is still required, even if it is a guess.

First, this forced decision principle persuades the judge to try harder. Second, this judge's "vote" is not lost to the pool of the taste test's figures. With a low number of judges in the test, a few less tasters can swing a final test evaluation from significant to nonsignificant. Consult your taste test significance tables to confirm this.

Of more importance is the fact that the forced decision principle is part of the quagmire of math statistics involving probabilities, chance, and what have you — enough of which I have, I think, already beset the reader with in this chapter. Still, if a judge is adamant that no preference exists or that a difference cannot be detected, then discard this judge's ballot sheet.

Taste Testing — An Acquired Skill

Running actual tests and learning more about the subject can only improve one's expertise in taste-testing techniques.

In the previous sections of this chapter, I dealt with a number of technological and scientific matters that are key factors in taste testing. There is no doubt that taste testing is based on scientific principles, such as the biological senses, physical controls, coding, statistics, psychology, and so forth. The operational techniques of the tests are clearly defined and rigidly prescribed. The evaluation of results is based on elaborate mathematical principles.

Still, no amount of scientific theory and technological data can tell you precisely how to design a taste test that will satisfy your particular aims and needs, which made you think of doing a test in the first place. What type of test should you use? Could you combine elements of one type with some of another? Where and with whom should you conduct the test? How many judges are required? These are all questions that only you can answer.

Then there is the issue of interpretation of results — how significant is "significant?" Is it at the right confidence level? Have you applied the results and conclusions in a correct manner to the issue at hand? Have you ignored some freakish condition during the test that could skew the results? Such are just more important questions.

And the cherry on top of them all is the following question: "Am I confident enough in my final decisions and recommendations for action?" This is especially important when large sums of money are involved in the forms of dumping product, launching a new brand nationally, supporting a claim against a supplier, and so on.

If you have been put in charge of taste testing in your workplace, you will usually be starkly alone in this function. Your peers and supervisors will look on you as the sole individual with the presumed required skills for this somewhat esoteric science of taste testing.

So, learn more about it, and run taste tests as often as you can.

Minding Your Ps and Qs

Earlier in this chapter, I undertook to tell a story about sample coding in taste tests. It goes something like this.

A large food company embarked on a national survey to compare its leading brand against that of a major competitor. A two-sample preference taste test was decided upon and conducted throughout the country with thousands of consumers as taste test judges. In these tests, the company decided to code its product with the letter "P." The competitor's brand code was decided upon, perhaps impulsively, as the letter "Q," the following letter of the alphabet. After all, a set of tasting cups labeled P and Q looks nice, does it not? After a few months of conducting the test all over the country, the results of the two-sample preference taste test, with this P and Q coding setup, were eventually analyzed. The conclusion, publicly relayed over all the national media networks, was that the company's product was very significantly preferred over that of the competitor's brand. Facts and figures of the taste test were published to support the conclusion.

Justifiably, the competitor organization was not too thrilled with this announcement, especially in view of the known and established fact that its brand was outstripping the other in sales volumes. What was the company going to do about it? A team of company sensory evaluation experts was formed to study the entire two-sample preference taste test technique employed in the hope of finding a flaw with which to discredit company P and nullify its published results. And indeed they did.

Some bright spark on the team had the remarkable inspiration to query the validity of the P and Q coding setup used in the taste test. After engaging the help of a linguist and psychologist in his studies, he came up with the theory that many English-speaking people subliminally regarded the letter Q, if anything else, as a weird letter.

> Think about it. In childhood, at school, it was drummed into us that Q always had to be followed by the letter "U," and nobody explained to us why. Later, we learned that there were exceptions to this steadfast rule when foreign language words like "Iraq" and "Qatar" were encountered. Also, Q is one of the most infrequently used letters of the English alphabet and occupies only three or four pages in any dictionary.

He proposed the following simple but profound hypothesis: Many English-speaking people are subliminally biased against the letter Q. Therefore, possibly many of the taste judges were biased against the sample labeled with the code "Q." This bias contributed to the number of tasters' preferences for samples coded with the letter "P," namely, that of the other company's brand. This bias was big enough to swing the preference for the other company's product into the very high significance level.

The competitor company latched onto this theory. I do not know if they first secretively successfully tested this hypothesis using in-house, similar two-sample preference tests. The competitor company proceeded with an identical repeat of the original nationwide taste test using a different coding setup for the samples. I believe that the normal random three-digit coding system was used, but I am not too sure about this.

Anyway, to cut the story short, the repeat test by the competitor company resulted in a significant preference for its product. The other company was publicly taken to task on its serious mistake in the taste-testing methodology of coding samples.

I always wondered if the company that used the P and Q coding system did so because it was, from the start, aware of the presumed subliminal bias against the letter "Q" and the probable result of a favored preference for its product, or was it just a simple oversight? I also wondered whether this is a true story. It was related to me at a sensory evaluation seminar presented by a reasonably reliable organization. Who knows?

In any event, whether true or not, this story drives home the point that taste testing can be a bit complicated, the message I am trying to convey in this chapter.

CHAPTER REVIEW

The scope of this handbook does not allow for describing the copious details of taste-testing theory, design, and procedure. This chapter has, however, attempted to present the reader with the most salient and critical issues involved in taste-testing theory and technique.

Many a time, food technologists in the soft drinks industry are called upon to conduct taste test projects. They are often looked upon, by their peers and supervisors in the workplace, as the sole custodians of this sometimes not too well-understood science. I hope that this chapter is of some assistance to them.

3 Food Laws — General Issues

GENERAL OVERVIEW

This chapter does not deal with the specifics of food legislation for any single country. Also, it does not attempt to methodically list and expound on the vast number of items and issues of which any food legislation system would be comprised.

Rather, the aim of this chapter is to convey to the reader the general concept of food laws and their basic criteria, structural formats, and mechanisms. Above all, the attempt is to demonstrate the role of food legislation in general in the food industry, the soft drinks industry in particular, and in the public at large.

WHAT ARE FOOD LAWS?

"Food laws" is a term used to refer to any of the statutory regulations proclaimed by a country's government that relate to the handling, manufacturing, and sale of food intended for human consumption. These regulations are contained in various acts (or bills) passed by the legislative authority of the government. A regulation may be part of an act specifically dealing with food matters, or it may be part of a non-food-specific act that includes references to food among other issues with which it deals.

Food laws are all the combined promulgated government legislation pertaining to foods intended for human consumption.

For example, a regulation dealing with permitted sweeteners may be found in an all-encompassing act regarding foodstuffs. On the other hand, regulations pertaining to the weight format on food container labels may be part of a metrology act dealing with many articles and items other than foodstuffs. Both such regulations are considered food laws.

Food laws should not be confused with stipulations, requisites, and conditions laid down by nongovernmental organizations related to specifications or standards of foods and food processing. Examples of these include the World Health Organization (WHO), the national standards bureaus, the Food and Agriculture Organization of the United Nations (FAO), the International Organization for Standardization (ISO) marking, Hazard Analysis Critical Control Points (HACCP) accreditation, consumer associations, etc. The requirements of such organizations are of a voluntary nature — they are not mandatory, as is the case with food laws decreed by the government of a country. Food laws may refer to such organizations and use their stipulations in the texts of regulations, but such stipulations on their own should not be considered as binding food legislation. Therefore, for the purpose of this handbook, "food laws" mean only those laws that were compiled and promulgated by an authoritative governmental agency.

Here it should be noted that soft drinks are considered a category of food, and as such, the term "food laws" applies to these as well. In this handbook, when regulations related specifically to soft drinks are dealt with, this will be clearly stated.

SOUTH AFRICAN FOOD LAWS

In this chapter, I used South African food laws as the vehicle with which to elaborate on general universal food legislation topics and issues common to most countries in the world today. Readers

from other countries should not find this "South African angle" disconcerting, because most food laws, regardless of the country in which they were created, adopt similar basic principles, structural formats, and administrative mechanisms. Regulation specifics pertaining to a certain issue may differ from country to country. Sometimes these differences can be significant. Also, the interactive legal references between individual sections and chapters in one country's legislation may differ from those of another. In the end, they all arrive at the same purpose destination — to prescribe what is considered safe and good for the public.

Why have I used South African food laws as my basic model for this chapter? Simply because, as a South African, I am fairly acquainted with these, and with all the ups and downs, ins and outs, and roundabouts that usually comprise food legislation. Let me also assure the reader that South Africa is, professionally, not all that of a third-world country, as it is often made out to be. I dealt with many overseas professionals and traveled the world extensively and found that we do not fall very far behind any of the first-world countries. This also goes for our food laws.

WHY ARE FOOD LAWS INCLUDED IN THIS TECHNICAL HANDBOOK?

Food laws focus mainly on technical issues related to foods and beverages.

Most regulations pertaining to foods and beverages deal with chemical, physical, and quality aspects of ingredients and packaging materials. They also focus on manufacturing processes and storage conditions requirements. Microbiological and nutritional issues are addressed. Hygiene and safety are frequent topics. Testing equipment and methods standards are often prescribed. These are just a few key aspects of food laws. Therefore, minimal expertise in food science and technology is usually required to understand most of the multitude of regulations involved. It would be far-fetched to expect an accountant or marketing person to be able to competently, fully understand the text content of these regulations, which in most cases is often highly convoluted (as all legal jargon usually is).

In most food businesses and organizations, the tasks of monitoring and implementing food laws fall into the hands of a technically qualified person, usually the quality controller, staff chemist, food scientist, or someone with a similar scientific background. In large international food companies, this person is given the title of regulatory affairs manager or something similar. The sole function of this position is to monitor and control the company's adherence to the region's food laws as well as to serve as the company's liaison officer with government agencies. It is no surprise that this food laws chapter found its way into my handbook. It is an important chapter.

ACTS AND REGULATIONS OF FOOD LAWS

This is the major body of legislation pertaining to food in South Africa: Foodstuffs, Cosmetics and Disinfectants Act, 1972

The total interacting mass of a country's food laws will usually be found in a number of different specific acts or bills. The predominant act around which all South African food laws revolve is that mentioned below.

Foodstuffs, Cosmetics and Disinfectants Act, 1972 (Act no. 54 of 1972), and its abundant array of regulations, is by far the most prescriptive set of rules for the food industry in South Africa. It falls under the control of the Department of Health, the government agency that performs a function similar to that of the U.S. Food and Drug Administration.

This particular act will, for abbreviation purposes, be referred to as FCD Act 54 from this point on in the handbook. As mentioned previously, other acts exist that contain regulations that refer to food legislation. These usually work in tandem with those of the main FCD Act 54 (but sometimes not, and then there is the problem of which supersedes the other).

One such Act, Agricultural Product Standards Act, 1990 (Act No. 119 of 1990), issued by the Department of Agriculture, contains a somewhat long-drawn-out and complex regulation (Regulation R.286, 7 November 1980) addressing the single issue of classifying beverages containing fruit juice into various categories and how such are to be labeled. It impacted heavily on the South African soft drinks industry for many years.

This act is a typical example of how one government agency, other than the more authoritative Department of Health, may issue major food laws of its own. The aims of these regulations were commendable, as they intended to preserve the integrity of juice-containing beverages in the eyes of the public. However, the regulation's overbearing prescriptive nature caused much concern in many categories of the South African soft drinks industry. Its effects are still being felt to this day.

South African food legislation also appears in another act, Trade Metrology Act, 1973 (Act No. 77 of 1973). This act deals with definitions and regulations concerning weights and measures and contains references to many food products. It prescribes the sizes of packaging and containers of foods and beverages, the acceptable weights or volumes of the net contents, as well as the allowed tolerances of these. Clear-cut references are made to items in the soft drinks categories.

Clear and simple "weights and measures" legislation.

A last act to be mentioned is Hazardous Substances Act, 1973 (Act No. 15 of 1973). This act does not relate to food but rather to hazardous materials and how they are to be handled, etc. I included it here because I think it wise to keep abreast of these lists of declared dangerous chemicals and materials, just to be on guard lest they find their way into food factories. There is, for instance, one special reference to foods. No used container of a hazardous substance may be used for the packing of food; likewise, no empty container of food may be used as a container for a hazardous substance. This is a neat and simple law for obvious reasons.

Finally, there are other acts containing regulations with peripheral references to foodstuffs, such as transport regulations concerned with freight conditions and labeling requirements for shipped materials. These may by sheer coincidence include a few categories of food ingredients or chemicals. Still, one must be aware of these. These examples of some South African food laws illustrate that a country's total complement of promulgated food legislation is probably found in an array of several separate and individual bodies of legislation. Some of these are prominently food related, while others could be of a more obscure nature and less known to a student of the soft drinks industry's food laws.

SOFT DRINK LEGISLATION

It was already noted that soft drinks comprise a category of food and will fall under all and any of the general food laws regulations. As such, a myriad of regulations apply to soft drinks as they do to any other ordinary foodstuff, e.g., general definitions and terminology, permitted ingredients and their allowable limits, labeling and advertising rules, nutritional claims, pesticide residues, allowed irradiation levels, standardized testing equipment and methods, etc. The list is almost endless.

Soft drinks as a food category fall under all and any food laws legislation.

When a new food regulation has been promulgated, or even when its final draft is published for public and industry commentary, it usually is aimed at all food categories. Certain aspects of the subject being dealt with may be unsuitable or impracticable for a certain category of foods. In spite of the probable in-depth and extensive research by the drafters of the regulation, these have been overlooked for one reason or another. That is no great disaster — after all, they are only human.

Let me offer a small and simple example of what can occur with legislation for the soft drinks industry. In a major revamping of food labeling legislation, a new specific regulation called for a host of information and data, in all letter sizes from 2 mm height and upwards, to be included and

printed on the main panel of the food package. The text was to include, among other information, the name of the product, the brand name, its food category descriptor and flavor (if applicable), and the address of the manufacturer. Now consider how this would have suited soft drinks filled into generic applied ceramic label (ACL) glass bottles?

> For the reader who does not know, a generic ACL glass bottle is one that is used for a range of different flavored soft drinks produced under a single brand or company name. The ceramic label artwork is originally applied onto the glass of the bottle when it is molded, hundreds of thousands if not millions of bottles at a time, at the glass factory. It is designed so that one particular bottle design can serve as a container for a large range of flavors, each of which is identified by the consumer according to the color of the beverage in the bottle (as well as by the small printed bottle crown or cap, if neccesary). The idea behind the generic ACL glass bottle is that it is an enormous cost-saving item in terms of a single high-cost bottle mold for all flavors, lower unit price cost for huge volume orders (especially in multifactory organizations with bottling plants in numerous geographical locations), standardized and flexible stockholding of one stock-keeping unit (SKU) for a wide range of flavors, reduction in downtime for flavor changes in production for these different flavors, and reduction of bottle out-of-stock situations. (I suppose there are other cost-saving items I have not thought of, but we will leave it as it is.)

Let us return now to the original question above. An ACL bottle is produced by the glass factory from a single bottle mold that has its own artwork label "embossed" on the glass when the bottle is formed in the mold. The customer's single order can run into quantities of millions of bottles at a time formed from this single mold that costs the client tens of thousands of dollars. This same mold is used many times over again for subsequent orders.

I will try to answer the above question of how the proposed labeling legislation requirements suit the generic ACL glass bottle as follows: It does not suit the ACL bottle user at all. To meet the legislation demands, the bottle user would have to have a different bottle mold for every flavor in the current range of products. He or she would need a new bottle mold for every new flavor developed in the future. Each bottle mold for any failed or discontinued flavor in the product range would have to be literally thrown away as it becomes obsolete.

> The bitter cherry on top of this huge cake of enormous expenses would be that in a multifacility organization, with several if not dozens of its filling plants in different locations, the company would require a different mold for each of the different plants at different manufacturing addresses. (No, I am only joking — the company would be allowed to print a generic "head office" address for all of them.)

Notwithstanding the above joke, soft drink manufacturers using ACL glass bottles would have to spend a fortune to meet the proposed new labeling legislation. Not only that, but the long history of convenience involved in the use of the ACL glass bottle would end and spell the death of its type in the soft drinks glassblowing industry. So it looks like, in this described legislation scenario, the drafters of the regulation, with all respect, did not take the issue of ACL bottles of the soft drinks industry into consideration.

> This is no big deal, because when an ACL bottle user, namely, the entire soft drinks industry of the country, would make representations to the legislation authorities about this problem, the latter would likely agree to make a special dispensation to our industry. We can put all the required print details of the main panel (that is the body of the bottle) on the crown or cap of the bottle instead.

But the story would not end here. The small size of the cap or crown cannot physically accommodate all the printed text at the stipulated different letter-size heights. Again, dispensation would be sought, and granted, to lower the letter-height sizes.

This example of soft drinks peculiarities with respect to general food legislation that may have been overlooked in the past by drafters of food laws or that were not anticipated in future devel-

opments, is only one of many such potential cases. One typical example of such a case of the latter is the caffeine content in guarana-flavored energy drinks. In the last decade of South Africa's new democratic history, the floodgates of foreign trade were widely opened to foreign food imports. We have been swamped with many variations of such imported energy drinks that usually contain, due to the South American guarana fruit flavor present, levels of caffeine far in excess of currently allowed levels and that are permitted in cola drinks only (to the best of my updated knowledge). The policy of South African food laws authorities in this matter is not clear as yet.

Whatever the decision may be, favorable or not, it will be needed to be written into the law. If a regulation specially dedicated to soft drinks is in existence, this can be simply attended to by a small single-insertion amendment into this regulation. Then, there will be no need to do so in all the many other individual food regulations dealing with caffeine content. This may still need to be done eventually for completeness sake and would take considerable time. However, the small amendment in the soft drinks regulation could be swift, and in that way, the entire guarana issue would be immediately legally covered to both parties' satisfaction. At the same time, the inclusion of an energy drinks definition in a new subcategory of soft drinks would also be possible and clear the air of this type of beverage's standing with the law as well as with the soft drinks industry as a whole.

The point to be made is that a specific food laws regulation dedicated to soft drinks as a food category would make life simple for the authorities, the industry, and the consumer at large. South African food laws contain such a regulation, and though it is still not fully comprehensive, it has often been of such help. If allowed to blow my own trumpet, I will state that I was personally involved in the creation of this regulation, along with the local legislation authorites in the 1980s, for the above-mentioned "soft drinks peculiarities" reasons. This regulation is R.1769, 9 August 1985, Foodstuffs, Cosmetics and Disinfectants Act, 1972 (Act No. 54 of 1972); Regulations: Soft Drinks.

An especially dedicated regulation for soft drinks exists in the FCD Act 54.

Another spin-off of such dedicated legislation is that this special regulation for soft drinks can play a major role as a guideline in new product development. It is also useful when checking ingredients declarations on label designs and artwork for new products or for those that are to be imported.

I want to emphasize that I do not maintain that soft drinks should deserve special consideration in the form of a specifically dedicated all-encompassing regulation because it is more important or complex than other food categories. Such categories are sometimes more complex and vast in subject matter, requiring specific legislation, and these do or should exist for meat, dairy, confectionery, and perishable foods, to name a few. What I am saying is that the huge soft drink segment of the food industry deserves the same consideration as the others. It can make life much simpler for all the players in the game: government, business, and the consumer public. I may be wrong, but I have not come across such soft drinks–dedicated legislation in many other countries' food laws.

WHAT IS THE PURPOSE OF FOOD LAWS?

The purpose of all laws, generally and simply stated, is to establish, maintain, and enforce "law and order." Food laws purport to establish the practical norms for foods and food processing. Legislation aims to ensure that the public is neither exposed to health and well-being hazards nor is deceived in its perception of foodstuffs available in the market. Thus, law and order must be maintained in the food industry.

The main purpose of food laws is to regulate the industry and safeguard the public.

The South African Health Department, with other involved governmental agencies, as the custodians of the food laws, maintain a constant vigil on the market for contraventions of the law.

Penalties for such transgressions, or rather the probability of these penalties being imposed, serve as a deterrent to breaking the law.

In reality, most people and businesses involved in the food industry do not comply with the law out of fear of the penalties involved. They usually recognize the need to avoid any harm to the public as a matter of moral principle. However, there are always those who will not heed the food laws — either wittingly or out of ignorance. It is on such that food laws legislators, together with the industry as a whole, must maintain this constant vigil.

HOW ARE FOOD LAWS MADE?

The mechanism leading to the final promulgation of a regulation in South Africa, by the Department of Health for example, follows a sequence of events in the following steps:

Step 1: The Department of Health researches the subject of the proposed regulation, including the scientific facts, technological aspects, practical implications, and potential impact on industry, business, and consumer. The department can do this in many ways, through consultation with overseas legislation bodies, local and foreign scientific organizations, consumer associations, and local food industry representatives.

Step 2: The regulation is compiled and published in the *Government Gazette* as a draft regulation inviting comments from the public and industry within a specified period. The *Government Gazette* is obtained by the public and industry food laws personnel by whichever method is chosen: post, electronic mail, Internet, or by subscription to commercial companies specializing in legislation updating. The onus is on the public and industry to obtain a copy of the *Government Gazette*.

Step 3: The parties concerned study the draft regulation and, if necessary, comments are relayed to the Department of Health. These must reach the department by the stipulated date. Industry officials who feel that the draft contains items unfavorable to their business operations or that items are factually or scientifically erroneous will usually arrange personal meetings with the department authorities to submit their cases. The department will listen to such but will usually not "promise" anything concrete.

Step 4: The Department of Health studies all comments received, and at its discretion, may meet with individual comment makers for further discussions.

Step 5: The Department of Health will publish the final regulation in the *Government Gazette* stipulating the date at which it will come into effect. The final regulation, in its first paragraph, will still allow for and invite comments by a certain date. At this stage, after receiving and studying the *Government Gazette* containing the final regulation, any persons or companies that have made representations to the department will observe whether their comments or objections were considered. Usually, if they have not been considered, the parties will accept the regulation as final and not make further comments.

Step 6: If the Department of Health receives a comment, or comments, that are pertinent to the integrity of the regulation, it will issue an amendment to the regulation. If a comment is received that requires an amendment, which sometimes happens, then a further individual regulation (usually in very brief format) is published in the *Government Gazette*, and the above cycle repeats.

Whatever the case, with or without the amendment, the first regulation becomes the law on the stipulated date. It must be noted that if an amendment is applicable, it exists as a regulation in its own right. The original regulation is not modified and reissued as a new regulation. Thus, the original first regulation must be read together with the amendment document as a kind of

"attachment." Over the years, an original regulation may have literally dozens of amendments, which together make up the final food law. It will exist in this format until the Department of Health in its wisdom decides to issue a completely new comprehensive regulation inclusive of all the applicable amendments, and at this opportunity, very likely with some new additional items.

ENFORCEMENT OF FOOD LAWS

Enforcing adherence to food laws starts with the promulgation of a regulation in the *Government Gazette*. Usually, individuals and companies subscribe to the *Gazette* in one form or another and are notified well in advance before a regulation comes into effect. Sometimes they are informed by word of mouth in the relatively small but cohesive technical community of the food

Promulgation of the regulation is the first step in enforcement —— it becomes the law.

industry. Whatever the case, the individual or company will acknowledge the new regulation and take action to comply with it. Sometimes the new regulation may involve stock of finished product, either in the warehouse or even already in the trade, being in contravention to the regulation.

As an example, let us say that a stock has an intense sweetener listed on the label as "artificial sweetener." The new regulation calls for it to be listed under the new descriptor as "nonnutritive sweetener." What would happen in this case is that the food processor of the stock would make representations to the Department of Health and explain the situation. There is a lot of money involved in destroying the stock in the warehouse and even more in recalling it from the trade.

In such a case where no real hazard to the public is evident, it is more than likely that the Department of Health will grant a concession to the processor in the form of a postponement in date of compliance, which is usually enough time to sell the "faulty" stock.

Reaction to contraventions is determined by the degree and nature of the offense.

Now, imagine the same scenario but wherein the stock contains a hitherto permitted ingredient that has by the new regulation been declared as extremely hazardous to health (by virtue of very recent scientific studies, as an example). There is no way that the Department of Health would grant a concession in such a case. It would demand the recall of the product and its destruction. The processor is usually aware of this and would not make any attempt to obtain such a concession.

Usually the processor would recall the stock in the trade and destroy it together with any stock in the warehouse. The processor will not do this out of fear of a penalty, rather it is out of a matter of company or brand image. The processor will not take the risk of tarnishing the company's name or that of the product if the facts somehow become known, and there are many ways this could come about. (Some notes will be presented about this later.)

These two examples illustrate that enforcement of food laws is a matter of degree of the particular deviation from the regulation's stipulations. They also show that enforcement is usually on a voluntary basis on the part of food industry individuals and companies.

Another principle plays a major part in enforcement of food laws. The "backyard" food businesses and processors are those that the Department of Health as well as the regular food industry companies are worried about. This is not to say that all of these small operations are run by unscrupulous individuals interested in making a buck at all and any costs. Small does not

In reality, the main offenders are usually the smaller food businesses — mainly out of ignorance of the food laws.

mean dishonest and crooked. After all, the saying goes that "all big businesses were once small businesses." If I will grant that not many such operators are necessarily unscrupulous when it comes to adhering to food laws, I will nevertheless claim that many of them are ignorant of the food laws. And in this ignorance lies the danger.

If such noncompliances by backyard operations are picked up by the Department of Health, an attempt will be made by the department to educate and constructively assist in food laws compliance — if ignorance is the sole reason. However, if blatant disregard is found to be the motivation of noncompliance, I think that the department will show no mercy. In fact, with such cases, as a corollary, the operation will usually turn out to be excessively substandard in many other legal respects and will be shut down without much ado.

The principle discussed here also implies that the "big boys" of the food industry are trusted by the Department of Health to adhere to regulations and are not really in the firing line of the department. When unwitting contraventions occur with these industry players, the Department of Health will usually negotiate a concession of sorts. But with deliberate disregard for the law — what was good for the goose will be good for the gander — there will be no mercy.

The leading food companies themselves practice a unique type of vigilance on contraventions — by watching their competitors.

This brings me to the subject I undertook to address earlier on how regulation contraventions "become known." The leading companies of the industry practice a unique type of vigilance on adherence to food legislation, albeit not for altruistic reasons or out of sheer respect for the law. Many a large food corporation is constantly looking for opportunities to "knock" the competition. Should such a company pick up a regulation contravention by a competitor, it will simply report the matter to the Department of Health. This would happen mainly if the company was of the view that the contravention is of a serious nature and that the Department of Health would have no option but to take drastic action with the offending competitor.

Here is another one of my stories.

This sounds nasty and ugly, especially if the motivation is nothing more than a pure wish to somehow thump the competitor. But in most cases, the motivation also includes an element of "why should he get away with it when I am complying, and at great effort and cost to my company?" or something along these lines. This reminds me to tell you another one of my stories that you will find occasionally sneaking into this handbook.

Many years ago, South Africa wisely shifted over to the International System of Units (SI) (from the ludicrous old British units of ounces and pounds, inches and yards, gallons and bushels, and barrels and what have you). The Trade Metrology Act, 1973 (Act No. 77 of 1973), mentioned previously in this chapter, prescribed this shift. As usual, all industries and businesses were given ample time to make the mammoth changes involved.

About a year after promulgation of the shift to the metric system, a beverage company launched a new low-energy diet drink and aired a short television commercial to promote it. The advertisement contained a catchy jingle with the lyrics focused on the low-energy value of the diet drink: "That's the one! That's the one! That's the ONE, the ONE-CALORIE DRINK!"

The story goes that a competitor beverage company complained to the appropriate authorities that the advertisement was "breaking the law" inasmuch as the unit of measurement calorie was made redundant and should therefore be replaced, by law, with the SI equivalent kilojoule. In other words, the lyric should read: "… That's the ONE, the 4.2 KILOJOULE DRINK!" (1 Cal being equal to 4.2 KJ).

Of course, the real intention was to get the advertisement off the air. I do not really know if this is actually how it happened, but this was the story doing the rounds. The advertisement was soon never seen again. The advertising billboards with the "one calorie" text suffered the same fate. Whether true or not, this story illustrates to what ludicrous extreme companies could go to knock their competition when it comes to contravening regulations in the food laws. All these notes on food laws enforcement are not taken from any official sources, reports, or studies, they are merely what I observed during many years spent in the food industry.

GENERAL FOOD LAWS REGULATIONS APPLICABLE
TO SOFT DRINKS

As mentioned before, the full complement of a country's numerous food laws related to soft drinks would normally be found in the myriad of regulations contained in several different main acts or bills.

In South African food laws, the FCD Act 54 is by far the most comprehensive piece of legislation. I used it to outline some of the main general food regulation categories that would profoundly affect the soft drinks industry anywhere in the world. This information is presented in Table 3.1.

CHAPTER REVIEW

This chapter served as an introduction to the concept of food laws — the legislation associated with the handling, processing, and sale of foods and beverages, among which soft drinks comprise a category.

South African food laws were used to demonstrate the principles, structures, and mechanisms of food legislation and could serve as a model for comparison with other countries' systems. By their nature, dealing largely with physical and chemical aspects of foodstuffs, ingredients, and processes, the understanding and appreciation of food laws require a measure of technical knowledge. For this reason, the subject is part of this technical handbook.

TABLE 3.1
Main Food Regulation Categories Applicable to the Soft Drinks Industry

Regulation Category Title	Comment
Preservatives and antioxidants	Comprehensive regulations on preservatives and antioxidants very applicable to soft drinks
Anticaking agents and the amounts thereof that may be used in foodstuffs	Applicable to powdered soft drinks
Acids, bases, and salts and the amounts thereof that foodstuffs may contain	A major regulation applicable to soft drinks
Emulsifiers, stabilizers, and thickeners and the amounts thereof that foodstuffs may contain	A major regulation applicable to soft drinks with special relevance to clouding agents and flavor emulsions
The use of sweeteners in foodstuffs	A major regulation applicable to soft drinks
Labeling and advertising of foodstuffs	A major regulation applicable to soft drinks
Food colorants	A major regulation applicable to soft drinks
Microbiological standards for foodstuffs and related matters	Contains specific standards for bottled waters category of soft drinks
Natural mineral water	Specific regulation for bottled waters, a very diverse category of soft drinks that is growing at an extremely fast rate and requires dedicated legislation control

4 Emulsions — The Cloudy Drinks

CLOUDY DRINKS

Generally speaking, soft drinks may be broadly divided into two types based on appearance: clear drinks, which are completely transparent, and cloudy drinks, which are turbid to one degree or another.

Soft drinks may be clear or cloudy, depending upon the flavors they are representing.

A typical clear drink is lemonade, which is usually crystal clear. Other common clear drinks are cream soda and ginger ale.

Cloudy drinks are usually those of fruit flavors, as the beverage purports to represent the appearance of the natural juice of a specified fruit species, which has a certain degree of cloudiness. Typical examples of these are the various citrus flavors. Thus, an orange-flavored carbonated soft drink will usually be formulated to be cloudy, as the natural squeezed juice of the fruit is cloudy (and it will also be colored a shade of orange).

On the other hand, fruit-flavored soft drinks representing fruit species, the natural juices of which are not commonly cloudy, such as grape and apple, are largely clear drinks in appearance. Strictly speaking, the natural juices of grapes and apples are slightly hazy, but the consumer has apparently been educated to expect these juices to be crystal clear, much like wine and cider. So when these juices are processed, they are clarified in one manner or another. Still, other soft drinks that are not fruit flavored may also be cloudy, as in the case of ginger beer.

EMULSIONS AS CLOUDING AGENTS

Juice beverages with 100% natural juice content, or those containing high percentages of natural juice, are cloudy in appearance by virtue of the turbidity of the natural juice. They do not require additional ingredients to give them their cloudy appearances.

Cloudifiers are basically oil-in-water emulsions that render the beverage translucent.

However, a soft drink with low natural juice content may require a clouding agent ingredient to boost the turbidity in order for it to resemble the cloudy natural juice of the fruit species flavor it is named after. This is definitely the case in cloudy fruit-flavored drinks that contain no natural juice.

Most clouding agents, which are also commonly called cloudifiers, contain an oil phase and a water phase and are oil-in-water emulsions. The suspended oil droplets in the beverage have an optical effect that renders the beverage liquid translucent to the eye of the viewer. This translucency may vary in degree depending on the cloudifier content and its strength. The oils used in cloudifier emulsions do not impart much, if any, taste or odor to the beverage. Therefore, such cloudifiers are referred to as neutral clouds.

FLAVOR EMULSIONS

Flavor emulsions allow for the use of water-insoluble flavor oils in soft drinks.

Another important aspect of emulsions in the soft drinks industry is that many flavorants used in beverage formulations are prepared in emulsion forms. In fruit-flavored beverages, the flavorants are mainly essential oils extracted from the fruit. These are not normally soluble or miscible in the water of the product. If added to the formulation on their own as pure essential oils, these would soon separate from the body of the beverage as oil droplets, or even an oil slick, and be quite visible, often as a neck-ring in the bottle. Not only would there be this visual defect, but also, more importantly, the flavorant would very likely not be dispersed homogenously in the beverage.

Using the essential oil as an emulsion solves this problem. This then is a flavor emulsion that keeps the flavoring oils in suspension in the beverage in the same way as in a neutral cloud. The difference is that such an emulsion now contributes the flavor to the product as well as acting as a cloudifier for the beverage. A flavor emulsion cannot be used for a clear-drink type of product, as it will make the beverage cloudy.

You may ask how are essential oils used in clear drinks, such as lemon oils in lemonade? Good question. The full answer will be given in another Chapter 14, which is dedicated to flavors, but here I will explain briefly that such lemon oils are subjected to a "washing" process in which the water-insoluble fractions are removed. This, however, renders them less effective as simulators of the original full fruit taste.

EMULSION TECHNOLOGY

Emulsion technology is complex, but the reader could benefit from some basic information on the subject.

The crucial issue of emulsion performance is that it will be stable in the final beverage and not break down in any way. Also, that it will perform the functions of cloudifying the beverage and keeping the flavoring oil well dispersed in the beverage for as long as its expected shelf life. The technology of emulsions, both in theory and in practice, is a complex subject on its own. The run of the mill soft drink quality controller or production manager in a bottling plant does not really need to be an expert in emulsions. And, beverage product development staff do not need to know much about this technology.

Usually these people source the cloudifiers required for their products from outside specialist emulsion manufacturers or suppliers, with all the accompanying information on how to use and handle them in their formulations and processes. It is my opinion, however, that soft drink technical personnel at bottling and canning plants as well as product development staff would benefit from some basic information on emulsions, the technology involved in their preparation, how they function, and especially what can go wrong with them. It is for this purpose that this chapter is included in my handbook.

The microscopic oil droplets that give the beverage its cloudy appearance must be kept in constant suspension.

In simplistic terms, an oil-in-water emulsion for a soft drink, whether this is a cloudifier or a flavor emulsion, is a stable suspension of microscopic oil droplets in the aqueous medium of the beverage. It is these microscopic oil droplets, themselves transparent, suspended in the crystal clear water of the beverage, that cause the optical effect of an overall "milkiness" of the drink.

As oils are normally lighter than water, the nature of these droplets must be such that they do not float to the top of the beverage. Furthermore, they must not coagulate to form unsightly flocs or sediments in the product and cause a complete breakdown of the emulsion. This ideal situation of a stable emulsion that will last for the expected shelf life of the beverage is determined by many

key factors interacting in a multitude of permutations. To list them all in detail is beyond the scope of this handbook, but a few of the most important ones will be briefly addressed in this chapter.

STOKES' LAW

No respectable discussion on the subject of emulsions theory can avoid mention of Stokes' Law. The reader should not be put off by what appears to be a complex mathematical equation with strange Greek letters and all. In fact, it is quite simple. I deliberately chose to start this discussion on the basics of emulsions theory with Stokes' Law, as I think it is the perfect vehicle to illustrate, one by one, the key factors that play important roles in a stable cloudifier or flavor emulsion for soft drinks.

The scientific mathematical basis of emulsion theory.

Stokes' Law says the following:

$$V = \frac{2gr^2(d_1 - d_2)}{9\eta_2}$$

where

V = velocity at which an oil droplet will sink (or rise) in the emulsion;
g = acceleration of gravity;
r = radius of oil droplet;
d_1 = density of oil phase of emulsion;
d_2 = density of water phase of emulsion; and
η_2 = viscosity of the water phase.

Having absorbed this information (and not having been intimidated by the mathematical equation of Stokes' Law), let us now proceed step by step with the basic details of emulsion theory and how it applies to cloudy drinks.

OIL DENSITY

First, let me present a few items of emulsion terminology. In an oil-in-water emulsion, we speak of the oil phase and the water phase. The oil phase consists of the oil, or combination of oils, and other oil-soluble ingredients used in the emulsion formulation. The water phase is the water and all other water-soluble ingredients of the formulation, such as acids, salts, preservatives, colorants (if any), gums, etc.

The density of the oil phase is a key factor in the stability of oil-in-water emulsions.

If the oil phase in an emulsion separates out by rising to the surface of the liquid, this phenomenon is called creaming. (The term most probably comes from the separation of milk fats into the cream at the top of unhomogenized milk — and milk is a natural emulsion.) If the oil phase, for whatever reason, sinks to the bottom of the liquid, we then have what is called sedimentation.

Now back to Stokes' Law. From the equation, one profound issue is immediately obvious: if the oil phase density d_1 is less than the water phase density d_2, then the expression $(d_1 - d_2)$ will have a negative value. This, in turn, means that V will also be negative, and the oil droplets will rise to the surface of the emulsion. There will be a creaming effect. We can therefore refer to V as the rate of creaming in an emulsion.

FIGURE 4.1 Neck-ring due to emulsion creaming in cloudy orange beverage.

Oils are normally lighter than water. For a stable emulsion system, such as in cloudy drinks, the one main issue we have to contend with is to prevent this creaming effect, which usually manifests itself as an unsightly whitish neck-ring in the bottle (Figure 4.1).

To minimize the potential creaming in the beverage, we need, as Stokes' Law tells us, to increase the density of the oil phase and bring it as close as possible to the density of the water phase of the beverage, which at Brix values of around 10 to 13 has a density of about 1.04. By doing so, we will minimize, if not eliminate, the potential creaming in the beverage. This can be achieved by adding a weighting agent to the oil phase.

WEIGHTING AGENTS

A weighting agent is an ingredient that raises the overall density of the oil phase.

The oils most commonly used in soft drinks cloudifiers, such as orange terpenes, have density values of about 0.85. To use them on their own would result in a high unacceptable rate of creaming in the beverage. This is also true for flavor oils in flavor emulsions. As stated before, in order to achieve stable emulsions with very low creaming rates, the oil phase should have a density as close as possible to that of the liquid of the beverage. This is where the weighting agent plays a critical role in stable emulsion preparation.

A weighting agent is a substance with a relatively higher density than the oil and is soluble in it. By adding a certain amount of weighting agent to the oil, the overall density of the oil phase is increased. It, in fact, will be the weighted average of the densities of the oil and the added weighting agent.

Brominated vegetable oil (BVO) was once the ideal weighting agent but is now restricted in use.

Many years ago, the ideal weighting agent was BVO, as it has a density of around 1.33 to 1.34 — indeed a very heavy material. By adding it to whatever oil was used in the emulsion, the oil phase's density was easily brought up to that of a soft drink's water phase. However, in the 1970s, many

countries' food legislators withdrew permission to use BVO in soft drinks due to its alleged health hazard (bromine accumulation in the body). The U.S., Canada, South Africa, and some other countries still allow its use but at a maximum level of 15 ppm in the beverage.

These limitations in the use of BVO in soft drinks caused no little havoc in the soft drinks emulsions industry, and a rush was on to find suitable replacements for BVO. To cut a long story short, only a few poor substitutes were really found. By "poor" I mean with densities nowhere near that of BVO. The more common weighting agents used today in soft drinks emulsions are ester gum and sucrose acetate isobutyrate (SAIB), with densities of 1.08 and 1.15, respectively. With such low densities, it is not always easy to "weight" the emulsion oil sufficiently, as was the case with BVO. Furthermore, not only are these weighting agents very messy to work with, but different countries have different allowable limits for their uses in soft drinks.

That is the way the cookie has crumbled. Emulsion manufacturers all over the world have battled to prepare satisfactory emulsions, as have their soft drinks producer clients in preparing stable cloudy drinks. But all is not lost. On the contrary, emulsion formulators and producers have, since the "outlawing" of BVO, been carefully and more closely addressing the other contributing factors to emulsion stability in soft drinks. There are very good, stable cloudy drinks in the marketplace — but stability problems still occur now and then.

OIL DROPLET SIZE AND DISTRIBUTION

Looking again at the Stokes' Law equation, you will see that r, the radius of the oil droplet, is squared (r^2). This in essence means that if the radius of the oil droplet is increased by a factor of 10, the rate of creaming will increase by a factor of 100. Thus, as a nominal quantitative example, if the period for poten-

Oil droplet size and distribution in the emulsion are key to its stability.

tial full creaming in a beverage emulsion with an average oil droplet radius of 0.1 μm is 1 yr, then in the same beverage with an oil droplet radius of 10 μm, this creaming would take place in one hundredth of a year, i.e., in 3.65 days. The beverage would be defective within 4 days of standing on the supermarket shelf.

This fact speaks for itself. The oil droplets need to be as small as possible in order to ensure a stable emulsion in the beverage. But they cannot be too small, as this can also be a problem, as will soon be explained.

I personally developed and worked with several emulsion formulation types and processes and can with reasonable confidence state, with all other as yet undiscussed stability-contributing factors being favorable, that:

A soft drink emulsion with an ideal stable and turbid emulsion should have over 80% of the oil droplets in the 0.4 to 0.6 μm diameter range. There must not be many droplets with diameter sizes in excess of 1.0 μm or below 0.3 μm.

The graph in Figure 4.2 shows the oil droplet sizes and distributions in such an ideal soft drink emulsion. Also shown for comparison is a graph of size and distribution of a hypothetical poor-stability emulsion. I will come back to the issue of the effect of larger- and smaller-size droplets on the stability and turbidity of the emulsion in soft drinks after a few other aspects of emulsion theory and practice are addressed in this chapter.
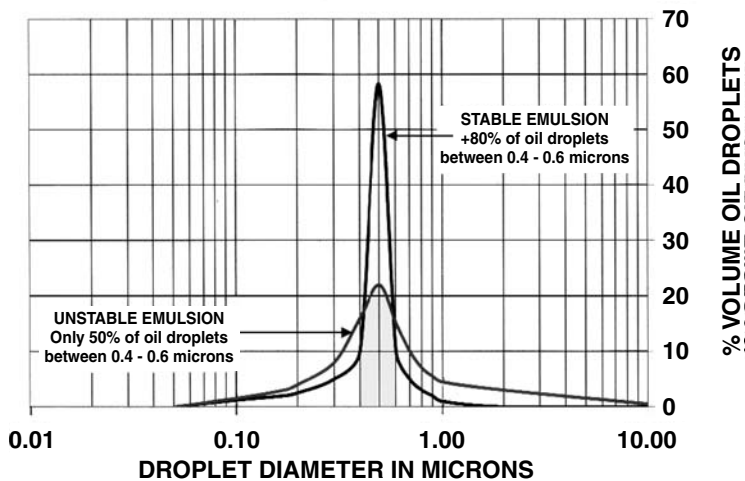
FIGURE 4.2 Oil droplet size distribution in emulsions.

STABILIZERS

The droplets must be kept out of contact with each other. This is the function of stabilizers.

The process of homogenization, which will be discussed in this chapter, prepares oil droplets of suitable microscopic size in the emulsion. However, the correct droplet size in an emulsion is not the last word in its stability story. The droplets must be dispersed in the water phase of the emulsion and prevented from forming droplet clusters or joining each other to form larger-sized droplets.

When individual good-sized oil droplets form clusters, the phenomenon is called flocculation. Aggregates of small droplets behave as a single larger droplet and will accelerate the creaming rate, leading to the formation of neck-rings in the bottle.

In addition to this, the sheaths of the outer layer of oil droplets can be disrupted. When two or more of such droplets are near each other, they can merge into a single larger droplet. This is called coalescence and will also, according to Stokes' Law, increase the creaming rate. When coalescence is excessive, this can lead to total breakdown of the emulsion.

In order to prevent flocculation or coalescence in soft drink emulsions, there is a need for stabilizers in the emulsion composition. These are hydrocolloids, which, through mechanisms of viscosity and electrostatic interaction, disperse the oil droplets in the water phase and prevent them from agglomerating.

Gum arabic has for a long while been the most favored stabilizer for soft drink emulsions.

The most commonly used stabilizer in soft drink emulsions is gum arabic. It is also called gum acacia, as it is derived from specific species of acacia trees mainly found in Africa. The gum arabic is added to the water phase of the emulsion, and after the homogenization process, it plays the role of an emulsion stabilizer.

It does this by forming fine film coatings around individual oil droplets. Thus, this helps to prevent flocculation and coalescence by physically keeping the droplets out of touch with each other. In addition to this, the gum arabic film increases the overall density of the droplet, thus reducing the potential creaming effect. Last but not least, the gum arabic increases the viscosity of the water phase, especially in the concentrated emulsion. Once again, according to our now well-known Stokes' Law, this will reduce the velocity of the upward migration of oil droplets in the beverage.

All in all, gum arabic is an excellent stabilizer for soft drink emulsions and has long been the predominantly preferred stabilizer for soft drinks. The raw material for the gum arabic production industry is obtained from the exudates of the acacia trees and is harvested manually in Africa, mainly from a single tree species of *Acacia senegal*.

In the mid-1980s, there was a worldwide shortage of gum arabic, and alternatives were needed. The main other suitable alternative stabilizers found were modified starches. I worked with these and could say that they are just as good as gum arabic. There are still other stabilizers, such as gum tragacanth and gum arabic from other tree species. The performance of these gums as stabilizers, much like others, depends entirely on how they are incorporated into emulsion formulations and homogenization processes.

WATER AND OTHER EMULSION INGREDIENTS

Other ingredients of emulsions, which are normally incorporated into the water phase, are preservatives, organic acids, and salts. If required, colorants can also be included to suit the requirements of the final cloudy drink into which the cloudifier or flavor emulsion is to be added. Of course, the main ingredient of the water phase is the water. The quality and composition of the water of an emulsion are critical to its stability.

In an emulsion, the suspended oil droplets as well as the dissolved stabilizer may acquire electrostatic charges, and the interaction between them could influence the degree of oil droplet aggregation. The entire complex electrostatic configuration of an emulsion is related to a stability factor called the zeta potential, which is associated with the electrolyte composition of the water.

Zeta potential is a measure of the electrolytic composition of the emulsion.

For this reason, water used in emulsion preparations should be treated in very much the same way as that used for beverage manufacture in the bottling plants. The general rule is that water for use in soft drink emulsions should not have an alkalinity exceeding 50 ppm calcium carbonate alkalinity.

This brings me to a short story about water used for emulsions. Some time ago while working for one of the large international soft drinks companies, I was charged with setting up an emulsion plant for cloudifiers and flavor emulsions. My mission was to develop in-house emulsions to replace those that were being purchased from an outside company. The aim was, by preparing our own cloudifiers and emulsions for flavors, to save about US$200,000 per year in the costs of these materials for the company's cloudy drink products.

During the development work in the laboratory, my staff and I initially prepared numerous trial emulsions that all failed stability tests in samples of beverages. They all developed neck-rings after a few days.

Water for emulsions must have some mineral content at about 50 to 80 ppm carbonate alkalinity.

We were extremely puzzled, and I went back to the drawing board and studied various documents and books I possessed at the time. I had often come across the zeta potential factor in these texts but failed to pay much attention to it. (It is a complex subject involving electrostatics of charged particles.) While rereading an item on zeta potential in emulsions, suddenly the penny fell. At the time, we had not yet installed a standard water treatment plant. In all of our formulations and trial runs in the laboratory, we were using laboratory-distilled water.

We immediately borrowed a few containers of treated water from a nearby company franchise bottling plant and repeated the most recent set of trials with this water. The sample emulsions were perfect. We wasted no time in installing a small water demineralizing plant targeting the treated water's carbonate alkalinity at 50 to 80 ppm and never looked back with respect to unstable emulsions and neck-rings in trial beverage samples. Attaining the US$200,000 per year savings target is another story.

HOMOGENIZATION

Homogenization is the process of reducing the oil to droplets of desired sizes.

The bulk oil phase material needs to be transformed into the suspended microscopic oil droplets in the final concentrated emulsion destined to be used as a cloudifier or flavor emulsion in cloudy drink products. This is achieved by homogenization. The bulk mixture of the oil phase and water phase, which I will refer to as the prehomogenate, is initially mixed in a tank, preferably by means of a high-shear agitator. This physically breaks up the oil phase solution into oil droplets of relatively large sizes, which are kept in suspension by means of the agitator. The prehomogenate is not an emulsion. If allowed to stand unstirred, the oils will soon separate into a large slick layer of oil on top of the water phase mixture.

High pump pressure and homogenizing valve adjustment.

Only when the prehomogenate is passed through a high-pressure homogenizer can the microscopic oil droplets of desired sizes be obtained. The high-pressure homogenizers with capacities from 100 l/h in a laboratory pilot plant trials model to several thousand liters per hour in production models, can vary in type and design. Essentially, they all operate on the following principles

The prehomogenate liquid is passed through the machine by means of a powerful positive-displacement pump so that pressures of up to 5000 psi/350 bar can be reached at the homogenizing valve assembly of the machine. This valve assembly, a relatively small-sized component when compared to the overall size of the machine, is the heart of the machine. It is the site where the prehomogenate with large oil globules is converted to an emulsion with microscopic oil droplets.

The homogenizing valve assembly is the site where oil droplet size occurs and is controlled.

The homogenizing valve assembly, often referred to as the "homogenizing valve" in daily parlance, consists of three components: the valve seat, the valve, and the impact ring. A drawing of the actual valve assembly is given in Figure 4.3. Note that in the drawing, the valve assembly is in a "dismantled" form to enable the reader to visualize how the three components fit together when in an operational state.

To understand the homogenization process that takes place in the valve, it is necessary to follow the flow of the unhomogenized liquid prehomogenate through the valve assembly, as schematically presented in Figure 4.4. The unhomogenized liquid from the pump's cylinders is forced through the valve seat at high pressure and reaches the face of the valve. There is a very fine gap between the valve and the seat, causing a restriction in the flow of the liquid. It is thus forced through the
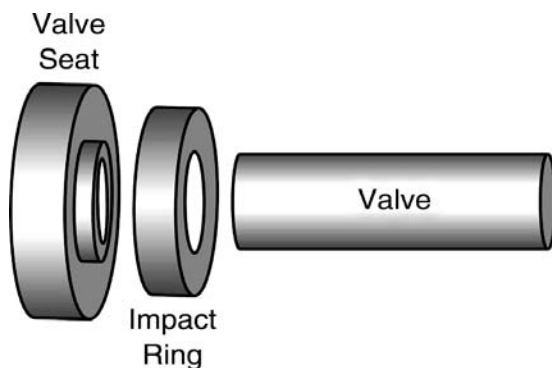
FIGURE 4.3 Standard homogenizing valve assembly (disassembled view).
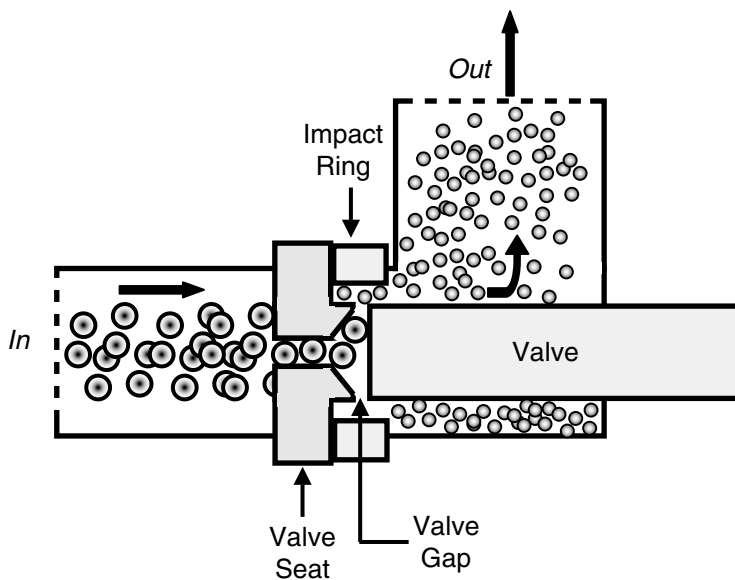
FIGURE 4.4 Liquid flow through homogenizing valve assembly.

fine gap at a very high speed and then hits the impact ring surrounding the valve and the seat. From there, the liquid, now homogenized, flows to the discharge outlet of the machine.

This process occurring at the gap between seat and valve takes only a few thousandths of a second, and it is where the homogenization of the prehomogenate occurs. The operator, by means of a handwheel, can set the gap size between the valve and the seat manually. As it is decreased, higher pressure is created, which is registered on a pressure gauge. The pressure at which the machine is set at the commencement of homogenization is critical to the oil droplet size and distribution in the final homogenized emulsion. The same emulsion formulation homogenized at different pressures can have different oil droplet size distributions.

The homogenizing pressure is the key process factor for obtaining stable emulsions. Most homogenizers in the soft drink emulsion industry are of the two-stage type, which have two homogenizing valves. The first-stage valve is set to a pressure anywhere between around 2000 to 4000 psi. The second-stage valve is set to around 200 to 500 psi and is a kind of "fine-tuner" for the first valve. With the two-stage homogenizer, the required pressures of both stages for a certain emulsion product are considered as critical parts of the specification for that product.

The homogenization process is more of an art than a science. First, a formulation for a cloudifier or flavor emulsion has to be developed successfully. Then, this has to be applied at suitable homogenization pressures for a good stable emulsion. Thereaf-

Homogenization is more of an art than a science.

ter, the results obtained for production batches can be fairly consistent. The operator must take good care of the valves, which tend to become scoured and worn due to the continuous abrasive action at high pressures that they are subjected to during frequent production runs. They must be inspected at close intervals, and every now and then they need to be repolished by expert service personnel.

The strange thing I found is that identical formulations on identical homogenizer models at identical pressures, in different factories in the world, do not result in emulsions with identical oil droplet size distribution and stability. I also found that the same emulsion formulation sometimes needs to be passed through the homogenizer twice in order to achieve the target droplet size distribution.

There are different theories as to how the oil is transformed into fine microscopic droplets. Most experts agree that it is not the shearing force alone, if at all, between valve and seat that forms the droplets. Other theories are those of cavitation and of turbulence. Also, the effect of the liquid hitting the impact ring at velocities around 500 km/h must play a significant role in any of these theories.

The experts are not in agreement as to how the homogenization process works.

The ultimate aim of the homogenizing process is to obtain an emulsion with the correct oil droplet sizes and distributions that will render it suitable for creating a stable cloudy beverage. This, of course, is assuming that the critical formulation parameters of the emulsion have been met, i.e., oil phase density, stabilizer content, water quality, etc. Figure 4.5 shows two emulsions in microphotographs taken at 1000× oil immersion magnification. In the stable emulsion, the even distribution of small-size droplets is fairly obvious when compared to that of an unstable emulsion.

TURBIDITY STRENGTH

Weak versus strong cloudifiers — the cost implications.

Until now, this chapter focused mainly on the stability of the cloud emulsion in the final beverage. There is another aspect to be addressed, namely, the strength or visual denseness that the cloud imparts to the beverage. In my own work on cloudifier development, I got into the habit of referring to the degree of turbidity that a cloudifier gives to the drink as its cloudifying power, a term I will also use here.

The cloudifying power of an emulsion in a beverage depends on its dosage in the formulation of the drink. Different emulsions at the same dosages do not necessarily give the same visual clouding effects. This is because they may not have the same standard cloudifying power. This is an important factor, if only from a cost point of view. There is no logic in formulating a beverage with a high dosage of cloudifier with a weak cloudifying power. Though its unit cost may be less than that of a strong cloudifying power emulsion, the latter may well, at a much lower dosage, give the same clouding effect but at a total lower ingredient cost in the formulation's bill of materials.

Cloudifying power, like stability, is related to a certain oil droplet size distribution.

Also, using a weak cloudifier at every dosage level may result in exceeding the legal limits set for some of the emulsion's ingredients, such as the weighting agents, which as mentioned previously may have different restriction levels in different countries. The cloudifying power of a beverage emulsion depends on the sizes of the oil droplets. In a previous discussion on this subject, it would seem that according to Stokes' Law, the smaller the droplet the lower the potential creaming rate. Thus, it would seem logical that if we should homogenize the emulsion to very small droplet sizes, it would be possible to attain maximum stability in the beverage. Sounds right, does it not?

But this is not the case for two reasons. First, it would appear that with very small droplet size, the cloudifying power decreases. I as yet cannot explain this optical phenomenon and have not come across any such explanation in the scientific literature (perhaps I have not looked around hard enough). What I know from experience is that in the numerous test trial runs I conducted, the very same emulsion formulation, when homogenized at higher first-stage pressures, resulted in a larger percentage of smaller droplets — but there was always a proportional decrease in cloudifying power.

The second reason is the following: if the droplets have very small diameter sizes, the potential for globule agglomeration increases due to the larger available surface area of the oil phase. Simply put, there are many more independent globules in potential contact with each other. As pointed out previously, contact between one globule and its numerous neighbors can lead to clustering resulting in flocculation or coalescence with a subsequent increased rate of creaming and even complete emulsion breakdown.

UNSTABLE EMULSION
There is an abundance of oil droplets
far in excess of 1 micron diameter size.

Very large oil
droplets 2 - 4
microns diameter

Standard size oil
droplets less than
1 micron diameter

10
microns
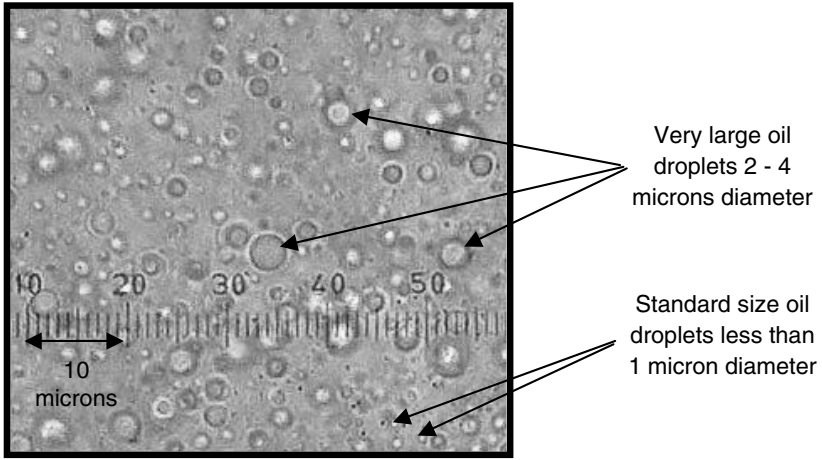
STABLE EMULSION
The vast majority of oil droplets are
below the required 1 micron
diameter size.

Single very large
oil droplet 2 - 3
microns diameter

Standard size oil
droplets less than
1 micron diameter

10
microns
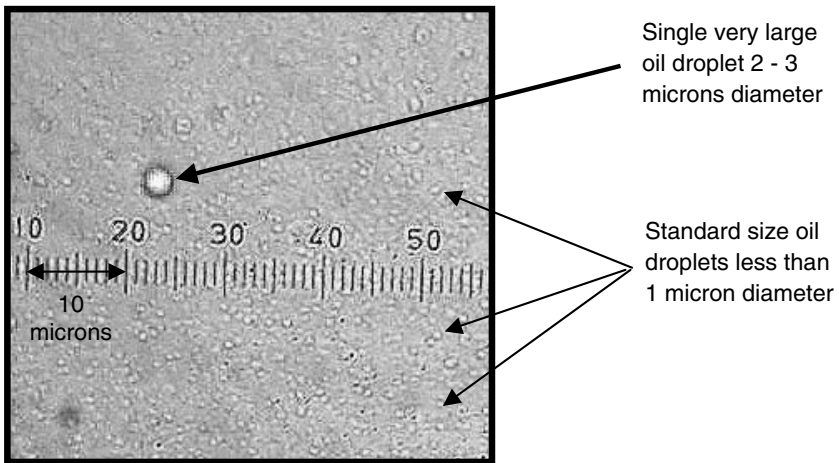
FIGURE 4.5 Oil droplet size comparison in stable and unstable emulsions.

For these two reasons, I have the droplet size distribution of around 80% in the 0.3 to 0.6 μm diameter range. It appears that in this diameter distribution range, the most favorable low creaming rate and cloudifying power relationship is attained. That this is found to be the optimum range of oil droplet size distribution in soft drink emulsions is no doubt the result of many years of research and experience by both academics and emulsion-producing companies.

BEVERAGE EMULSIONS

Emulsions for beverages are of a unique type, as they are expected to perform in a large variety of products with different stability-related factors.

In this chapter, mention was often made of the term "beverage emulsion," which sometimes referred to the concentrated cloud-ifier or flavor emulsion as supplied by the manufacturer and at other times to the diluted emulsion in the beverage. This double meaning for the term is precisely what I wish to focus on in this section. Emulsions used in soft drinks are considered as one of the more unique types of food emulsions. This is because their ultimate function is in diluted form in the beverage and not as the concentrated emulsion prepared by the manufacturer of the cloudifier or flavor emulsion.

Therefore, all the stability factors discussed in this chapter have to apply to the concentrated emulsion prior to its usage in beverage preparation as well as after it has been diluted several hundred times in the beverage. It also has to maintain its stability in high-Brix/high-density syrups for the dilutable soft drink categories, such as squashes and cordials. This is also true for carbonated soft drink syrups in filling processes, where syrup–water proportioning is used, in which such syrups may be kept stored in batch tanks with capacities of thousands of liters for up to 24 h or longer. Last, but not least, the emulsion must be stable in very concentrated syrups of squashes and cordials that use intense sweeteners to achieve up to a 1 in 13 syrup/water dilution ratios.

In all these cases, there are extreme variations in one or more of the water phase stability factors, such as density, viscosity, electrolyte content, and acidity. The uniqueness of emulsions for beverages is that a concentrated cloudifier or flavor emulsion is expected to be stable on its own during storage in the factory as well as when introduced into a broad variety of end-product beverages that are to stand on the shelves of the stores. It is difficult for a single concentrated emulsion to perform properly for this large variety of beverage products, and it is impractical to expect it to do so. A formulator of a new soft drink product, be it the supplier or the in-plant product development manager, must take this fact into consideration.

When such formulators do not consider this uniqueness of beverage emulsions, the brunt of this error is usually borne by the plant QC or production management inasmuch as an unstable neck-ringed product is sent into the trade.

QUALITY CONTROL OF BEVERAGE EMULSIONS

The quality of cloudifiers and flavor emulsions should be guaranteed by the producer.

In the normal scheme of things, the soft drink manufacturer is not really concerned with the quality control of beverage emulsions. These are specialty ingredients of which the quality and satisfactory performance should normally be guaranteed by the manufacturer, be it a specialist emulsion supplier, usually a flavor house, or the internal beverage base plant of the larger international soft drink organizations.

In-plant soft drink QC management should perform basic vigilance checks to ensure the quality of cloudy drinks.

Emulsion suppliers normally conduct rigid quality tests with regard to stability factors, such as oil droplet size distribution, oil-phase and water-phase densities, cloudifying power, neck-ringing in beverage samples, etc. Below-standard product seldom reaches the beverage producer.

However, the in-plant QC manager is advised to perform the following simple tests and procedures with all emulsions supplied:

- Check the expiry date of the emulsion batches received, and ensure that none will be used after such date. Some emulsions are imported from distant sources, spend most of

the expected shelf life as cargo on the seas, and arrive at their destinations at the end half of this shelf life period.

- Prior to use, visually check concentrated emulsions for creaming, oil slicks, and general homogenous appearance. With experience, these are very easy to spot.
- Ensure that certificates of analysis (COA) results for each batch received comply with originally established specifications, which should include oil droplet size distribution, neck-ringing absence, turbidity strength, and so on. These results need not be quantified, merely noted as "passed." Should beverage stability defects develop, these results could be quantified, especially in cases of claims against the supplier.
- Check beverage retention samples of the company's cloudy drink products on a frequent basis. If a sample shows a neck-ring, check out the same batch in the trade, if such still exists.

CHAPTER REVIEW

Almost the entire chapter revolved around the stability aspects of beverage emulsions, whether these are related to formulation or homogenization. The reader should be consoled by a basic technical fact: all emulsions, by definition and according to scientific laws, are destined for eventual breakdown. The emulsion state is not the physical–chemical stable form of the oil phase in the water phase — the separated portions of these two phases are the stable ones. In reality, what happens is that the concentrated beverage emulsion is hopefully designed by the formulator and produced by its manufacturer to last in the final drink for the expected shelf life of the beverage.

Emulsions are inherently unstable, and we should only expect them to perform adequately for the specified shelf life of the beverage.

To conclude this chapter, I invite the more curious reader to perform the following simple experiment:

A small simple experiment.

Take a 2 l PET bottle of any cloudy drink beverage brand, such as an orange flavor, for example, from your local store. Remove its wraparound label so that all the contents are visible. Lay the bottle down in a horizontal position on a table, and secure it so that it cannot be bumped or rolled over. You will see a large elongated ellipsoid meniscus at the surface of the liquid along the length of the bottle.

Let the bottle stay undisturbed in this position for 3 or 4 days, after which you should inspect the meniscus. If the product's cloud is due to an emulsion ingredient (and not to the presence of natural fruit juice) in the formulation, I will be very surprised if you do not clearly see a white creamy ring around the meniscus. This is a result of creaming in the beverage's emulsion. This neck-ring may be very thin, of the so-called hairline size, and you may think that the ring is actually the outline of the meniscus and not a ring at all. To check this out, tap the bottle a few times with your finger. If it is a ring, you will see it disintegrate slightly. Tap a little harder until the ring completely disappears.

I realize that I am sticking my neck out in this matter, but I am confident that in most cases this rapid creaming phenomenon will be observed. I have done this experiment many times without fail. Why this happens I cannot fully explain — nor could a few emulsion experts with whom I discussed this. What I think happens is that because of the low height of the horizontal bottle, the oil droplets have very little distance to rise in, and the full creaming rate is therefore accelerated. Also, I think that the relatively large area of the meniscus surface of the beverage plays some role in amplifying the visual impact of the neck-ring on the viewer.

This issue was presented to drive the point home that emulsions are by nature unstable. Their breakdown, to one degree or another, is to be expected, as long as it is not within the specified shelf life of the cloudy drink product.

5 Water Treatment — The Key Process

WHY IS WATER TREATMENT NECESSARY?

The title of this chapter indicates that the treatment of water is the key process of soft drinks manufacture. This is because water is the major component of a soft drink. A carbonated soft drink can contain about 87 to 92% water, whereas a bottled water product may be pure 100% natural spring water. As such, the quality of the water used in a beverage has a critical impact on the taste of the drink, its appearance, and its physical and microbiological stability on the shelves in the store. The water used by soft drink manufacturing facilities may come from two main types of sources. The most common source is the municipal water supply, but there are also water sources that are privately owned wells. The source water before it is treated in the factory is often referred to as "raw water," a term that is used in this handbook.

Though raw water is normally treated by the municipality or private well owner to render it potable and fit for human intake, it may still have characteristics and components that can adversely affect the quality of the beverages in which it is used. These need to be eliminated or at least reduced so that their effects are minimized. Raw water from a single source may also vary considerably in composition and physical and chemical characteristics due to seasonal or environmental changes in the source conditions. Again, though the raw water may still be completely potable, these changes could impact significantly on the quality of final beverages. A soft drink manufacturer should endeavor to maintain a consistent quality in its products, and such changes must be neutralized. Raw water from different source locations may differ considerably. Large soft drink companies, especially those with international markets, need to maintain a consistent quality image of their brands, regardless of the geographical location. Thus, water used in their products must be rigidly standardized in quality aspects.

Still another reason for the need to treat water for soft drink production is that on occasions, infrequent as they may be, municipal water treatment plants may encounter problems. Although these may be considered as mere inconveniences by the public so affected, to the soft drink manufacturer, it could present serious marketing and cost hazards should such water be used in its products.

In certain underdeveloped countries and communities, there are no source water treatment facilities. Soft drink manufacturing operations in such places must therefore treat the raw water themselves to render their products fit for human drinking. Still another factor to consider is that though the municipality may very well treat source water, it can become contaminated on its way to the end user due to faults in the often-complex distribution system.

The soft drink manufacturer cannot afford, for obvious reasons, to take a chance on using substandard water in any single batch of final beverage it produces. Raw water must, therefore, always be treated to meet the established quality specifications of the soft drink manufacturer.

RAW WATER ADVERSE QUALITY FACTORS

Raw water, as supplied to the public for human intake and general use, in most cases, meets stringent quality and health standards of local authorities or the World Health Organization (WHO). Even as such, it may still have characteristics that do not suit the delicate and sensitive interactive structure of a soft drink's composition on which its general good quality depends. This dependence on good quality water in the drink is especially true when source water treatment is inadequate or absent.

The following briefly describes the possible adverse factors of raw water that could affect the quality of final-product soft drinks.

Suspended Matter

Raw water often contains suspended colloidal matter and organic particles. These not only can cause unsightly appearance and turbidity, especially in clear beverages, but can also provide anchorage sites for microorganisms. Such "hiding places" can protect the microorganisms from the disinfection process in water treatment.

Chemical Composition

The dissolved minerals determine the alkalinity and pH of the raw water. High alkalinity/pH neutralizes the acidity component of the beverage and, thus, could affect the overall taste profile of the beverage.

Certain compounds, such as those of iron, chlorides, and sulfates, at even very low concentrations, can impart off-tastes to the beverage. This is also true of residual chlorine, which is sometimes deliberately retained in raw water by the source water treatment process. Raw water may sometimes contain dissolved organic compounds that impart an off-taste or off-odor to the beverage. Raw water may also inadvertently contain organic compounds hazardous to health, such as trihalomethane (THM) or residual pesticides. (THM will be discussed briefly later in this chapter.)

Microorganisms

One of the prime aims of municipality treatment of source water is to eliminate pathogenic organisms from the source water. This is of prime concern from the public health aspect, and raw water is normally free of such hazards. However, soft drink manufacturers cannot take any chances in this matter, and all raw water must be disinfected adequately to remove such a potential health hazard from their products.

All local and WHO raw water specifications allow for a certain level of nonpathogenic bacteria. These microorganisms, as a rule, are not a major beverage spoilage factor, but it is always wise to be on the safe side. This, therefore, should also be checked by the soft drink manufacturer and addressed by disinfection in the treated water process.

Source Water Quality Variation

Source waters, of both the surface and underground types, are often subject to seasonal changes as well as to unpredictable local events in the nearby environment that can cause significant changes to the raw water quality. These can still be within the specification of the source water treatment process and, as such, have no special significance to the public water user. However, the changes may impact heavily on the soft drink manufacturer as explained above. The manufacturer usually aims to keep product brand images as consistent as possible, and changes in appearance or taste are not desirable.

Raw water from different source locations may differ considerably. An individual soft drinks facility may have to use one or more raw water sources. This is unavoidably true for national or

international multiplant organizations. In both of these cases of variations in source water quality and composition, there is a need for standard treated water specifications in order to achieve unwavering consistent quality in the facility's products.

A SHORT DIGRESSION

The reasons for this requirement of raw water treatment in the soft drinks industry brings to mind some of the occasions when I was questioned by family or friends on my work as a food technologist in the soft drinks industry. When on the subject of water treatment, I have sometimes been bluntly asked why raw water has to be specially treated when it has already been through such a process by the municipality's water department. Some of these people, that is, the more logical thinking ones, basically follow a train of thought such as which follows:

If a soft drinks company has to treat raw (municipality) water because some "undesirable" elements, such as those explained above, may be present in the raw water, does this not mean that those who work at the company and their family members are drinking at home water that could be "dangerous to their health?"

It is all very well to treat the raw water to eliminate things that could affect the taste and appearance of a soft drink. But with regard to the bugs, hazardous pesticides, and other no-no materials, does this mean they and their kids are at risk when drinking water from the tap at home?

Does this mean that our local water authorities are failing to provide hazard-free water to the community?

When you come to think of it, as I sometimes have, the concern expressed by these people is to a certain extent quite justified. I cannot exactly remember how I answered these questions, but it was probably something along these lines:

No, the water authorities are not failing in their duties. In fact, all things considered, they are doing an excellent job. It is just that sometimes, as with any process, things can go wrong. If and when such happens, members of the public can be assured that they would be timely notified by means of the local media and warned of any serious threat to health.

Yes, there is always an element of risk, as slight as it may be, that there could be, at times, something wrong with the water at home. It is a risk that we all have to take, along with all the many other risks involved in modern daily life — like getting stuck in a lift during a power failure.

But, a soft drinks company does not need to take this risk. It wishes to avoid any and every health hazard to the public it can adequately address. This is not only in the interest of public safety but also to avoid costly product recall and damage to the company's image.

Yes, a low count of bugs in water is expected and allowable — our bodies can handle this. After all, we are exposed daily to far more serious bug contamination situations in daily life. It is the disease-causing bugs (and those that cause product spoilage) that the soft drinks industry, like all other food industries, is concerned about. So it goes the extra mile by disinfecting regular raw water supplied by the local authorities — just to make sure.

This short digression has been included in the chapter of water treatment just in case readers find themselves in a similar situation and perhaps could use some of my answers.

WATER TREATMENT TECHNOLOGY

The technology of water treatment in the soft drinks industry, if not too complex, is nevertheless too vast and diverse to be fully covered in this handbook. This chapter will be confined to a brief general outline of the technologies involved and issues related to water treatment in the soft drink manufacturing operation.

Water treatment technology is esoteric in nature, involving at least some basic knowledge of various chemistry disciplines, microbiology, engineering, and equipment design. The effective operation of a water treatment plant requires process-operating skills and more than a little experience. Staff members in the larger soft drink corporations charged with water treatment duties and responsibilities are usually specifically trained for this purpose. In smaller independent companies, if not properly trained in water treatment essentials, staff members are best advised to master the basics of the operation for the daily routine running of a water treatment plant and leave its design, installation, commissioning, and general maintenance to outsourced specialists in the field. With time, however, such company staff may well become experts in the field.

Water treatment plant design and level of technology involved should be based on a few pivotal considerations regarding the quality of raw water supplied to the soft drink manufacturer:

- Confidence in the source water treatment process
- Consistency in quality
- Standard levels of adverse raw water quality factors (e.g., alkalinity, microbiological, suspended matter, dissolved minerals, disinfectant residues, etc.)
- Protection from external contamination at the source as well as throughout the distribution system
- Seasonal variations in source water composition and characteristics

The more favorable these factors are, the less complicated and involved is the technology for the treated water plant design and operation. Also, the costs involved will be less.

Another major consideration is the type of soft drink end product. It would be pointless, for instance, to use ozone as a raw water disinfectant for a carbonated soft drink, where the residual ozone in the bottled product would be immediately used up by the various ingredients and also could oxidize some of the key flavor and color components. On the other hand, chemical treatment of raw water for bottled water products is not only sometimes prohibited by law, but also it will alter the natural or added mineral content of the product.

THE MULTIPLE BARRIER CONCEPT

A series of complementary processes that incrementally eliminate or reduce adverse factors is a multiple barrier system.

The treatment of raw water intended for use in soft drink production consists of a number of processes aimed at controlling diverse and separate features that could adversely affect the quality of the final beverage. As such, the design and operation of an effective water treatment plant uses the multiple barrier principle to achieve a combined process system that will effectively and totally control these various features.

A multiple barrier system can generally be described as an orderly series of reliable processes that, in a complementary and incremental manner, completely removes or reduces targeted raw water adverse quality factors to acceptable levels. Each process on its own serves as a "barrier" to adverse factors, either eliminating one or more or reducing the level at that barrier stage. In soft drink water treatment, the multiple barrier principle is applied by combining separate individual processes, the end result of which is the highest-quality water at the lowest practical cost.

MULTIPLE BARRIER WATER TREATMENT

As mentioned before, the design and operation of a multiple barrier water treatment plant depend on the composition of the raw water, the consistency of its quality, the reliability of its *The main design considerations.* supply, and, to a certain extent, the type of end product being manufactured. The major considerations for the design of the system that will result in high-quality treated water at the lowest possible cost for the final beverage are as follows:

- The quality of the raw water
- The treatment process for microorganisms
- The treatment process for removal of or reduction in suspended and dissolved materials
- The treatment process to eliminate off-tastes and off-odors
- The treatment to ensure high-quality product appearance
- The overall effective treatment for all water used in all the company's product types

Figure 5.1 is a schematic representation of the basic processes required of a multiple barrier water treatment plant. Each process will be briefly described separately. However, it must be remembered that in a multiple barrier system, the processes are complementary to each other. Only the full combined effects of each process result in the final end product of high-quality treated water for use in soft drink manufacture.

ENHANCED FILTRATION

The most critical process of a multiple barrier system is that of enhanced filtration. This refers to a filtration process that is capable of removing minute matter at the molecular level, as *Filtration at the molecular level.* opposed to simple filtration in which only relatively larger particulate matter is filtered out of the water. Enhanced filtration removes a variety of adverse suspended matter and dissolved chemicals:

- That could not be filtered out by operations further along the line in the water treatment process
- That could protect microorganisms from the disinfection process
- That could react with the disinfectant and reduce the latter's effectiveness
- That could serve as precursors for THM formation
- That the activated carbon filter would otherwise remove, which reduces the working load on the carbon filter and enhances its performance in removing the specifically adverse materials at which it is targeted; also, the carbon filter's operating life is lengthened, with subsequent cost savings in regeneration or replacement of activated carbon granules

There are two main types of enhanced filtration systems: coagulation/flocculation and membrane filtration.

COAGULATION/FLOCCULATION

BATCH SYSTEM

As the name implies, this consists of two processes. The following is an outline of these processes as they occur in a batch system of coagulation/flocculation. A cationic coagulant such as ferric chloride is added to the tank with the water to be treated (Figure 5.2).

Raw Water

```
Enhanced
Filtration
```

```
Alkalinity
Control?
```

```
Disinfection
```

```
Activated
Carbon
Purification
```

```
Polishing
Filtration
```

Production
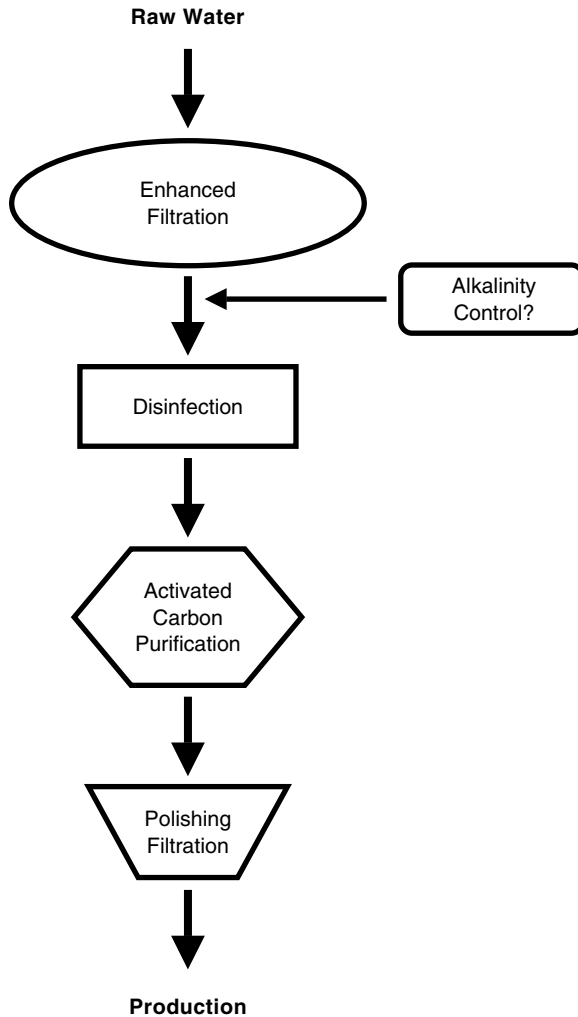
FIGURE 5.1 Basic water treatment process.

It is converted to its gelatinous hydroxide form (1), and its cationic positive charges neutralize the negative charges of suspended colloidal particles in the water (2). These particles now do not repel each other, and together with the hydroxide flocculent, start coagulating into larger gelatinous masses that are commonly called floc (3).

The floc masses grow in size until they are large and heavy enough to start slowly sinking to the bottom of the tank (Figure 5.3). As this now dense cloud of floc slowly sinks, it physically entraps and carries organic and inorganic particulate matter with it. This layer of cloudy floc can be likened to a very fine filtering device slowly moving downward through the water, trapping matter in its path (instead of the more common filtering situation of moving water passing through a stationary filter).

The floc with all the entrapped material eventually settles at the bottom of the tank in the form of sludge, which is periodically removed and disposed. The supernatant water in the tank is drawn off and passed through a conventional type of pressure sand filter that entraps any floc that remains in the water. It also retains any small amounts of suspended matter that for some reason may not have been previously filtered out.
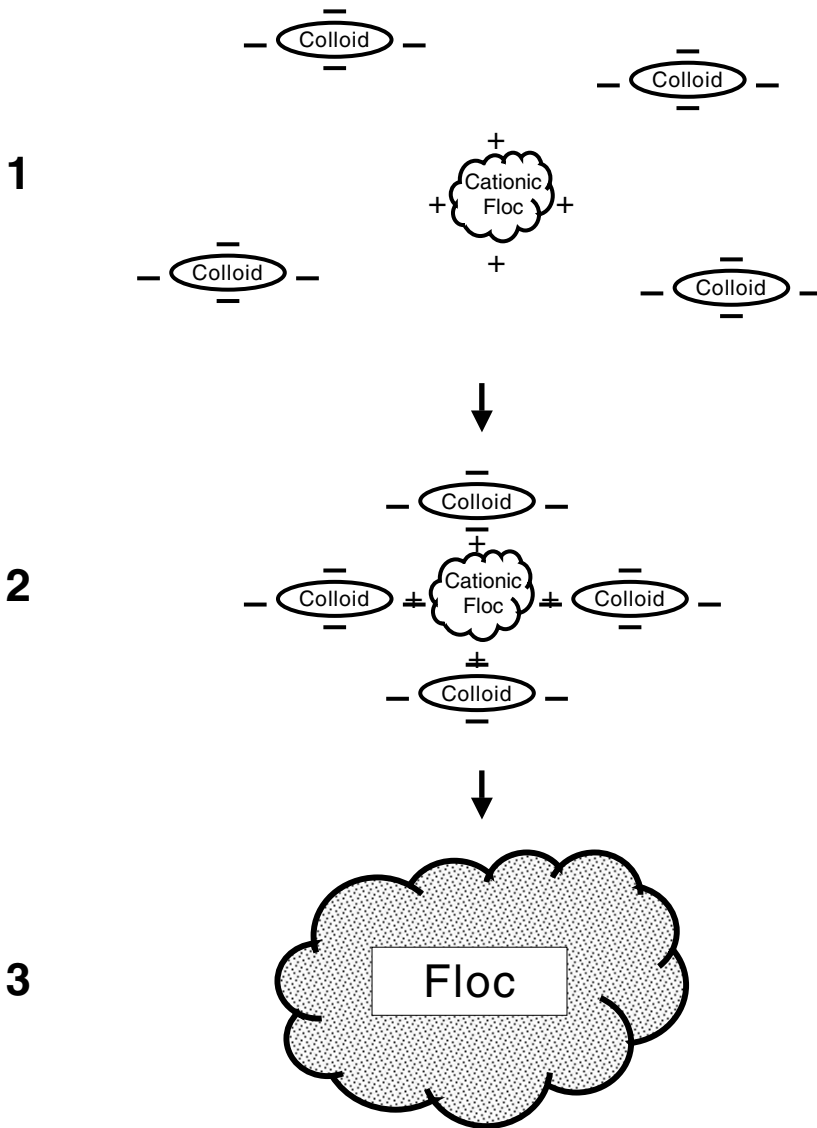
FIGURE 5.2 Coagulation/flocculation.

In an in-line coagulation and flocculation system, the same principles apply, but the equipment design is different. Small amounts of cationic flocculent are continuously dosed at a predetermined rate into the incoming raw water flow leading to a relatively small static mixer. From the mixer, the raw water is fed into a deep-bed granular filter (e.g., sand filter). The rapid coagulation and flocculation process starts immediately in the pipes after the mixer and continues in the deep-bed sand filter in the spaces between the sand granules. As flocculation proceeds, much the same as in the batch system, the floc penetrates deeper into the filter bed and is retained on its way by the filter media. For this reason, the filter vessel needs to be much taller with a deeper media bed than a regular sand filter to ensure that all the floc is retained and only clear filtered raw water exits from the bottom outlet.
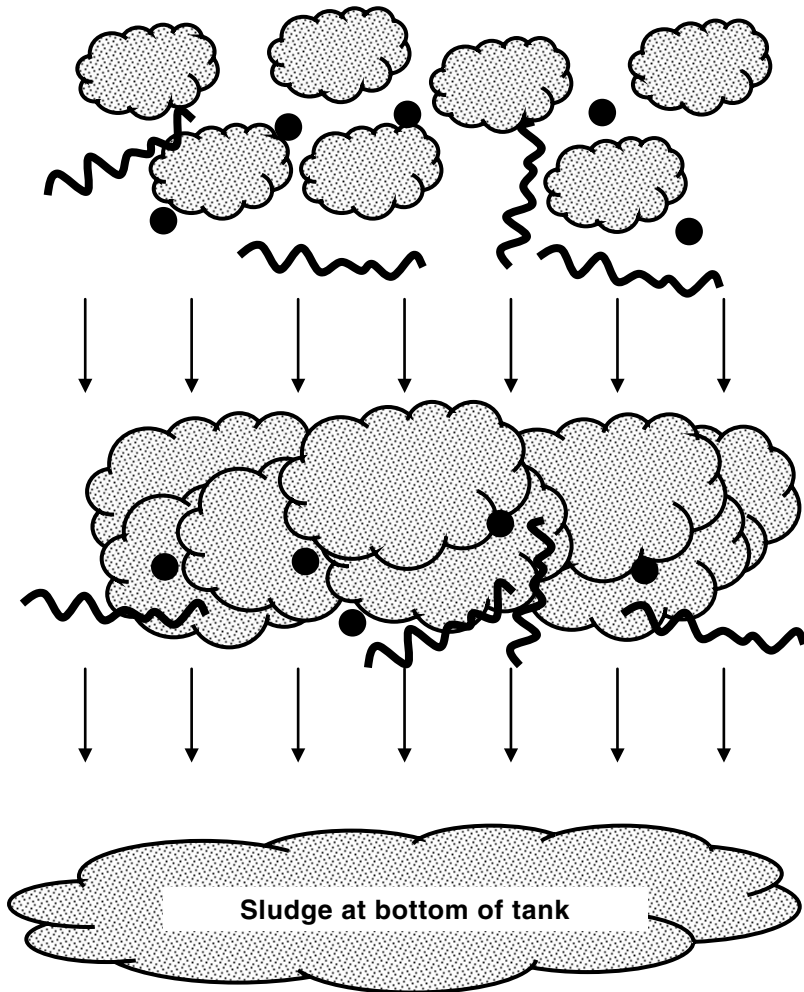
FIGURE 5.3 Coagulation/flocculation completed.

The advantages of the in-line system, as opposed to the batch system, are that it is less expensive in equipment, coagulant, and wastewater costs; it occupies less space; and it is relatively easy to operate. However, it is only suitable for raw water of very good quality with low levels of suspended or dissolved materials. Also, the in-line system does not combine alkalinity reduction with the filtration processes, as does the batch system.

MEMBRANE FILTRATION

The second type of enhanced filtration technology used in raw water treatment for soft drinks is that of membrane filtration. The basic principle involved in membrane filtration technology is the use of a pressure differential to force materials through a membrane on a selective basis. The membranes are called semipermeable, because, depending on the pore sizes, small particles and molecules may permeate (pass through) the membrane, while others of larger sizes are not allowed to do so and are retained in the water being filtered.

There are different classes of membrane filtration based on the sizes (or molecular weights) of the materials that can permeate through the membrane. Of interest to us are three types of membrane filtration systems:

- Reverse osmosis
- Nanofiltration
- Ultrafiltration

REVERSE OSMOSIS

Reverse osmosis obtains its name from the process of osmosis, in which the water of a solution of low dissolved solids diffuses through a semipermeable membrane into another solution of higher solute content. A special case of osmosis is when instead of the low solute solution, we have pure water. The pure water as "the low solute solution" diffuses through the membrane into the high solute solution.

This process of osmosis and that of reverse osmosis are explained in Figure 5.4. The first diagram (1) shows that when a solution of salt is brought into contact with water, the molecules of water, according to the principle of diffusion, migrate toward the salt; those of the salt migrate into the water. This process, if allowed, will continue until a state of equilibrium is reached in which a homogenous diluted salt solution is formed. The molecules of water and of salt are dispersed evenly throughout the liquid.

In diagram (2), a semipermeable membrane is first placed between the water and salt solution. This membrane is permeable to water molecules but not to those of the salt. Simple diffusion will start, but there will only be migration of water molecules through the membrane into the salt solution. The membrane barrier will block the salt molecules' diffusion into the water. The water passing through the membrane is called the permeate.

As a result of the permeation of the water into the salt solution, the level of the latter will rise and form an osmotic head (A) in the tube. The level of this head will rise as more water permeates through the membrane. When the weight of the now somewhat diluted salt solution in the head becomes equal to the osmotic pressure generated by this particular system, the osmosis process will stop.

Diagram (3) shows that if a high enough pressure (B) is applied to the osmotic head, e.g., by means of a pump, it will overcome the osmotic pressure of the system and start pushing the water molecules back through the semipermeable membrane. With sufficient applied pressure, a large portion of the water molecules of the salt solution will also be pumped through the membrane, and the level of the water will rise in the tube (C). We can see that the process in diagram (3) is the reverse of what happened in the osmosis process of diagram (2). Hence, this process is called reverse osmosis.

If the semipermeable membrane is such that it allows some molecules other than water to pass through it, this can be used to selectively allow these to also be included in the water permeate and block other undesirable ones.

Being a biochemist by qualification and having a passion for the biological sciences, I cannot refrain from mentioning that osmosis plays an important role in a multitude of essential life processes in plants and animals at the cellular level. The cell membranes of living organisms are semipermeable, and processes such as nutrient absorption and water balance control, to name a few, use the principle of osmosis. Even reverse osmosis occurs in living organisms and is known as active transport, where solutes are transported through the cell membrane against a concentration gradient. The most well-known example of this is the sodium/potassium pump, which is involved in neural impulse transmission. Nature is way ahead of us in that the selective semipermeability of cell membranes can be rapidly changed or switched on and off.
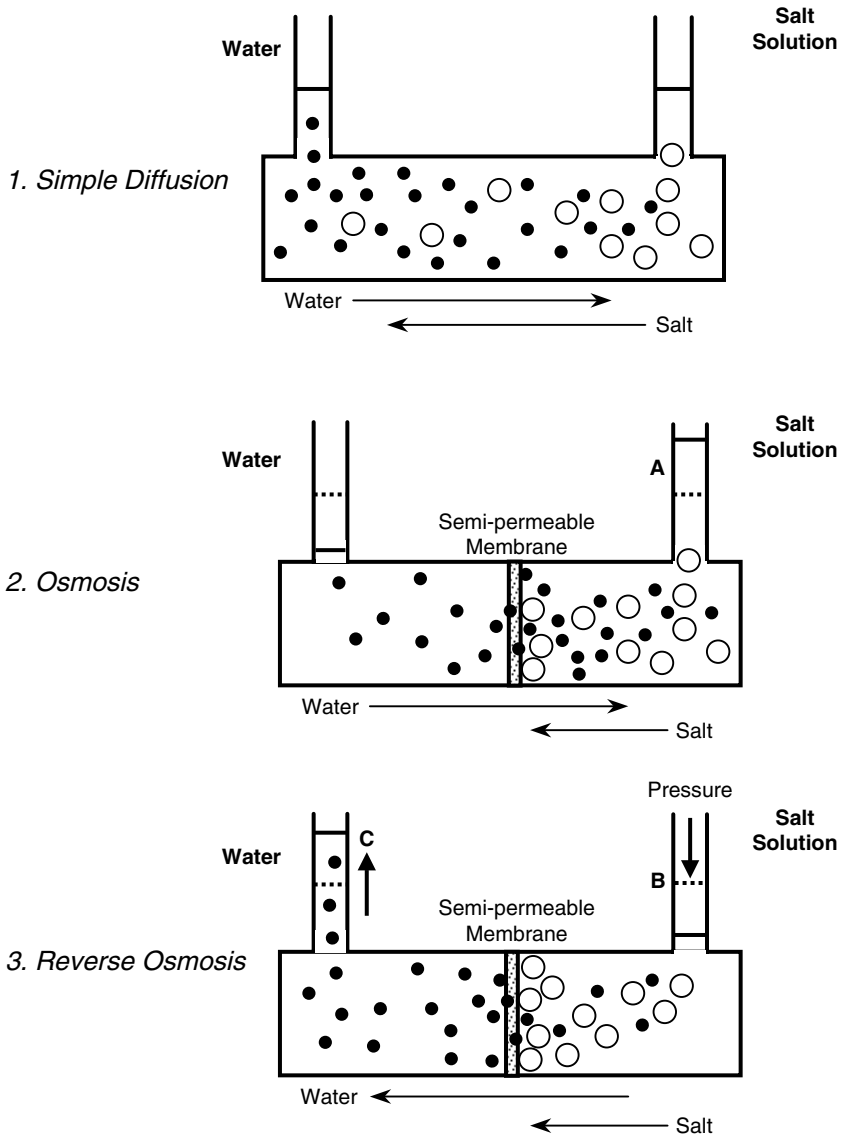
FIGURE 5.4 How reverse osmosis works.

Now, we go back to our topic of membrane filtration technology in water treatment.

NANOFILTRATION

Nanofiltration is similar to reverse osmosis but only treats particles of slightly larger sizes.

ULTRAFILTRATION

Ultrafiltration can be considered a straightforward filtering of small particles through membranes of larger pore sizes than those of nanofiltration and reverse osmosis.

Concentrate

The difference between these three membrane filtration systems lies basically in the materials that can be blocked by the membrane. Ultrafiltration can separate microorganisms and suspended solids, while reverse osmosis does this and can filter out even smaller molecules such as dissolved solids and salts. Nanofiltration covers the filtration of a range of particles somewhere between the other two.

In all membrane filtration systems, there are two outlets from the filtering unit. One of the outlets is for permeate (the filtered water), and the other is for the retentate. Unlike conventional filtration processes, where all the water passes through the filtering device, in membrane filtration the retentate is that part of the water being filtered that does not flow through the membrane. Under pressure from the pump, it flows out through its own outlet, carrying away the material that was rejected by the membrane. During operation, these materials will accumulate in the retentate and increase in concentration. For this reason, the retentate is often called the concentrate. In membrane filtration processes, this can reach up to 15% of the volume of raw water being treated. The concentrate is usually disposed to waste and is a cost consideration in multiple barrier design using membrane filtration.

Membranes

The two main types of materials for membrane construction are cellulose acetate and polyamide.

Cellulose acetate is less costly and can tolerate low levels of chlorine. They are, however, vulnerable to attack by microbes, which favor cellulose as a food source. Therefore, these membranes should continuously be subjected to a residual chlorine flow, which can usually be built into the multiple barrier water treatment design.

Polyamide membranes, though not prone to microbiological attack, are not resistant to oxidation by chlorine. They therefore should, in the multiple barrier design, be placed after carbon filters that eliminate the residual chlorine in the water being treated. That these membranes do not tolerate chlorine implies that special measures need to be taken in their cleaning to avoid microbiological fouling.

The prevention of fouling of membranes is an important factor in the use of them for water treatment. Due to their small pore sizes, they are easily blocked up by excessive filtered components such as colloidal matter, microorganisms, and precipitated salts. Precipitated salts are deposited on the membrane if the flow of the concentrate is not fast enough and the previously dissolved salts concentration exceeds their solubility levels in the water.

System Design

The quality of the raw water to be treated is the key consideration for the design and installation of membrane filtration in the multiple barrier water treatment system. Obviously, the water should have low levels of potential membrane-fouling components. However, general composition, expected seasonal changes, and adverse quality components that require elimination or reduction in levels will be critical considerations in choosing the membrane filtration type. These considerations will also determine at which stage in the multiple barrier system it should be installed.

Membrane filtration technology is somewhat complex, and the equipment used in a filtration unit is highly sophisticated. It is best to consult with a membrane filtration supplier expert when designing a multiple barrier water treatment system that is to include such a filtration unit. Furthermore, the supplier should be retained for the maintenance of the unit and should be on call for troubleshooting during its operation.

This should not put off anyone considering membrane filtration utilization in water treatment, as the sophisticated unit is virtually self-running. Only continuous periodic quality checks on the filtered water need to be conducted, as in any other type of enhanced filtration process, to verify satisfactory operation of the unit.

ALKALINITY REDUCTION

The next step of alkalinity control is only necessary with raw waters of high alkalinity. If this is the case, it must be reduced, as high alkalinity neutralizes some of the acidity of soft drinks and could adversely affect the overall taste profile of the beverage.

Many raw waters have satisfactory low alkalinity levels, and if consistent in this respect, the alkalinity step may be omitted. As a rough guideline, raw waters of alkalinity below 85 ppm expressed as calcium carbonate do not require alkalinity reduction treatment.

Raw waters usually contain bicarbonates and carbonate of calcium and magnesium and, to a lesser degree, those of sodium. These are all soluble components in the water, and their presence in dissolved form contributes to the alkalinity of the water.

HYDRATED LIME TREATMENT

The most commonly used process for alkalinity reduction is that of hydrated lime treatment. Hydrated lime is actually calcium hydroxide and is commonly called "slaked lime." It would seem strange that the addition of one calcium compound can result in the removal of another calcium compound from the water. However, this is based on a simple chemical reaction in which the hydroxide converts the soluble calcium bicarbonate to an insoluble carbonate, which, in turn, precipitates out and is thus removed from the water:

$$Ca(HCO_3)_2 \quad + \quad Ca(OH)_2 \quad \rightarrow \quad CaCO_3 \quad + \quad 2H_2O$$

| Calcium Bicarbonate | Hydrated Lime | Calcium carbonate | Water |

$$\downarrow$$
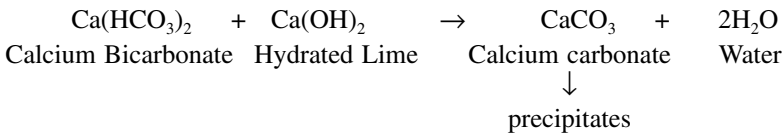
precipitates

With the magnesium bicarbonate, the reaction takes place in two steps: first, some of it is converted to insoluble calcium carbonate and the remainder into magnesium hydroxide, which is also insoluble and precipitates out. Thus, more hydrated lime is required for magnesium alkalinity reduction than for that of calcium.

The reader will notice that we talk of alkalinity reduction and not complete elimination. This is because a low level of alkalinity improves the enhanced filtration of the coagulation and flocculation treatment process, which is usually performed in conjunction with the hydrated lime treatment in the same reaction tank. This low alkalinity provides the pH conditions for the solubility of the cationic coagulant as well as the hydroxyl ions to convert it into the gelatinous flocculent hydroxide form. Furthermore, the settling out of the precipitated calcium carbonate and magnesium hydroxide enhances the flocculation effect. In raw waters not requiring alkalinity reduction, the low alkalinity already present is sufficient for the above-mentioned purposes.

Sodium bicarbonate alkalinity cannot be reduced by hydrated lime treatment alone. It must first be reacted with calcium chloride or calcium sulfate to convert it into calcium bicarbonate, which then reacts with hydrated lime as described above. These reactions also produce sodium chloride or sodium sulfate, which in excessive amounts can cause salinity taste problems in the treated water and in the final beverage. Care must be taken to control this salinity factor.

ION EXCHANGE

Ion exchange systems in various cation and anion combinations can also be used for alkalinity reduction, but they can be associated with some major disadvantages. An ion exchange system may completely eliminate the alkalinity of the water. Usually, the ion exchange water needs to be blended with some untreated water to achieve the required low alkalinity in the finally treated water. Second,

ion exchange water can result in high levels of acids and their salts, the presence of which may need to be somehow negated. In some systems, the resin beds require periodic regeneration using concentrated acids or alkalis, which could present safety hazards to operators.

Ion exchange systems do not really suit straightforward and simple alkalinity reduction purposes, but they are very effective in dealing with specific inorganic salts that are excessively abundant and problematical in some raw waters destined to be used in soft drink manufacture. Ion exchange systems are very well suited to soft drinks that for some reason require demineralized water in the final products, such as in bottled waters, some types of health and diet beverages, etc.

DISINFECTION

Disinfection is aimed at the total elimination of any pathogenic microorganisms present in the raw water and the reduction, if not elimination, of nonpathogenic microorganisms to acceptable levels. This may be done with chemicals or by physical means or through a combination of both.

CHLORINATION

Chlorine treatment is the most preferred chemical method for disinfection of raw water for soft drinks manufacture. The advantages of chlorine are the following:

- Effective against a wide range of microorganisms
- Effective at very low dosages
- Rapid microorganism inactivation rate (short contact time)
- Able to provide residual disinfection
- Able to oxidize some types of soluble organic matter into insoluble forms
- Can destroy off-tastes and off-odors
- Can easily be removed by activated carbon
- Can easily be detected in order to determine and control its level in the water

Sources for chlorine may be one of the following:

- Chlorine gas
- Liquid sodium hypochlorite
- Solid calcium hypochlorite

CHEMISTRY OF CHLORINATION

The basic principle is that the chlorine source is converted to hypochlorous acid when added to water. Thus, with calcium hypochlorite, for example, the reaction is as follows:

$$Ca(OCl)_2 + 2H_2O \rightarrow 2HOCL + Ca^{++} + 2OH^-$$

| Calcium Hypochlorite | Water | | Hypochlorous Acid | Calcium Ion | Hydroxide Ion |
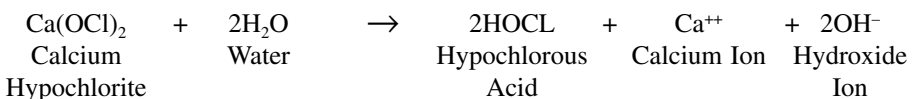
The hypochlorous acid is a strong oxidizing agent and is the component that destroys the microorganisms and oxidizes other organic matter. It can ionize in a reversible reaction to the hypochlorite ion OCL^- and hydrogen ion H^+, but at around pH 8 more hypochlorous acid is available, and disinfection is more effective.

Free and Combined Chlorine

Free chlorine is that portion of the total chlorine existing as hypochlorous acid, which is the major form of chlorine that reacts chemically and biologically with microorganisms and organic matter.

When chlorine is added to the water, the free chlorine will react with any nitrogenous (organic) matter present in the water and will form compounds called chloramines. There may have been preexisting chloramines in the water. Chloramines are called combined chlorine and are not nearly as effective as free chlorine. In order to achieve required levels of free chlorine in the water, the chloramines must be eliminated and only thereafter will free chlorine be available for further disinfecting purposes. Free chlorine and combined chlorine are referred to as total chlorine.

Chlorine Demand

The amount of chlorine consumed in oxidizing the nitrogenous (and other soluble inorganic) matter in the water until free chlorine is available is called the chlorine demand. The point where completely free chlorine is available is called the break point. Therefore, the calculated added chlorine to the water will not always result in the same amount of free chlorine measured in the water thereafter.

As a guideline, with chlorine dosage in normal raw water at around 8 ppm, the break point is always passed, and significant amounts of free chlorine are available for further disinfection. In each water treatment system, the raw water should be checked to determine its average chlorine demand. Chlorine dosage should be established accordingly.

Chlorination in the Multiple Barrier System

Chlorination points as a disinfection process in the multiple barrier system depend on the design of the system. The raw water may be pretreated with chlorine before entering the system, or it may be chlorinated together with the coagulation and flocculation and alkalinity reduction steps in the system. If treated water is stored in bulk, it can also be chlorinated to maintain its microbiological integrity before being passed through the carbon purifier at a later stage.

Trihalomethane (THM)

Chlorination of raw water as a disinfection process in the soft drinks industry as well as in the general municipal water supply systems industry has been the preferred method for many years and still is the most effective way to combat microbiological infection. In recent years, some by-products of chlorination have been found in waters and are referred to as trihalomethanes (THMs). They are chemical substances that are formed when chlorine reacts with the natural organic compounds found in almost all source waters. The THMs are a group of chemicals. A typical example is chloroform ($CHCl_3$). Numerous studies linked the THMs to various and diverse health hazards. Though the risks are considered very low, local and world health authorities prescribed a maximum allowed limit of 100 ppb (parts per billion) total trihalomethanes (TTHMs) in drinking water. This has become the standard for treated water in the soft drinks industry. It is imperative that continuous testing for THMs is conducted.

As mentioned elsewhere in this chapter, THMs can be removed by the various enhanced filtration systems as well as by the activated carbon purification process. The fact that the THMs present a hazard risk that is extremely low and that they can easily be detected and removed in an effective multiple barrier water treatment system does not warrant the discontinuation of disinfection by chlorination. Simply put, the advantages of chlorination as a very effective disinfection process in drinking water treatment outweigh the low risk hazards that THMs may present.

OZONATION

Ozonation is another chemical disinfection process, which though not as commonly used as chlorination in the soft drinks industry, is gaining more prominence in water treatment due to research into ozone technology and the development of available commercial ozonation equipment.

WHAT IS OZONE?

Ozone (O_3) is the naturally occurring three-atom form of oxygen. It is a pungent gas and is very unstable under normal atmospheric pressure and temperature, decomposing rapidly into the two-atom oxygen molecule O_2 with which we are more familiar. It is an extremely active oxidizing agent, attacking both organic and inorganic substances, and as such makes it a powerful disinfection chemical against microorganisms. It is effective in very low concentrations (0.1 to 0.4 parts per million), and with a contact time of around 1 min can deactivate most pathogenic and other microorganisms.

Most of us are more familiar with the term "ozone" with respect to the ozone layer, a part of the higher atmosphere where natural ozone is formed by the reaction of sunlight on oxygen. This ozone layer protects us from the full strength of the sun's ultraviolet radiation.

This natural source of ozone is obviously not available to us. To use ozone as a disinfectant chemical, we have to produce it ourselves. As ozone dissipates very quickly, it cannot practically be containerized or conveyed. When required, it has to be generated on-site in the factory by means of an ozone generator (an ozonator) of some sort and must be used immediately thereafter.

OZONE GENERATION

In nature, ozone is most commonly produced by ultraviolet radiation of oxygen in the air. This process can be simulated to produce ozone for commercial use. However, the more commonly used method is that of the silent electrical discharge method, also known as corona discharge.

The basic principle of this method is the electrical excitation of gaseous oxygen, splitting the O_2 into its two atoms, each of which combines with another oxygen molecule to form the triatomic O_3 molecule of ozone. This is done by passing the oxygen through a very high-voltage electrical field in the narrow gap between two metal electrodes. The source of the oxygen may be air or pure oxygen gas. For effective generation of ozone, the feed gas must be free of contamination with oil, dust, and other particulate matter. It must also be dried and free of water vapor.

The description and detailed operation of an entire ozone generating unit, also called an ozonator, with all the equipment for process conditions controls and essential ancillary equipment for dispersion of the ozone in the water to be treated is far too complex and beyond the scope of this handbook. Anyone contemplating the installation of an ozonator for disinfection of water for soft drinks should consult with the specialists of ozonator suppliers.

DISINFECTION WITH OZONE

Ozone is a very unstable molecule and will, within a short time of even less than 1 h, tend to revert to the original stable state of molecular oxygen. In doing so, it will release one atom of oxygen. Therein lies the extremely high disinfection capability of ozone. In the short period before these single atoms recombine back into oxygen, they have highly powerful oxidative properties and will chemically attack almost all organic and many inorganic substances. In fact, ozone is considered as much more powerful in oxidation potential than chlorine.

Ozone has important functions as part of a multiple barrier water treatment system inasmuch as it specifically precipitates out soluble iron and manganese in water; oxidizes organic matter; and removes tastes, odors, and colors. However, the prime function of ozone in water treatment is to eliminate microorganisms. A unique aspect of ozonation as a disinfection system for water is that the very low residual decomposes into oxygen, eventually leaving no traces of ozone in the treated water.

Ozone vs. Chlorine

Being such an effective disinfection agent, the question is asked why ozonation is not as commonly used as chlorination in soft drink water treatment systems. The answer to this is probably mainly that an ozonation system involves a potential health hazard and also that it is relatively much more costly.

Ozone as such is not a poison, but at even very low concentrations in the air it can, if inhaled, cause serious damage to respiratory tract tissues. Occupational Safety and Health Administration (OSHA) authorities in most countries, if allowing the use of ozone at all, limit the ozone concentration in the workplace environment air to a maximum of around 0.1 ppm by volume for specified time limits during the working day. Though even at this low concentration the ozone can be detected by smell, air monitors are usually prescribed by the authorities to detect such traces in the factory environment.

An ozonation system, in addition to the corona discharge unit, involves complex and sophisticated ancillary equipment, such as air driers, heating and cooling devices, ozone bubble diffusers, and air monitors, to name a few. This renders ozonation an expensive item when compared to chlorination systems. Notwithstanding these two arguments, health hazard and cost, ozonation is the preferred disinfection system in the bottled waters industry.

Bottled Waters

Bottled water products are one of the fastest-growing segments of the soft drink market. This segment includes the natural spring water products as well as a diverse range of table and other mineral water types of drinks.

Natural spring water, by definition, implies that no chemical treatment has been involved in its production and that it is preservative free. Food law authorities in most countries are very strict in this matter, and justifiably so. Still, disinfection of natural spring water is considered a basic requirement by most producing companies. Ozonation fits the bill perfectly in such a case — there are no added chemicals and no traces of disinfectant are to be expected in the beverage when consumed by the public. Thus, ozonation can usually be considered as a suitable disinfection process for natural spring waters.

In addition to this, there is another unique feature that makes ozonation the suitable disinfection process for all nonflavored and noncolored bottled waters. As the residual ozone has a relatively short life before it changes into oxygen, the treated water must be filled immediately after it is ozonated. This results in bottled (or canned) product with an ozone residual in the filled and sealed bottle. Therefore, the bottled water product is still being subjected to ozone disinfection until the ozone completely dissipates, which, depending on the nature of the water's composition, can take a good few hours. Thus, what we actually have is a kind of final "in-the-bottle" disinfection process that would eliminate any microbial infection that could occur during the filling operation. Such infections could occur from airborne microorganisms in the filling room, from inadequately rinsed empties and closures, or from other contaminated sources.

The allowed residual ozone in the bottled product is intentional and provides greater confidence in a microorganism-free product. Product must, however, not be dispatched into the trade before the residual ozone concentration is less than about 0.02ppm to 0.05ppm, a level where taste or odor of ozone is not normally discernable. By storing the filled product for 24 h prior to entering the trade, absence of any health hazard or sensory defects in the product can be guaranteed.

In conclusion, it would appear that ozonation is the preferred option as a raw water disinfection process for bottled waters, provided that these are uncolored and flavorless products. In such products, the ozone residual would play havoc with the color and flavor of the product and also negate the in-the-bottle disinfection process.

Ozone disinfection can generally be built into a multiple barrier water treatment system with or without a chlorination process. Inclusion of an ozonation system would depend mainly on the intentions of the system designer and cost considerations.

ULTRAVIOLET IRRADIATION

Ultraviolet irradiation, commonly called UV light, is a nonvisible component of sunlight and can be produced by specially designed lamps. UV light is effective in killing microorganisms by disrupting their cells' DNA genetic coding so that they cannot reproduce and multiply into levels of infectious significance.

The detailed technology of UV light equipment and its application to water treatment, as for some other topics in this chapter, are far beyond the scope of this handbook. All equipment installation and operation considerations should be left to the expertise of the supplier. However, the basics of disinfection by UV light are given below.

UV LIGHT DOSE

In order to destroy or inactivate microorganisms, a certain amount of UV irradiation (intensity) must be delivered to the microorganisms in the water for a certain period of time (exposure time). This relationship of intensity and exposure time is called the UV light dose and is the critical factor in effective UV light treatment of water. As the intensity is the amount of UV energy generated by the lamp on a unit of surface area at a given distance from the lamp, the UV light dose unit of measurement is expressed as follows:

$$\text{microwatt-seconds per square centimeter} = :\mu W.sec/cm^2$$

UV LIGHT DISINFECTION EQUIPMENT

The germicidal effect of UV light is accomplished in a few seconds so that the treatment can be applied during the flow of water through the standard piping of the multiple barrier water treatment system. Therefore, a UV light disinfection unit is usually positioned in-line in the form of a reaction chamber in the water-flow piping. Figure 5.5 is a schematic illustration of a typical unit (in which the wall of the reaction chamber has been "cut away" to expose the internal structure of the unit).
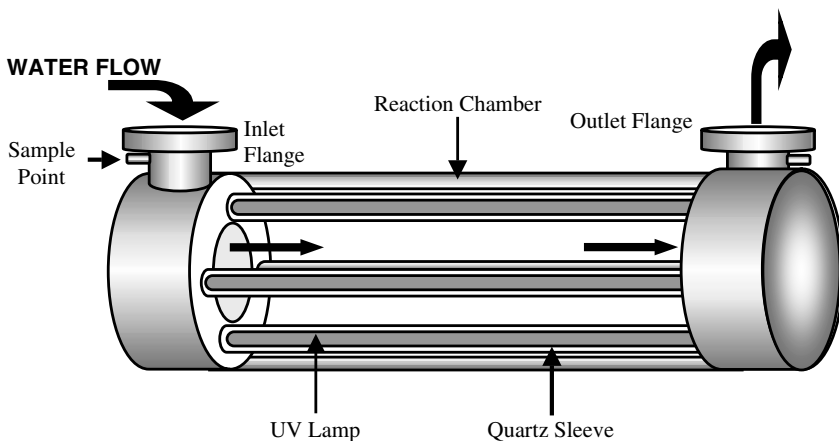
FIGURE 5.5 UV lamp.

Like visible light, UV light intensity decreases by the square of the distance of the lamp from the surface area upon which it acts. The real value of intensity of a single lamp would be that on the farthest point away from the UV light source that is being treated. For this reason, an effective UV light assembly usually has a multiple lamp coaxial arrangement in the reaction chamber of the treatment unit, more or less covering all the water in the chamber at the shortest distance from the lamps as possible. A quartz sleeve protects each UV light lamp.

Water sampling points, before and after treatment, are provided so that microbiological testing can be periodically performed to determine effective reduction in microorganism counts in the water being treated.

The UV light unit should be designed in conjunction with the supplier for the particular process involved. Roughly speaking, it should deliver a UV light dose of about 50,000 :µW.sec/cm^2 to water being treated. It is of paramount importance that the flow of water in the reaction chamber be such to allow the required exposure time. Thus, the size, i.e., the length of the chamber, must be such to provide the exposure time to the maximum flow rate in the water treatment operation. Alternatively, the flow of water must be adjusted to deliver the required exposure time for effective germicidal effect. Theoretically, the lamps should last for about 8000 h of continuous operation before losing their initial intensity. Also, the unit should have sensors with alarm signals to monitor lamp operation. An alarm should sound when intensity is below a required minimum or when lamps, for whatever reason, turn off during a water treatment operation.

How Effective Is UV Light Disinfection?

A correctly designed and operated UV light unit can effectively destroy a large spectrum of microorganisms, provided the inlet water has been suitably pretreated and does not impact negatively on the operating UV irradiation intensity.

What do I mean by this proviso of inlet water being suitably treated? UV light is absorbed by impurities and also by some other dissolved compounds in the water. These could significantly reduce the intensity of the irradiation on any microorganisms present, thus lowering the actual UV light dose below that required. Suspended particles in the water could provide an irradiation shield for microorganisms. This also means that if the microbial load is excessively high, some microorganisms will serve as physical shields for others.

It goes without saying that turbid water will render the UV light disinfection almost useless. This also applies to water that has bubbles of entrained air, which occurs every now and then in any liquid agitation or pumping system. In order to be effective, a UV light disinfection unit must receive the inlet water without any of the above possible negative features.

This implies that the UV light disinfection process in a water treatment system is basically of a secondary disinfection nature. It could be considered in most cases a "cherry on top of the cake" to a well-designed and operating multiple barrier water treatment process that has eliminated or reduced the above-mentioned negative features. It should, for example, not be used as the first or sole disinfection process for incoming source raw water. Also, it should not be positioned before the enhanced filtration processes in the system.

So, where and when should one consider a UV light disinfection process in a multiple barrier water treatment system? I can think of only two main situations where it can be used to good effect:

- To disinfect any bulk, already-treated water stored for some time prior to its flow into a subsequent step of a multiple barrier system design
- As an added precaution ("the cherry on top of the cake") to disinfect fully treated water after the polishing filter (This serves as the last step in the system before the water is delivered to the fillers in clear bottled water operation or to a soft drink filling operation that uses water/syrup proportioning equipment.)

These are the only two cases where the use of a UV light water disinfection process could possibly justify its cost as well as the benefit of added confidence in using water of the highest microbiological quality.

ACTIVATED CARBON PURIFICATION

Raw waters may contain compounds causing off-tastes and undesirable odors. Enhanced filtration processes in the multiple barrier system do not always remove these compounds. This is also true for other organic compounds, such as THMs and some pesticides.

Even if such compounds are absent in the raw water or were removed by an enhanced filtration process, there is still a need to remove the chlorine residue introduced in the disinfection process. Removal of chlorine is the prime function of the activated carbon purification process. The removal of chlorine and the other adverse quality compounds in the raw water being treated is accomplished by means of activated carbon.

WHAT IS ACTIVATED CARBON?

Activated carbon is an amorphous form of carbon that has been specially treated with steam at very high temperatures. This results in a material with a very porous internal structure. The pore sizes are microscopic, and the extensive porosity of the activated carbon gives it a very high total surface area with which to carry out the water purification action. This is achieved by a physical chemical process called adsorption.

Adsorption is not to be confused with the process of absorption, which is basically a simple physical penetration of one substance into the internal structure of another. Adsorption on the other hand, is based on the van der Waal forces, which simply put, is a weak attraction force that exists between all molecules. It can be likened to gravitational force but of much lower magnitude and at much shorter ranges. This force is the principle on which the activated carbon attracts molecules (or atoms and ions) of impurities as they flow through the microscopic pores and holds them on its highly porous and enormous surface area.

THE CARBON FILTER

The carbon purifier, often referred to as the carbon filter, is the equipment used in the water treatment multiple barrier system. In design, it is very much the same as a pressure sand filter, where a bed of granular activated carbon replaces the bed of sand (Figure 5.6).

The operation life of an activated carbon charge in the filter depends on the "load" placed on the filter. An activated carbon charge may last a few years, but the sure sign that it needs replacing or regenerating is a "chlorine breakthrough," namely, the presence of chlorine, at any level, in the filter effluent of the carbon filter. This indicates that the ability of the activated carbon to remove chlorine has been exhausted. Regeneration or replacement of the carbon bed then becomes necessary and should be performed according to the supplier's recommendations.

As the total free available surface area of the activated carbon in the filter is related to its operational efficiency, effective enhanced filtration is important in keeping the surface of the carbon granules free of foreign matter for the elimination of which it is not designed.

The carbon filter, like the sand filter, can become a site for microorganism growth. Normally, the flow of chlorinated backwash water will take care of this problem. However, it is still necessary to periodically open the carbon filter and sanitize it thoroughly. This sanitizing is to be performed according to methods recommended by the supplier. The design, operation, and maintenance of the carbon filter is preferably accomplished in consultation with the supplier.
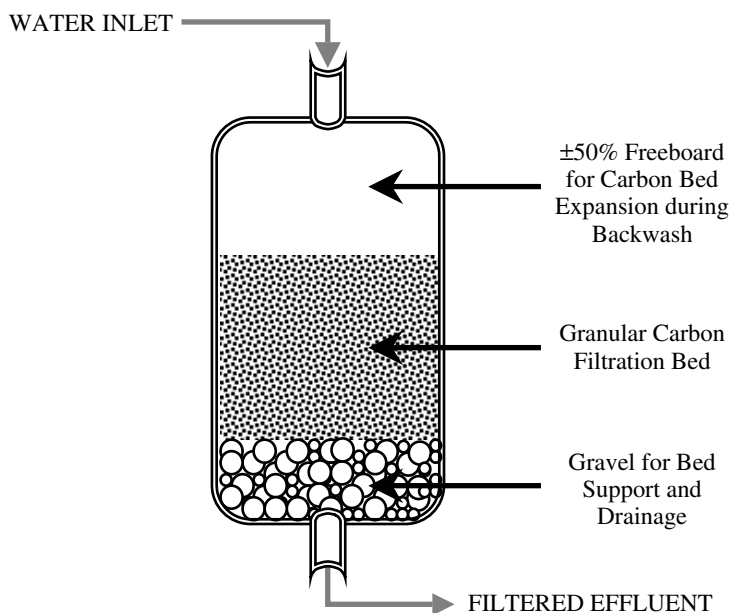
FIGURE 5.6 Carbon filter.

TYPES OF GRANULAR ACTIVATED CARBON

There are various types of activated carbon based on the granule sizes and the source material from which it was prepared. The principle is that the finer the granules, the higher their adsorption abilities. Fine granules also allow for better bed expansion during backwashing. Smaller granule size, however, increases the packed bed density, which will result in a greater pressure drop between inlet and outlet. Too fine a granular size also increases the potential for carbon breakthrough during filtration and would require finer polishing filter requirements. In addition, finer granules can be more easily washed out of the filter during backwashing.

It would seem that the optimum granular size would be a compromise between adsorption capabilities and the disadvantages mentioned above. All of this depends on raw water quality, the flow rates and pressures of the individual water treatment, and backwashing processes concerned.

The source material of activated carbon favored by the soft drinks industry is mainly that from coal (preferred over that from peat or wood). One strict rule to be observed when sourcing activated carbon is that only virgin granular activated carbon should be used. Activated carbon of the "reactivated" type is to be avoided in soft drink water treatment operations. Reactivated carbon is carbon that was already used in processes and was sold to an activated carbon manufacturer for "reactivation" for further resale. Such carbon may have previously been used in a type of industry that could make its use hazardous in soft drink products.

BACKWASHING

Backwashing is the flow of water through the carbon filter in the reverse direction to its normal operation and at higher flow rates and pressures. This vigorously stirs up the activated carbon bed into the upper freeboard space of the filter chamber.

Backwashing of the carbon filter is required because of the channeling effect that occurs in the filter due to the relatively low weight of the granules. When the raw water being treated passes through the carbon bed, it seeks the "path of least resistance" and forms small channels through

which most of the water would rapidly flow, thus decreasing the overall adsorption efficiency of the bed. The backwash stirs up the carbon granules and destroys these channels.

Note: Channeling in the carbon bed can result in chlorine presence in the carbon filter effluent. This type of "chlorine breakthrough" should not be interpreted as indicative of the complete exhaustion of the chlorine adsorption capability of the activated carbon, as mentioned in a previous section of this chapter.

Theoretically, the carbon filter should not entrap foreign matter, as this should have been removed in the earlier stages of enhanced filtration; however, this can still occur. Therefore, backwashing of the carbon filter is also required for this purpose, as the powerful stirring up of the carbon bed dislodges these entrapped particles that are then removed to waste by the backwash flow. Only chlorinated water should be used for backwashing purposes in order to avoid possible introduction of microbiological contamination into the filter beds.

CARBON REGENERATION AND REPLACEMENT

Though a bed of activated carbon in a standard-sized carbon filter has an enormous surface area, its adsorption ability can eventually, over time, become exhausted. It then becomes necessary to regenerate the carbon bed to restore some of its adsorption capability. This is usually done with steam, which by passing through the bed dislodges many of the organic compounds it adsorbed over the operation period, thus restoring some of the adsorption capability. Hot caustic regeneration is another method used. Steam regeneration is the preferred method over this alternative, as the use of hot caustic can be hazardous. Eventually, after a few regeneration processes, the activated carbon will lose most of its adsorption powers. That is the time to consider a full replacement of the bed with new activated carbon. Full exhaustion of the activated carbon adsorption ability indicated by chlorine breakthrough is not the only time regeneration is required. The other occasion requiring regeneration is associated with the phenomenon of desorption.

Activated carbon's adsorption powers vary with different soluble organic compounds, favoring the less-soluble over the more-soluble ones. During normal operation, these compounds are adsorbed equally on the available sites. However, as the adsorption sites diminish, these compounds start competing for the available sites. When they are completely used up, the less-soluble compounds, with greater affinity to the activated carbon, start to displace the already adsorbed more-soluble substances that are then released into the carbon filter effluent. This is the desorption process.

The THMs are of the more soluble types of organic compounds. If present in the water being treated, they will, as a result of the desorption process, become present in the treated water effluent of the carbon filter. This then can be considered as a "THM breakthrough." When the concentration of THMs starts approaching the prescribed maximum level, it is again time to consider regeneration or replacement of the activated carbon in the filter.

POLISHING FILTRATION

Polishing filtration is considered as mandatory in any multiple barrier water treatment design. Its purpose is to remove any granular activated carbon granules that occasionally may have been carried out of the carbon filter bed during the forward flow of the treated water. Sand particles may also be carried through the system, as well as flakes of scale or rust that occasionally break loose into the water and pipes.

The aim of polishing filtration could be summed up simply as to provide crystal-clear treated water for use in soft drink manufacture. As such, the polishing filters are positioned downstream of the carbon filter and immediately before the final product filling line.

THE POLISHING FILTER

There are a few types of polishing filters that use different filtration media, such as paper sheets, membranes, or cartridges. The media most commonly used in soft drink operations is the wound fiber cartridge type.

As the name implies, these cartridges are constructed of wound fibers, usually made out of polypropylene and available in a variety of size lengths. The cartridges are fitted into sup-plier-designed housings. The number and configuration of cartridges in the housing unit will depend mainly on the required treated water flow rate. The pore size for these filters in the soft drinks industry is typically between 5 and 20 μm.

Figure 5.7 shows a typical structure of a single cartridge and how it works. The water flows from the exterior, through the wound fiber media, to the center core from which the effluent is discharged. As the water proceeds to the core, the wound fiber becomes denser, and the pore size decreases. The operational lifetime of a cartridge depends on the filtering load to which it is subjected. In an effective water treatment system, they could last for months at a time.
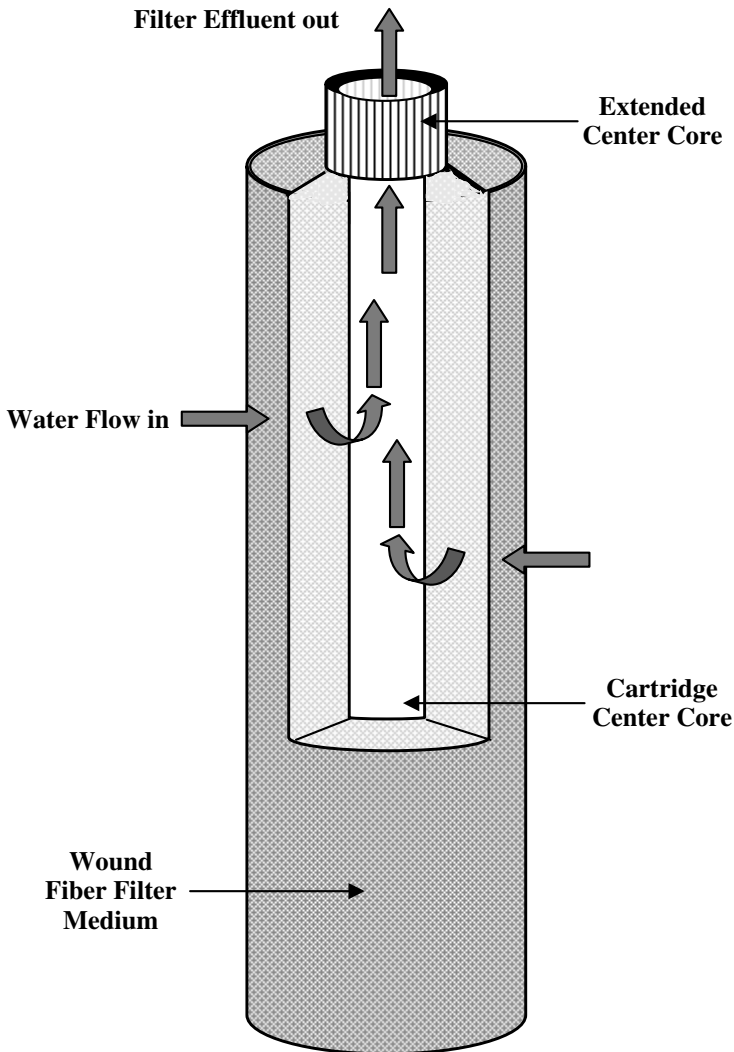
FIGURE 5.7 Wound fiber cartridge.

Polishing filters can be considered as ideal sites for microorganism growth, as any organic matter not effectively removed during previous treatment stages can be trapped and lodged in the cartridge pores, serving as substrate for microbial growth. Chlorinated treated water left in the lines and filling equipment overnight can take care of this problem. However, if this is not the case, the cartridges must be periodically removed and adequately cleaned and sanitized.

Cartridges need to be periodically checked visually for fouling, which is evident as discolored areas in the woven fiber penetrating along the radius of the cartridge. Rapid fouling of the cartridge would indicate improper design or operation of the water treatment system. Fouling of the cartridge with black carbon specks serves as an indication that there is an unusually high frequency of carbon breakthrough from the carbon filters.

It is a good idea to position a pressure gauge on the effluent side of the polishing filter. When the pressure drops below a designated value that can be determined by experience (or by supplier recommendation), this would serve to indicate that the cartridge is becoming blocked and needs to be replaced.

The main problematical item with polishing filters is the fouling issue — how to minimize this and to determine when the cartridges need to be replaced. Otherwise, polishing filtration is a simple operation with proven results in the aim of supplying the filling lines with crystal-clear clean treated water.

CHAPTER REVIEW

As stated before, the subject of water treatment is too vast and diversified to describe in detail in this handbook. This chapter merely attempted to convey the importance of this key process in soft drink manufacture. It described the basic principles of the diverse technologies involved in multiple barrier water treatment systems and highlighted some issues involved in treating water used in soft drinks.

For a reader who wishes to learn more about this vast subject of water treatment, I am reminded of the story of an ancient Jewish sage who was asked by one of his pupils what the vast texts in the numerous books in the Bible were all about. The wise old Rabbi replied: "It is all about loving thy neighbor as thyself — now go and study all the rest of it yourself!"

6 Brix — Sugar Inversion

SUGAR CHEMISTRY TERMINOLOGY

Before proceeding with the subject of sugar inversion and its technical aspects in soft drinks I thought it wise to clarify a few items of terminology in sugar chemistry so that confusion does not arise in the course of this chapter.

Some terminology of basic sugars chemistry is required to better explain the concept of sugar inversion.

When the term "sugar" is commonly used, it normally refers to cane sugar (or sometimes beet sugar), which is the familiar household commodity many of us use to sweeten our coffee. In chemistry, sugar is the name given to any one of a large group of carbohydrate compounds that share common structural and chemical properties. In addition to cane sugar, known chemically as sucrose, other more familiar sugars are glucose and fructose.

The sugars group has different subgroups based on molecular structural configurations or on other chemical properties. For the purpose of this chapter, sugars will be referred to as either monosaccharides or disaccharides. Monosaccharides are sugars that have the chemical formula $C_6H_{12}O_6$ and are all isomers of each other. In other words, they have the same chemical formula but differ in their molecular configurations. Examples of monosaccharides are glucose and fructose. Monosaccharides are able to combine with each other to form chain molecules of any number of monosaccharide units, which are called polysaccharides. However, of interest to us at present are the disaccharides, which consist of two monosaccharide units. Cane sugar, or sucrose as it will be referred to, is a disaccharide, and it is the only one that needs to be mentioned in this chapter. Now that this terminology has been established, we can return to the subject of this chapter.

WHAT IS SUGAR INVERSION?

Sucrose is a disaccharide of combined glucose and fructose and has the chemical formula $C_{12}H_{22}O_{11}$. The chemical bond that combines the glucose and the fructose can be broken in several ways that will result in the sucrose splitting up into its two monosaccharides, glucose and fructose. One way that this can

Acid hydrolysis of sucrose results in its conversion into glucose and fructose.

come about is by hydrolysis, the chemical process in which a molecule of water breaks a bond between two parts of a molecule of another compound. In a sucrose solution, this hydrolysis reaction takes place under acidic conditions and is, therefore, called acid hydrolysis. The lower the pH, the faster the reaction proceeds. Heat will also increase the speed of the reaction.

This hydrolysis of sucrose can be presented in the following chemical reaction. I indicated the molecular weights of the compounds, as these will be referred to shortly.

Sucrose	+	**Water**	$\rightarrow$	**Glucose**	+	**Fructose**	(6.1)
Mol. Weight		Mol. Weight		Mol. Weight		Mol. Weight	
342.3		18.0		180.16		180.16	

Figure 6.1 describes the mechanism of this hydrolysis reaction and is explained as follows. The structure of the disaccharide sucrose molecule shows the monosaccharide units of glucose and fructose combined by the central oxygen atom, the glucose on the left and the fructose on the right.
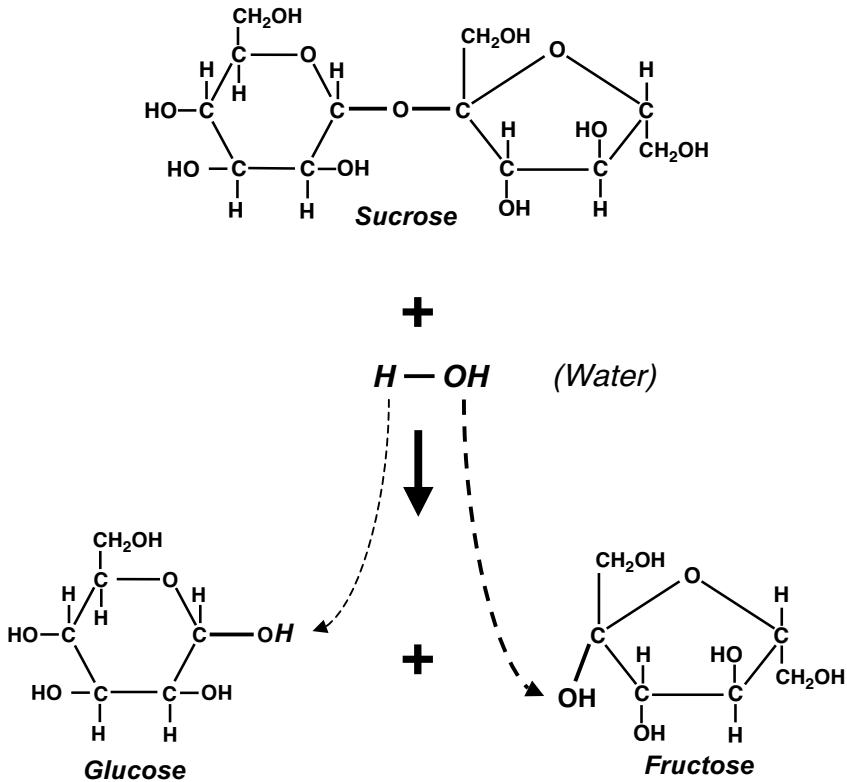
FIGURE 6.1 Sugar inversion reaction by acid hydrolysis.

When the water enters the reaction, it splits into its hydrogen and hydroxyl (OH) components, and they break the oxygen bond between the monosaccharide units. The hydrogen combines with the oxygen to give the glucose its regular monosaccharide configuration, while the OH radical combines with the appropriate fructose carbon atom, which after the splitting of the sucrose molecule has one of its four valence bonds free.

Inversion results in an increase in dissolved solids weight and, hence, an increase in Brix.

Now let us return to the molecular weights involved in this reaction. These indicate that 342.3 kg of sucrose would react with 18 kg of water to result in a total of $2 \times 180.16 = 360.32$ kg of glucose/fructose mix. This means that from a starting quantity of 342.3 kg of the disaccharide sucrose, we now have an extra 18 kg of sugar in the form of the two monosaccharides: glucose and fructose.

If this reaction takes place in X kg of a sucrose solution, this also means that after the reaction there will be 18 kg more dissolved solids in the same X kg of solution. By definition of the Brix concept, i.e., percentage of dissolved sugar in a water solution on a weight-for-weight basis, this increase in solids can therefore be translated as follows. The hydrolysis reaction results in an increase in the Brix value of the solution. This increase factor can be calculated as $360.32/342.3 = 1.053$. In other words one can expect the Brix value to increase by about 5%.

The sucrose acid hydrolysis reaction that causes this increase in Brix is called *sugar inversion*.

WHY IS IT CALLED "SUGAR INVERSION?"

Solutions of sugar have a chemical property of rotating the plane of polarized light either clockwise (to the right) or in the opposite direction (to the left). Those sugars, such as glucose, that rotate the polarized light to the right are called dextrorotatory. If the rotation is to the left, the sugar is levorotatory, as is the case of fructose. (For this reason, glucose and fructose are often called dextrose and levulose, respectively.)

The term "inversion" is derived from the change in the direction of polarized light rotation that occurs in inverted sugar solutions.

The angle at which the plane of polarized light is rotated is specific for each sugar and is called the angle of rotation (or specific rotation) and is expressed by the symbol α. If the angle of rotation is levorotatory, the value is preceded with a minus sign (-).

The inversion reaction given in Equation 6.1 above, with the respective angles of rotation for the sugars involved, could be represented as follows:

$$\text{Sucrose} \quad + \quad \text{Water} \quad \rightarrow \quad \text{Glucose} \quad + \quad \text{Fructose} \qquad (6.2)$$
$$\alpha = 66.5° \qquad\qquad\qquad\qquad \alpha = 52.7° \qquad \alpha = -92.4°$$

This shows that sucrose and glucose are dextrorotatory sugars, while fructose is highly levorotatory. In the acid hydrolysis of a sucrose solution, if allowed to go to full completion, the resultant solution would be a 50/50% glucose/fructose mixture. This mixture would have an angle of rotation that would be the sum effects of the two monosaccharides. As the levorotatory rotation of the fructose is higher than the dextrorotatory rotation of the glucose, the solution of the two monosaccharides will display a levorotatory rotation. The net effect of this hydrolysis of sucrose is that a sugar solution that was at first dextrorotatory has now become levorotatory.

As the polarized light rotation of the original sucrose solution was "inverted" from right to left, the name given to the glucose/fructose mixture was *invert sugar*, and the process is called *sugar inversion*.

Invert sugar is the name given to glucose/fructose mixtures resulting from inversion.

It is also interesting to note that this invert sugar solution will be sweeter than the original sucrose solution due to the fact that fructose, which is about 1.6 times sweeter than sucrose, contributes its higher sweetening effect to the mixture. Invert

Honey is a form of natural invert sugar produced by bees.

sugar is found in nature. In fact, the honey that bees produce is an invert sugar. Bees invert the sucrose they consume with the aid of the enzyme invertase, much in the same way as the acid hydrolysis reaction. Man-made invert sugar is commercially produced by acid hydrolysis and by enzymatic sucrose inversion processes and has special uses in the food and other industries.

SUGAR INVERSION AND SOFT DRINK TECHNOLOGY

Sucrose is the major natural sweetener in soft drinks. Though in some parts of the world high-fructose corn syrup (HFCS) is being used as a preferred alternative natural sweetener, sucrose is still widely used in beverages. It is in these naturally sweetened beverages that sugar inversion plays an important role, and they are the subjects of this chapter on inversion. The sugar inversion process takes place under acidic conditions and speeds up with a decrease in pH.

As acidic conditions promote the inversion process, it will take place in sucrose-sweetened soft drinks due to their usually relatively highly acidic nature.

Soft drinks are flavored with acids to achieve the sourness notes essential for their taste profiles. They are therefore acidic drinks, usually in the pH = 3 range. This is especially true of the sour fruit flavors, such as lemon and other citrus fruit species. Cola beverages that often use phosphoric

acid as the acidulant are at even lower pH values. In carbonated soft drinks, the dissolved carbon dioxide is converted to carbonic acid, which further adds to the acidification of these drinks.

Regardless of the exact acid content of such beverages, they can all be considered, to a lesser or greater degree, as acidic solutions. As such, some inversion of the sucrose in these beverages will take place. As we have seen, one of the consequences of inversion is an increase in Brix. How and to what degree does this potential change in Brix impact on soft drink technology? To answer this question, let us look at each aspect of this Brix increase impact.

INVERSION IN FINAL SYRUPS

Many soft drinks, especially the carbonates, are produced using the principle of blending bulk concentrated syrups (called final syrups) with treated water at the filling point by means of some type of proportioning equipment. The water-to-syrup blending ratio can be in the ranges of between about 4:1 to a 5:1 and is a rigidly prescribed quality specification for the individual final beverage concerned. Adhering to the prescribed water-to-syrup ratio ensures not only that the target Brix and sugar content of the final beverage are achieved and maintained throughout the filling run but also that all other key ingredients, such as flavors, colorants, preservatives, etc., are correctly incorporated into the final beverage (see Chapter 1).

The Brix of the final syrup is established at such a value so that when the syrup is proportioned with treated water, the resultant beverage solution will be at the prescribed Brix for the particular final beverage concerned. Thus, for example, final syrup at 52.6°B when proportioned with treated water at a 5:1 water-to-syrup ratio will result in a final beverage at 10.50°B.

Soft drink syrups are concentrated and have high acidity levels that will promote the inversion process more rapidly.

Final syrup is, by virtue of its concentration, much more acidic than the final beverage. In syrup designed for a 5:1 water-to-syrup ratio, the acidity is in fact six times higher than in the beverage. This high acidity is definitely going to set off an inversion process in the syrup. If the syrup stands for any length of time, e.g., overnight, the inversion process will reach a very noticeable level as far as the syrup Brix is concerned.

This happens in practice. In the case of a syrup mentioned above at 52.6°B, standing overnight before being bottled the following day, it can, by the next morning, due to inversion, reach a Brix value of up to 53.00°B or even higher. As final syrups are usually allowed a maximum storage period of up to 24 h before filling into final beverage, the increase in Brix can be still higher.

The target Brix for final beverage filling needs to be adjusted to the degree of inversion in the final syrup.

So now, what must the filling supervisor do? He or she has a final syrup way above the specified Brix. To fill final beverage at the quality control (QC) Brix specification of 10.50°B, the final syrup proportion in the prescribed 5:1 water-to-syrup ratio must be reduced, or the reverse (increase the water proportion). But he or she is not allowed to tamper with the water-to-syrup ratio specification. How is this problem solved?

The answer is quite simple. One can calculate at what target Brix values a beverage should be filled when using final syrup that has partially inverted (without changing the water-to-syrup ratio). These calculated target Brix values will ensure that all quantities of sugar and other key ingredients are correctly maintained in the beverage.

Table 6.1 demonstrates how this relatively simple calculation is performed in the case of the 52.6°B syrup that has inverted to 53.0°B using a 5:1 water-to-syrup ratio:

TABLE 6.1
Calculation of Final Beverage Target Brix Using Final Syrup 53.00°B
at a Water-to-Syrup Ratio of 5:1

Item	Calculation		Result
Weight in kg of 1 liter of final syrup at 53.0 Brix (D20 from Brix/density tables)	D20 = 1.24521	(1)	1.24521
Weight in kg of 5 liters of treated water (density of water at 20°C = 0.99717)	5 × 0.99717	(2)	4.98585
Total weight in kg of 6 liters of water/syrup mix (final beverage)	(1) + (2)	(3)	6.23106
Total kg solids in 1 liter of final syrup	53.0% of (1)	(4)	0.65996
Target Brix of final beverage	(4)/(3) × 100	(5)	10.59

Step 1: From the Brix/density tables, the density at 20°C value (D20) at 53.0°B is 1.24521 and is the weight of 1 liter of the syrup (1).

Step 2: Using the D20 of water, 0.99717, calculate the weight of 5 liters of treated water (2). (Does the reader recognize the "magic" number of 0.99717 from Chapter 1?)

Step 3: As the water-to-syrup ratio is 5:1, by combining (1) and (2), the weight of 6 liters of final beverage will be obtained (3).

Step 4: In these 6 liters of final beverage, all the dissolved sugar (solids) is from the 53.0°B syrup. By definition of Brix, this is 53.0% of the weight of 1 liter of syrup in result (1).

Step 5: By definition of Brix, the target filling Brix of the final beverage would be the percentage of dissolved solids in 6 liters of beverage (4) with the total weight of (3). The target Brix would therefore work out to 10.59°B.

No one is really expected to perform this calculation every time a final syrup inverts. In practice, production or QC staff members are usually issued with a preprepared chart of final beverage filling target Brix for each beverage brand and flavor produced by the company. Each chart has the calculated target Brix for a range of final syrup Brix values expected due to inversion for each particular product.

Target Brix tables are usually supplied to the production staff for final beverage filling operations.

The interested reader will find, in Appendix 6 of this handbook, sections of copied Microsoft® Excel worksheet templates with which the targeted Brix values can be calculated. Template B shows the actual calculation formulas in the applicable worksheet cells. The target final beverage Brix values for any chosen range of final syrups Brix can rapidly and easily be calculated by inserting, in the applicable column cells, the Brix values of final syrups, their corresponding D20 values (obtainable from density tables), and the water value of the water-to-syrup ratio.

The sucrose inversion phenomenon in final syrup is one aspect of how it impacts soft drink technology. How serious this impact is and the issues involved will be covered in an upcoming section of this chapter.

Before leaving this section on final syrup and inversion, I want to briefly mention how this inversion issue used to be dealt with in the "good old days," before computers and sophisticated Brix-measuring instrumentation.

A historical note about target Brix.

Before a final syrup was used for filling of the final beverage, just prior to the filling run, a standard test, as it was called, was performed with the syrup. If, for instance, the water-to-syrup ratio for the beverage was 5:1, a 50 ml sample of final syrup was accurately measured into a 50 ml volumetric flask. It was then transferred, with several treated water rinses of the emptied flask, into a 300 ml graduated cylinder and topped up as accurately as possible to the 300 ml mark with treated water. This simulated the 5:1 water-to-syrup ratio.

The graduated cylinder was "sealed" by covering its mouth and pressing with the palm of one's hand. It was then inverted upside down a few times to thoroughly mix the syrup and water. This resulted, of course, in a simulated final beverage solution, which was allowed to stand on the bench for a few minutes to get rid of any entrapped air bubbles.

The solution in the graduated cylinder was then tested for Brix with a hydrometer. The Brix reading obtained was recorded as the final beverage target Brix for the filling line operators, who usually were waiting for this result and were watching the entire standard test operation in the laboratory. Having this target Brix, bottling would immediately commence.

This standard test was performed for each syrup batch before a bottling run with that syrup. It was even repeated on the same batch of syrup in the morning if the full batch had not been used up during the previous night's bottling run.

This standard test obviously took care of any inversion that had taken place before the syrup was used and even while it was being used, if the run was a long one. It served the same purpose of calculating an inversion-increased target bottling Brix for the final beverage, as is described in this section. So it looks like we knew what we were doing in the good old days — we actually went to the proverbial horse to count its teeth.

FRESH BRIX AND INVERTED BRIX

Fresh Brix and inverted Brix are two pivotal concepts in Brix quality management.

Before proceeding further with the subject of sugar inversion in soft drinks, two concepts need to be explained. These are fresh Brix and inverted Brix.

Fresh Brix is the Brix value of a product (syrup or beverage) at the time of its preparation. The Brix value obtained on testing immediately after preparation will usually agree with the theoretical value calculated from the total dissolved solids content of the product. Fresh Brix, therefore, implies that no inversion has taken place in the product.

Inverted Brix, on the other hand, is the Brix value of a product in which all the sucrose content was inverted to glucose and fructose. This could also be referred to as fully inverted Brix, but in our jargon, "inverted Brix" is taken to mean fully converted. If the inversion process has started in a sugar solution but has not run to full completion, we then talk of a partially inverted product.

In practice, we do not normally encounter fully inverted syrups or beverages in the factory or on the shelves in the market. This is because much higher acidities and temperatures are required conditions for full inversion of the sucrose to take place. This, however, can be accomplished in the laboratory by adding small amounts of concentrated acid to a beverage sample and heating it to a high temperature ($\pm 90°C$). In about 1 h under such conditions, all the sucrose is hydrolyzed, and the sample is considered to be fully inverted. The Brix of such a sample is referred to as its inverted Brix.

Why there is a need to fully invert a beverage to read its inverted Brix value will become clear in the next section of this chapter. However, this need can be explained here simply.

The fresh Brix of a partially inverted beverage sample can be calculated from its inverted Brix value. Thus, it can be determined if that beverage was prepared to its correct standard Brix specification.

WHAT IS THE IMPACT OF INVERSION IN SOFT DRINK TECHNOLOGY?

We already saw in what way inversion affects soft drink preparation in the factory in the target final beverage Brix issue discussed in a previous section of this chapter. Two significant facts were not mentioned. The first is that a final syrup with a Brix value far in excess of the usually prescribed 0.2°B quality control tolerance range is "allowed" to be used in filling operations. The second is again a matter of quality specifications seemingly being ignored. If one looks again at the chart of Brix target tables in Figure 6.2, it seems that at high syrup Brix, e.g., 53.4, the beverage target Brix is above the commonly prescribed 0.15°B tolerance specification.

Are these both cases of blatant disregard for quality specifications? No, they are not. They were allowed because of recognition of the role played by the sugar inversion phenomenon. We know that if the syrup and the final beverage of seemingly high-out-of-specification Brix values were to be fully inverted in the laboratory, their inverted Brix values would agree with their respective fresh Brix specifications — that is, of course, if the syrup in the first place was prepared correctly to its Brix specification.

This "agreement" between the inverted Brix and fresh Brix of the syrup or final beverage is based on a scientific mathematical correlation between the two Brix concepts. There is a specific numerical relationship between a product's fresh Brix value and its inverted Brix obtained in a laboratory-performed full inversion exercise.

The relationship between inverted Brix and fresh Brix allows us to determine the true status of partially inverted beverages.

This relationship and how a fresh Brix can be calculated from an inverted Brix will soon be explained fully. Before doing so, let us consider another scenario, which I will try to make a bit humorous for the reader's benefit.

FRESH FINAL SYRUP °BRIX :   52.60

FRESH BEVERAGE °BRIX :   10.50

WATER/SYRUP RATIO :   5:1

FINAL SYRUP °BRIX	BEVERAGE °BRIX
52.40	10.45
52.50	10.47
52.60	10.50
52.70	10.52
52.80	10.54
52.90	10.57
53.00	10.59
53.10	10.62
53.20	10.64
53.30	10.66
53.40	10.69
53.50	10.71

FIGURE 6.2 Final beverage Brix target chart.

You are the QC manager of a large soft drinks–producing company. You have just been summarily summoned to the office of a recently appointed new financial director of the company. This director has been studying some routine quality reports that landed on his desk for the first time. The director noticed that in many of the last week's filling runs, the Brix values of final beverages were well above the specifications of those of the company's final beverages. He knows this because, as a new appointee in a new industry, he studied his plant's product specifications, albeit cursorily.

He noted that the high Brix values are often 0.05°B above the allowed 0.15°B upper tolerance limit for final beverage Brix. Being a very competent financial manager, he also already studied sugar costs aspects of the business and learned that it is very economical to fill final beverage in the lower tolerance range of the Brix specification. He is aware that tens and even hundreds of thousands of dollars can be saved in this manner.

He is horror-struck that not only are the production staff filling beverage in the upper Brix tolerance ranges but also they are blatantly, very frequently, as per the reports on his desk, exceeding these upper tolerance limits. He is convinced that the company is losing a lot of money, and the first person he can think of to confront with this issue is (naturally) the QC manager. He is now awaiting your arrival at his office.

After brief greetings and niceties are exchanged, you are given a short lecture on quality control and economics, after which one of the quality reports is flapped in front of your face and then handed to you to study. The following discussion then ensues:

Financial Director: This bottling run of cola, the beverage was filled at between 10.6 and 10.7 Brix?
You (studying the Brix graph on the report): Yes.
Financial Director: The Brix spec for cola is 10.5?
You: Yes.
Financial Director: Yes?! Is 10.7 not way above the spec?!
You (slightly confused): But the target Brix was 10.69 for that run and …
Financial Director (interrupting you): Are you people not aware that you should run in the lower range of the Brix spec?!
You: Yes, of course we are, but …
Financial Director (interrupting you again): Do you realize how much money this is costing us?!
You (adamant to get a word in): But sir, this particular run is perfect, they were well within the lower tolerance range of the target Brix, look at the Brix graph — you will see.
Financial Director: Target Brix? What target Brix! Do you not bottle to Brix spec of 10.5?
You: No sir, we bottle to target Brix specification.
Financial Director (becoming a bit confused and worried): What is target Brix?
You: You see, sir, due to sugar inversion …
Financial Director (even more confused and worried): Sugar inversion?
You: Yes sir. Sugar inversion is …

   You briefly explain to him what it is all about. He apologizes to you and even invites you out for lunch at his favorite restaurant.

People dealing directly or indirectly with soft drink technology should be familiar with the basic aspects of the inversion concept.

This scenario is possibly slightly exaggerated, but it delivers two distinct messages about inversion in soft drinks. One is that the inversion concept is of a "need-to-know" nature for people directly or even indirectly involved (as was the financial manager in the above scenario) with soft drink technology. This situation could be compared to that of when a captain of a commercial airline informs the passengers that "the aircraft is traveling at an airspeed of 500 km/h." He does not bother to explain that there is a difference between airspeed and ground speed. The average passenger does not need to know that with a

tailwind, his ground speed is greater than the airspeed. All the passenger wants to know is that he or she will arrive safely in time at the destination.

The second message is more important. It is that when dealing with a soft drink's true Brix status, especially when this status is of critical nature, for whatever reason, then the inversion issue is of paramount importance. When do such situations arise?

The relationship between inverted Brix and fresh Brix allows us to determine the true Brix status of partially inverted beverages.

One that comes immediately to mind is that, notwithstanding the seeming deviations from prescribed Brix specifications, these deviations need to be confirmed as being inversion generated, and not due to genuine erroneous syrup or beverage preparation in the factory. This can be accomplished by periodic fresh Brix and inverted Brix determinations in the laboratory. In recent years, this has been highly facilitated by densitometry Brix determination with highly sophisticated (and expensive) instruments that are capable of determining fresh Brix values of test samples by algorithmic means.

What one needs to remember is that a sucrose-sweetened soft drink is, from the time it was produced, especially inclusive of its precursor final syrup if such is applicable, in a state of a slow but inevitable inversion process. It is constantly in some stage of partial inversion before it is consumed, and its current Brix value is not always what it appears to be.

One last aspect of the impact of inversion in soft drink technology is prominent in quality index rating. Many organizations in the industry practice one sort or another of quality index systems to keep tabs on their products' quality histories and statuses. In such systems, be they simple or sophisticated, several key quality parameters of the beverage are selected for periodic testing in randomly selected trade samples, of all brands, package sizes, and types. The test results are recorded on a "go or no-go" basis as "pass or fail" in adherence to laid-down specification tolerances for the quality parameter concerned. Simplistically put, the number of fails as a percentage of total samples tested is calculated and expressed as a quality index for the product. In more sophisticated and elaborate systems, this quality index can be applied to a parameter, a package size or type, a geographical location in a multiplant organization, a particular filling line if there are more than one, and so forth. The items indexed and permutations and combinations thereof are numerous.

A quality index system can provide invaluable information on a company's product quality statuses, pinpoint problem areas, etc. It can also promote positive competition for highest-quality index ratings in multifacility organizations between individual plants (especially if periodic cash bonuses are awarded to relevant staff involved in quality building into the products).

The Brix quality parameter is usually included in the system, and it should very well be so, as one of the key quality and cost factors in soft drink production. If the products rated include sucrose-sweetened beverages, then the Brix parameter must obviously be tested as the fresh Brix item. To do so, unless one of the sophisticated densitometry instruments is used, the samples must be fully inverted. Thereafter, their inverted Brix results must be converted to fresh Brix values.

In a quality index rating system, the Brix parameter should always be based on the fresh Brix basis.

HOW IS INVERTED BRIX CONVERTED INTO FRESH BRIX?

In the section entitled "What Is Sugar Inversion?" we saw that there is an increase in the theoretical weight of the monosaccharide glucose and fructose after full sugar inversion when compared with the weight of the original sucrose that was inverted. We also saw that this increase is by a factor of 1.053. Thus, the factor with which to convert the monosaccharides back into noninverted sucrose would be the reciprocal of 1.053. This calculates to 0.94967, which can be rounded off to 0.95 without any significant mathematical error.

This means that if we had an inverted Brix value, by multiplying it by 0.95 we would obtain its equivalent fresh Brix value. As an example, the fresh Brix for an inverted Brix value of 10.53 would be 10.00. As a rule, one could say:

$$\text{Fresh Brix} = \text{Inverted Brix} \times 0.95 \tag{6.3}$$

HOW IS THE FRESH BRIX OF A SUCROSE-SWEETENED BEVERAGE DETERMINED?

The first step is obviously to convert the beverage into fully inverted form. This is a fairly simple procedure performed in the laboratory. Actual procedure will depend on the equipment available and the degree of accuracy desired for the fresh Brix result. (By "degree of accuracy," it is meant to what decimal place of the fresh Brix value, and this will be addressed soon.)

The essentials of the method are as follows:

1. If the beverage is carbonated, the sample (about 100 ml) must first be degassed as for an ordinary Brix test and then placed in a suitably sized glass bottle that can be tightly sealed with a cap.
2. The sample is then acidified with a few drops of a solution of concentrated HCl that was diluted about four times with distilled water. The bottle is then tightly sealed.
3. The sample bottle is placed in a hot water bath or oven at approximately 90°C for ±1 h.
4. The bottle is then gradually cooled to ambient temperature (to avoid any sudden breakage due to thermal shock).
5. When completely cooled, it is gently mixed to capture any water condensate that may have accumulated on the sides or cap of the bottle.
6. The Brix is determined by whatever method is chosen and is recorded as the inverted Brix.
7. Using the inversion factor, the Fresh Brix is calculated as indicated in Equation 6.3.

This is all it takes to determine the fresh Brix of a beverage. With suitable densitometry instruments, this can be even easier.

Splitting hairs over the second decimal.

There is the outstanding item of the "accuracy desired" mentioned above. It is possibly a pedantic matter of "splitting hairs," but I would be at fault, if only for scientific thoroughness, if this chapter did not briefly mention the following two items.

The first is simple and is that of the added few drops of HCl for acidification of the sample. These add a dilution factor, infinitely small as it may be, to the sample and could add a very slight error in the inverted Brix reading. This could be negated by any simple procedure or calculation that I leave to the interested reader's creative talents.

The second is slightly more complex but also of small impact. A sucrose-sweetened soft drink beverage that is intended for fresh Brix determination will invariably contain a relatively small amount of dissolved solids components that are not invertible. The components could be of different types, like acidulants, salts, preservatives, colorants, natural juice sugars (glucose, fructose, etc.), to name a few. As dissolved solids, they contribute to one degree or another, no matter how small this may be, to the total fresh Brix of the beverage as well as to the total value of the inverted Brix determined in the above-described method.

As such, each beverage, by virtue of its particular composition of noninvertible dissolved solids, would require a small adjustment to the standard 0.95 inversion factor used in calculating the fresh Brix from the inverted Brix. The inversion process only applies to the sucrose content, as the noninvertible solids

content of the test sample remains unchanged throughout the entire process. Therefore, we should add a small value to this 0.95 factor for every different beverage formulation being tested. In other words, every beverage formulation would have a particular fresh Brix inversion factor.

This beverage-specific factor can be calculated, but I will not burden the reader with this slightly complex calculation, because, at the end of the day, this added "correction" is for most purposes insignificantly small. It would increase the calculated fresh Brix by only 0.01 to 0.03°B at the most. As such, for normal practical purposes it can be ignored, and the standard 0.95 factor can be used for all beverages. In rigidly controlled quality index rating systems, this 0.01 to 0.03°B "correction" in fresh Brix value could mean the difference between a pass or fail verdict and would then be of some significance — but that then is another story.

CHAPTER REVIEW

Acid hydrolysis of sugar in sucrose-sweetened beverages is a normal expected phenomenon and is not a problematical issue in soft drink technology. It causes no defect whatsoever in the beverages but involves the fresh Brix vs. inverted Brix issue. This issue, more than anything else, plays a technical administrative role in quality management when the true and accurate Brix status of a beverage is of critical concern.

The inversion phenomenon and its impact should be "built into" all syrup and beverage manufacturing procedures and documentation as well as into QC management systems. The concept of inversion and the subject of the resultant apparent increase in product Brix values should be considered as a "need-to-know" nature. All company staff directly and indirectly involved in matters in which the sugar inversion phenomenon plays a critical role should be well acquainted with the phenomenon and its ramifications in soft drink technology affairs.

7 Fruit Juices — A Special Technology

GENERAL OVERVIEW

This chapter deals with fruit juice as a general commodity used in the preparation of a large variety of beverage types in the soft drinks industry. It does not deal with these specific juice beverages but rather focuses on the food technology aspects associated with fruit juices as raw materials used in these types of drinks.

This chapter focuses on the fruit juices as ingredients in soft drinks and not on the juice beverages.

A further distinction to be made is that this chapter does not deal extensively with the details of fruit juice processing. The aim is to address those technological issues related to fruit juice processing that are of special interest to the soft drink manufacturer and consumer.

Processed fruit juices occur in many forms. Generally, a fruit juice may be defined as:

The liquid obtained from the edible portion of a ripe fresh fruit or from a fruit kept in fresh condition by suitable means.

In this particular definition, the emphasis is on the "edible portion" of the fruit. As an example, this means that in orange juice, we do not expect to find any seeds or peel in the juice. On the other hand, in juices where it is common to eat the seeds and it is almost impractical to remove them completely in the processing method, these are acceptable in that particular juice. A typical example of such could be passion fruit or strawberry. Some juices exist as purees, which are basically the whole fruit, peel, and seeds crushed together with the juice, as is the case of guava puree.

Then there are the comminuted fruit juices, in which the inedible portions of the fruit, such as the peel, are included in the processed juice. This particular type of juice is used mainly in beverages to obtain the bitter astringent peel taste, as in bitter orange and bitter lemon beverages.

Last, there are juice pastes in which the entire fruit — skin, peel, and all — is macerated into a paste-like pulp, as in tomato paste (yes, the tomato in botanical terms is a fruit and not a vegetable).

Juices used as ingredients are usually available in the form of processed juice concentrates.

Most fruit juices extracted from the fruit, as liquids with relatively low solids contents, are heat processed and, with water evaporation, they are transformed into what are called fruit juice concentrates. It is these concentrates with which this chapter is concerned. Most juice drinks, be they pure juices, fruit nectars, or fruit-flavored drinks containing juice, have concentrates as their juice components in the beverage formulations. The reasons for this are mainly economical, because storage and transport as the dilute extracted juice, of which about 80 to 90% is water, would be a costly exercise, both to the processor and the soft drink manufacturing customers. Furthermore, whether preserved or in a deep-freeze state, in concentrated form, the juice is far more resistant to microbiological spoilage, a vulnerability very characteristic of fruit juices.

From the brief overview given above, it becomes clear that fruit juices exist in a large variety of forms and in an obvious enormous diversity of flavors. So, in order to simplify matters, I will select a juice concentrate of one fruit species as a model on which to base this chapter. Using this chosen fruit juice, we will focus on its technological aspects as an ingredient in the various types of soft drinks.

Lemon juice concentrate is used as an example in this chapter.

I chose the lemon for this purpose and have done so because not only is it a fruit juice with which I have above-average experience, but also because this particular juice has many of the attributes that can serve the main purpose of this chapter very well. This is not to say that other fruit species will not be mentioned, but merely that the focus will be mainly on lemon juice.

SINGLE-STRENGTH JUICE

"Single-strength juice" is one of the basic concepts in fruit juice technology.

When juice is squeezed from a lemon, a slightly cloudy liquid is obtained that is very sour to the taste. This is 100% pure lemon juice and is referred to as single-strength juice. This term denotes that the juice was not processed or concentrated in any manner, and nothing was added to it or removed from it. It is in its natural form, as it exists in the fruit before it is extracted.

A single-strength juice of any particular fruit has characteristics and composition typical for that fruit. For lemon, as an example, the single-strength juice of the mature ripe fruit contains about 7.5% solids and an acidity level of around 4.6% as citric acid anhydrous, with both of these values expressed on a weight-for-weight basis.

As most fruit juices are used in their processed concentrated forms, a standard benchmark is required to establish just by how much they were concentrated from their natural states when first extracted. The single-strength juice characteristics and composition is used as this reference.

These characteristics and composition values may vary slightly in different samples of a fruit species, depending on various factors such as the climatic and soil conditions in which the fruit was grown and the state of ripeness of the fruit at the time of harvesting. However, on average, these values are fairly constant, and international agricultural authorities established worldwide accepted single-strength juice specifications for most fruit species (though occasionally, local specifications may differ slightly for one or a few specific species).

Single-strength Brix is the main reference benchmark for the degree of concentration of a juice.

The primary specification for a single-strength juice is its solids content on a weight-for-weight basis, which is none other than the Brix value of the juice (as we established in the first chapter of this handbook). Furthermore, the specification is often stipulated as the Brix measured by the refractometric determination method. This refractometric Brix stipulation is of paramount importance, as we will see later.

For lemon juice, the standard Brix value on single-strength juice basis used in this handbook is 7.5°B. Table 7.1 lists the single-strength juice Brix values of a few of the more common fruit species. (Note that the values in this table may differ somewhat from the latest figures established by international agricultural and food organizations that periodically review such specifications.)

BRIX ACIDITY CORRECTION

An acidity correction must be applied to refractometric Brix readings of juices.

Before proceeding on the subject of fruit juice technology, it is essential to address the subject of Brix acidity correction. The regular Brix refractometer instrument used to determine Brix in sugar solutions is calibrated on the refractive indices of pure

TABLE 7.1
Single-Strength Juice Brix Values of Some Common Fruits

Fruit	Refractometric Brix Value Single-Strength Juice
Apple	10.5
Apricot	11.0
Grape	13.0
Grapefruit	9.5
Guava (puree)	8.5
Lemon	7.5
Mandarin/tangerine	10.5
Orange	10.0
Passion fruit	12.5
Peach (puree)	12.0
Pear (puree)	12.0
Pineapple	9.50

sucrose solutions. We are aware that beverage and syrup contain some dissolved solids other than sucrose, but the soft drinks industry ignores this, as the error in Brix determinations is considered very small. Thus, all dissolved solids are considered, as far as the measurement reading is concerned, as sucrose.

In most fruit juices, however, the acidity content in the form of soluble organic acids, such as citric acid, is relatively high enough to considerably affect the refractometer reading as far as the true total dissolved solids content is concerned. In other words, the high soluble acid component of fruit juices refracts light differently to sucrose solutions for which the instrument was calibrated. Therefore, an error will be introduced in the Brix reading obtained. The reading will, in fact, be lower than in reality. For this reason, when measuring the Brix of fruit juices, especially those with high acidity contents, an acidity correction must be added to the reading.

Fruit juice processors and technologists over the years established what these acidity corrections are for various acidity levels in juices and have drawn up tables for these corrections. These tables usually regard the acidity component, for convenience sake, as citric acid anhydrous. Appendix 5 gives an example of such a table.

When talking of a fruit juice Brix value, it is important to always note whether the value stated is corrected for acidity. If corrected, it is usually written as the Brix value followed by the notation "corrected for acidity." Failure to denote whether a correction was applied can lead to an enormous amount of confusion.

Let us see how this is applied in our single-strength lemon juice.

A sample of freshly squeezed lemon juice is measured for Brix with a refractometer. The reading is 6.70°B at 20°C. The sample is titrated for acidity, which is found to be 4.6% citric acid anhydrous on a weight-for-weight basis. By consulting the acidity correction tables, we find that the correction to be added to the Brix reading at 4.6% acidity is 0.89.

The Brix corrected for acidity is, therefore:

Refractometer Brix reading at 20°C = 6.70
Acidity correction at 4.6% acid   = 0.89
Acidity corrected Brix at 20°C   = 7.59

This little exercise does not seem to be of any earth-shattering significance, but this will become more significant when dealing with a lemon juice concentrated by juice processors to around the 30°B level (uncorrected for acidity) and commonly called Lemon 30 Brix. At this Brix level, the lemon concentrate will have an acidity value around 21.6% citric acid anhydrous. From the correction tables, this acidity indicates a correction of 3.99. The corrected Brix calculation will then be as follows:

Refractometer Brix reading at 20°	= 30.00
Acidity correction at 21.6% acid	= <u>3.99</u>
Acidity corrected Brix at 20°C	= 33.99

This calculation shows that the true dissolved solids content of the lemon concentrate is just about 34% and not 30% as stated in the commodity's description. What are the implications of this higher value of Brix corrected for acidity? There are many such implications, most of which mainly relate to the conversion of concentrate from weight to volume and vice versa, from volume to weight.

One simple example is the following scenario:

You formulated a new beverage product using Lemon 30 Brix concentrate. In the laboratory, you developed the final formulation to contain 15 kg concentrate in 1000 liters final beverage. Your company plans to sell about 9 million l of this beverage per year.

You now have to prepare a bill of materials (BOM) for production and need to convert the 15 kg concentrate into liters for the simple reason that the standard price of the concentrate in your company's accounting system is based on volume, at US$2.00 per liter for the Lemon 30 Brix stock item. (Also, let us say that production finds it more convenient to measure out the concentrate quantity for their batches by volume.) To convert your 15 kg formulation quantity of concentrate to liters, you will need Brix/density tables to find the conversion factor from weight to volume, namely, the D20 (density at 20°C) of the concentrate.

I will demonstrate (see Table 7.2) what will happen if you erroneously use the Brix of the concentrate uncorrected for acidity compared to if you use the acidity corrected figure as required. The D20 (2) obtained from the Brix/density tables using the uncorrected Brix is lower than that for the acidity corrected Brix. When converting the 15 kg concentrate to liters, the volume for the uncorrected Brix will be higher (4). The production BOM will have an extra 0.23 l per 1000 liters final beverage (5). At 9 million liters final beverage production per year, this will amount to 2027 liters overusage of Lemon 30 concentrate (7). At a price of US$2.00 per liter, this will amount to a total giveaway of over US$4000 per year (9).

The relationship between the annual giveaway in US$ and the annual final beverage production is a nominal one portraying the relative magnitude of monetary loss to the company. If the company's annual production was, for example, 10 times larger, the loss would be over US$40,000 per year. I would hazard a guess that whatever the company's annual production, be it higher or lower than in the example demonstrated, the relative calculated loss would be of significant magnitude for any company.

It should be added that the extra liters of lemon concentrate would also impact slightly on the Brix and acidity specification of the final beverage. This impact may be trivial in the example where the lemon concentrate quantity would result in a final beverage with around 6% single-strength lemon juice. If, however, the formulation was for sweetened lemon nectar at around 12% single-strength lemon juice, this impact would be doubled and perhaps become significant. It goes without saying that the annual giveaway would also be doubled to over US$8000 per annum.

The use of Brix corrected for acidity acquires major importance when calculating the formulation amount of juice concentrate required in a beverage with a legally specified single-strength

TABLE 7.2
Example of Erroneous Use of Brix Not Corrected for Acidity

	Calculation		Brix Corrected for Acidity	Brix Not Corrected for Acidity
Brix value used		(1)	34.00	30.00
D20 from Brix/density tables		(2)	1.14530	1.12594
Lemon 30 concentrate (kg) in 1000 l final beverage formulation		(3)	15.00	15.00
Lemon 30 (l) in production BOM for 1000 l beverage	(3)/(2)	(4)	13.10	13.32
Extra liters concentrate per 1000 l BOM due to using Brix uncorrected for acidity	13.32–13.10	(5)	0.23	
Liters final beverage produced per year		(6)	9,000,000	
Extra concentrate used in liters per year	(5) × (6)/1000	(7)	2027	
Price of Lemon 30 (US$2.00/l)		(8)	2.00	
Giveaway per year in U.S. dollar	(7) × (8)	(9)	4054	

juice content. In addition to the cost factor, a legal labeling issue is involved. This will be illustrated in a further section of the chapter.

At the end of the day, regardless of the implications of not applying the acidity correction, be they trivial or profound, the principle involved is that of scientific correctness. To obtain the true and accurate dissolved solids content in a fruit juice from a refractometric Brix reading, the optical distortion of the reading due to the acid content must be corrected, if only for the sake of scientific precision.

THE BRIX/ACID RATIO

As mentioned previously, the juice of a ripe fruit has a dissolved solids content (Brix) characteristic of that particular fruit species. This is also the case for the acid content of a fruit juice. The levels of both of these items in the juice may vary in a narrow range depending on climatic and environmental conditions in which the fruit was grown as well as on the ripeness state of the fruit when harvested.

The ratio of juice Brix to acidity is characteristic of a particular fruit species.

As these two values of Brix and acidity are more or less distinctive for each fruit species, the consequence will follow that the ratio of the two values will also have a distinctive value typical for the fruit species. This ratio is termed the Brix/acid ratio (sometimes also referred to as the dissolved solids/acid ratio). This ratio of Brix to acidity could be described as the "sweetness to sourness" relationship in the taste of the juice.

In lemon juice, the Brix (corrected for acidity) of single-strength juice is, on average, 7.5°B, and the acidity is at around 5.0% (as citric acid anhydrous w/w). Therefore, the Brix/acid ratio of lemon juice will work out to 1.50. In another fruit juice, orange for example, the Brix/acid ratio can be in the range of 8.0 to 12.0.

What do these two figures tell us? They indicate that the orange is much sweeter to the taste than the lemon. Well, we do not really need the Brix/acid ratio to tell us such a well-known fact. What then is the purpose and importance of the Brix/acid ratio concept?

The fruit juice processing industry together with international government agricultural and food organizations established the standards of Brix/acid ratio specifications for most of the world's known edible fruits. The values established are expressed as a Brix/acid ratio range or a minimum

(or maximum) limit. If a fruit juice is tested for its Brix/acid ratio value, and the result obtained does not meet the specification of that particular fruit species juice, then something is wrong. Either the juice is not of the fruit it purports to have been derived from, or the juice has somehow, deliberately or unwittingly, been modified from its natural composition.

A deviation from the Brix/acid ratio specification indicates that something is amiss with the juice.

In this sense, the Brix/acid ratio specification serves as a simple "fingerprint-type" parameter for the identification of a fruit juice and for products derived from these juices. If we take our lemon juice as an example and find that its Brix/acid ratio is 3.5, well above the stipulated 1.5 value, one reasonable conclusion is that it was sweetened with extra added sugar. This added sugar will increase the value of the Brix/acid ratio value. This is no great train smash — it is permitted to sweeten a lemon juice product, but it can no longer be called pure lemon juice. It would most probably be described on the label as "sweetened lemon juice." If not, then the most likely conclusion would be that the lemon juice was adulterated.

Adulteration of fruit juices is of major concern to the public and industry authorities all over the world. The Brix/acid ratio is the first step in identifying this unscrupulous practice. Other steps are much more sophisticated but will not be discussed in this handbook.

The link of the Brix/acid ratio concept to soft drink technology, the real subject of this chapter, is somewhat less dramatic and can be briefly described as follows. In the soft drinks industry, other than in the companies that have a core business in the fruit juices and nectars category, the intricacies and quirks of juice technology are not commonly known to technical and other involved staff who may be dealing with juice ingredients present in some of their company's ranges of products. They cannot be blamed or faulted in this respect, as they are most probably very much involved with their own core nonjuice business technology issues. This is particularly true of the smaller independent and private companies that do not usually have the luxury of head office boffins and specialists to help them out.

An "out of spec" Brix/acid ratio should be immediately queried with the supplier.

Here is where the Brix/acid ratio can be of some assistance. Every batch of incoming fruit juice should have the supplier's blessing in the form of a certificate of analysis (COA) specifying the Brix/acid ratio value of the batch. If in-house routine testing of Brix and acidity by the QC staff of the company results in a calculated Brix/acid ratio out of the stipulated specification, then something is amiss with the batch. It is not necessarily a case of deliberate adulteration but rather, most probably, a processing error on the part of the supplier or processor. For instance, it may be a case of the processor having used fruit that was harvested too early and had not ripened fully, in which case the Brix/acid ratio would be much lower than usual. Alternatively, if the juice is of the sweetened type, too much sugar may have been added in error. Then the Brix/acid ratio would be too high.

It could be argued, and justifiably so, that if the Brix and acidity quality parameters of a juice are found to be within specification, the corollary of a Brix/acid ratio within specification should follow. So why use the Brix/acid ratio parameter? The answer is that this is not altogether quite true. The Brix as an individual specification may be at its highest permitted value and the acidity, also as a specification on its own, at its lowest tolerance value. The ratio then may exceed the prescribed Brix/acid ratio for which the processor must be held responsible. The same applies to the reverse — lowest Brix and highest acidity could result in a ratio lower than specified.

A second argument in this respect is that an individual Brix (or acidity) value of the juice may be slightly higher than the allowed specification, and the consignment could still be released for use in production, as no great calamity could be caused by an extra bit of dissolved sugar in the juice (after all, it would be a case of "money for nothing"). But, the Brix/acid ratio calculated could well be out of specification. This implies that something is wrong and needs to be addressed with the supplier. The Brix/acid ratio, therefore, serves as a cherry on top of the cake of your confidence in that the processor used good, wholesome, ripe, and fresh fruit for processing your juice, and he

has processed it correctly. After all, as with all ingredients used in your facility, you are interested in juice of the highest quality available.

Strictly speaking, a deviation in one of the parameters, as in both arguments above, should always be accompanied by an equivalent change in the other, and in the same direction. This is the boon of a ratio-type specification between two individual parameters — they should always go hand in hand together. If not, "something is wrong." To sum it up in another way, if you draw your juice supplier's attention to Brix/acid ratio issues you may come across, he will only develop more respect for your technical acumen, and that is not a bad thing at all.

Last but not least on the subject of the Brix/acid ratio of juices: If you are involved in new product development and want to formulate products with little-known exotic-sounding fruit species, the knowledge of their Brix/acid ratio values could well serve as an indication of their potential sweetness and sourness effects on the new products. This, in turn, could guide your overall taste profile design of new products in respect of what target sugar and acid levels these should have. If, for instance, the exotic obscure fruit of a new planned beverage has the same Brix/acid ratio of orange, build your new product formulation on a composition template similar to an existing orange formulation in your company's range of products. This will save you a lot of time in trial and error steps to achieve a reasonable prototype formulation on which to work.

CALCULATING THE PERCENTAGE OF JUICE IN A BEVERAGE

Occasionally, a soft drink company's technical officer is asked to calculate how much juice concentrate should be added to a beverage in order to attain a prescribed legal minimum juice content in the drink. The reverse also happens, where the person is asked if the juice content in an existing juice-containing beverage is what it says it is on the label of the product.

This calculation often stymies soft drink technologists not acquainted with juice technology.

As I mentioned in the previous section, soft drink technical personnel (other than in companies where juices are the core business), are often not too familiar with the finer peculiarities and esoteric nature of fruit juice technology. If the person asked to do such a calculation has never done this before, he or she is usually stymied at first but then reacts logically enough to say something along these lines:

I was told that the juice is six-times concentrated, so I must add a sixth of the target juice percentage in the form of concentrate to a certain volume of beverage, and thus, the required target juice percentage will be achieved.

This might work, but it is very likely that he or she will significantly overshoot the minimum specified percentage level, and as such all is legally in order. However, fruit juice is a relatively costly item and a lot of money could be going down the drain. Also, overshooting the target could affect some of the quality parameters of the beverage, e.g., Brix, acidity, cloud intensity, and general overall taste.

In this section, I propose to show the reader that this calculation, though seemingly complex, is actually very simple when mastered. The first item to clarify and establish in this calculation is that the percentage juice in a beverage is usually required by food laws to be expressed (e.g., on the label) on a volume-for-volume basis. Thus, in a 6% juice beverage, one expects there to be 6 ml of juice in every 100 ml of beverage. The second basic item is that these 6 ml of juice must be on the single-strength basis of the particular juice involved.

Having established these two basic prerequisites for correct calculation methodology, we can now proceed. I will employ this 6% juice numerical example to demonstrate the calculation and use what by now is the well-known lemon juice concentrate Lemon 30 Brix, as the juice involved. It will be referred to as lemon concentrate.

Given:

Lemon concentrate:
    Brix corrected for acidity = 34.00°B
    D20 (from tables) = 1.14530

Lemon juice, single strength:
    Brix corrected for acidity = 7.50°B
    D20 (from tables) = 1.02685

Required:

Calculate the volume of lemon concentrate required in 1000 liters of final beverage to obtain 6% vol/vol single-strength lemon juice in the beverage.

Calculation:

Step 1: 1000 liters of final beverage must contain 6% vol/vol of single-strength lemon juice. Therefore:
    (1) 6% of 1000 = 60 liters
Step 2: Calculate total dissolved solids in 60 liters of single-strength lemon juice:
    (2) Weight of 60 liters of single-strength lemon juice
        = 60 × (D20 single-strength lemon juice)
        = 60 × 1.02685
        = 61.611 kg
    (3) Total dissolved juice solids in 61.611 kg single-strength lemon juice
        = 61.611 × (Brix single-strength lemon juice)
        = 61.611 × 7.50°B (expressed as percent)
        = 61.611 × 0.075
        = 4.62083 kg
    This is the amount of lemon juice solids that the 1000 liters of beverage must contain in order for the beverage to have the equivalent 6% vol/vol single-strength lemon juice. These solids will be supplied from the lemon concentrate that will be added to the beverage formulation.
Step 3: Calculate weight (W) of lemon concentrate that will contain 4.62083 kg dissolved solids.
By definition of Brix:

$$\frac{\text{Lemon Concentrate dissolved solids}}{\text{Weight (W) Lemon Concentrate}} = \frac{\text{Brix Lemon Concentrate}}{\text{(expressed as percent)}}$$

Therefore, (4)

$$\frac{4.62083}{W} = 0.34$$

Therefore, (5)

$$W = \frac{4.62083}{0.34}$$

$$W = 13.59066$$

This is the weight of lemon concentrate that will contain 4.62083 kg lemon juice dissolved solids.

Step 4: Calculate the volume V (in liters) of 13.59066 kg lemon concentrate.

(7)

$$V = \frac{13.59066}{\text{(D20 Lemon Concentrate)}}$$

$$V = \frac{13.59066}{1.14530}$$

$$V = 11.86646 \text{ liters}$$

Result:

$V = 11.86646$ liters of lemon concentrate and will contain 4.62083 kg lemon juice dissolved solids. This volume of lemon concentrate will represent 6% vol/vol single-strength lemon juice in 1000 liters of final beverage. The value can be conveniently rounded off to 11.866 liters.

This then is one way to calculate how much juice concentrate is required to achieve a specified percentage of single-strength juice in a beverage. This method was presented in order to enable the reader to understand the rationale of the steps involved and the interplay of Brix, density, dissolved solids, etc., that result in the final volume figure of concentrate.

All of these calculations can be represented in a single math formula applicable to any juice, at any target percentage in a beverage:

$$V_{fjc} = \frac{P \times V_b \times D_{ssj} \times B_{ssj}}{B_{fjc} \times D_{fjc}}$$

where

V_{fjc} = the volume (in liters) of fruit juice concentrate required to achieve the target percentage of single-strength juice in the beverage;

P = the target percent single-strength juice for the beverage (in decimal form);

V_b = the volume of the beverage in liters;

D_{ssj} = the D20 of the single-strength juice (from Brix/density tables);

B_{ssj} = the Brix of the single-strength juice (in decimal form);

B_{fjc} = the Brix of the fruit juice concentrate (in decimal form); and

D_{fjc} = the D20 of the fruit juice concentrate (from Brix/density tables).

Note: A point to take note of is that the Brix and percentage values should always be used in decimal format, e.g., 7.50°B as 0.075 and 6% as 0.06. This will save having always to divide by 100 and will put the decimals in their right places in the calculated results.

This formula can be mathematically rearranged to calculate the reverse, i.e., if the volume of fruit concentrate in a formulation is known, by isolating for P, the percentage single-strength juice in the beverage can be calculated.

OTHER JUICE-RELATED ISSUES

There are several other issues related to fruit juice technology that are of special relevance in soft drinks containing fruit juice. These are discussed briefly below.

Pulp Content

Most fruit juice concentrates contain certain levels of insoluble suspended solids derived from fleshy or fibrous parts of the fruit that find their ways into the juice during the extraction process. In lemon juice, as well as in other citrus fruit species, this material comes mainly from the fibrous walls of the juice sacs and fruit segments, which are macerated during the extraction process. Also, some small pieces of the inner parts of the fruit skin can be incorporated into the extracted juice. All of these suspended materials are referred to collectively as pulp.

Excessive pulp in a juice concentrate can cause various problems.

Pulp can cause some problems if present in excessive amounts. In operations using the syrup-to-water proportioning system, the pulp will rise to the surface of the syrup if the latter is not agitated gently during the filling operation. Also, at the end of a filling run, usually the last few hundred liters of syrup cannot physically be agitated at all, as the shaft and impellor blades do not reach these syrup remnants (if such an agitation mechanism is used). In both cases, the syrup being sent to the filling machines becomes heavily laden with the floating pulp, which results in filled product with an excessive pulp layer eventually settling at the bottom of the beverage container. In bottled product, this can be very unsightly.

In bulk ready-to-drink (RTD) filling operations, this can happen at the start of the run, as the unagitated pulp settles very quickly at the bottom of the holding tank. Pulp can also block the sieves of some types of filling valves that have such sieves by design. For a run with pulp-containing product, these are usually removed. In high carbonation products, the pulp can cause excessive foaming at the filler. In lemon juice concentrate, the pulp content can be anything from 2% upward. For concentrate used in soft drinks, the lowest pulp content (below 4%) should be agreed upon with the processor or supplier. The specification should also stipulate that all the pulp present should pass through an 850 μm screen. The processor is usually able to meet such requirements. In fact, some processors actually mill the concentrate to reduce the pulp particle size.

Microbiological

Fruit juices are renowned for their vulnerabilities to spoilage by microorganisms, especially by mold species. This is due to the natural sugar content as well as other fruit micronutrients that serve as excellent substrates for the microorganisms to grow upon. In operations with fruit–juice–containing products, these are considered as "more sensitive" than others, and special cleaning and sanitizing systems need to be implemented. Also, in-line pasteurization before filling is recommended. Tunnel pasteurization, hot-filling, and general aseptic filling are recommended for final beverages that are suitable for such processes.

Preservation

SO_2 carryover into the beverage can cause some problems.

Juice concentrates may be supplied as preserved or frozen. Concentrates are commonly preserved with sulfur dioxide (SO_2). In lemon juice concentrate, the level is around 1500 to 2000 ppm SO_2. Special note must be taken in regard to SO_2-preserved concentrates: At the SO_2 levels mentioned, there could be a high carryover of SO_2 into the final beverage. If the concentrate quantity content results in more than about 5 to 10 ppm carryover, the typical harsh odor of SO_2 may be detectable. This may not be a desired attribute of the final beverage product.

The SO_2-preserved concentrates are not normally recommended for canned beverages, as even a low 2 ppm SO_2 carryover into the beverage could result in the attack of the can metal by the SO_2. The can supplier should be consulted in such cases. The best alternative is to use frozen concentrates

for canning operations. Frozen concentrates are also mainly used for preservative-free final beverage products. For these, the "sensitivity" factor mentioned previously increases considerably.

The use of frozen concentrates obviously implies deep-freeze storage facilities, either in the plant or at outsourced deep-freeze companies. Thawing mechanisms or systems also become necessities. Thus, frozen concentrates are usually considered as a "hassle" by operations staff, but if required, they will put up with these.

CLOUD STABILITY

Many fruit juices are of the cloudy type. Concentrates from such fruit species, like lemon, will have a cloud stability specification. This specification relates to the potential possible destruction of the natural fruit cloud suspension due to various factors, one being excessive residual pectinaze enzymatic activity in the juice after processing. As the cloud in the final beverage may be solely derived from the juice, destruction of the cloud suspension could result not only in loss of turbidity but also in unsightly layering in the beverage. In extreme cases, this could be in the form of lumpy coagulated matter, commonly and humorously called "scrambled eggs."

CHAPTER REVIEW

Fruit juices are used in pure juice and nectar-type beverages. They are also used in other soft drink categories, like carbonated soft drinks, still drinks, and dilutables (squashes and syrups). In these products, the juices are normally used in the form of juice concentrates sourced from external juice processors.

Fruit juice processing and its specialized technology are not usually well known to the average technical staff of companies producing these categories of soft drinks that contain juice components. This chapter attempted to highlight a few of the more critical aspects of fruit juice technology for the benefit of the readers who may, in the course of their business, encounter fruit juice technical issues.

AUTHOR'S COMMENT

Throughout my long and interesting career in the soft drinks industry, I always wondered about the business logic of marketing soft drinks containing fruit juices at the relatively low percentage levels seen in the market. These types of beverages, with single-strength juice content below 10% and often even much lower, serve, in my modest opinion, no real purpose. The low juice content is neither of much nutritional benefit nor does it contribute much fruit taste to the beverage. Fruit juices are relatively expensive. It also introduces in such beverages a heightened spoilage hazard incommensurate with the benefits they allegedly claim to offer.

But then it would appear that the consumer likes these beverages and wants them — and, of course, I really should not argue with that.

8 Food Laws — Labeling the Package

OVERVIEW

Labeling of products in accordance with a country's legal requirements is one of the major issues of food laws. These requirements may vary from country to country in the specifics, but there are some basic prescribed principles that can be considered as global guidelines. It is with these that this chapter deals.

Label design is a combination of creative artwork by marketing departments and food laws compliance by technical staff.

When a new product launch is planned in a soft drinks company, be it small or large, a stage is arrived at where a label for the product or range of products is created. This involves a fair amount of artwork design — brand name, colors, logos, decoration frills, sizing, positioning, and so forth. The marketing people do all this. However, eventually, the prototype designs land up on the desk of someone in the technical department with the request to "sign off" the design with regard to food laws requirements. This relates mainly to items such as the text and format of ingredients lists, nutritional value tables, product descriptors, content volume, and any special statements or declarations that may be included in the artwork design.

This vetting step by a technical person is crucial, as it usually is the final one before the artwork is ultimately approved and the go-ahead is given to the supplier printer to produce the final product's label. This may be in the form of a wraparound PET bottle sleeve label, the design for a can, or the design for a bottle cap. Whatever it may be, one does not want to produce hundreds of thousands of these only to find afterwards that there is some gross legal error in the design. This chapter will attempt briefly to outline the items of soft drinks food laws labeling to which special attention should be paid by persons involved in the label design and approval thereof.

GENERAL PRESENTATION

The following are some of the more common general labeling requirements.

LEGIBILITY

All information on the label must be clear, visible, and indelible. Any pictorial or other artwork items must not obscure text.

LANGUAGE

In countries that have more than one official language, legislation must be consulted to determine applicable regulations as to which language or languages are to be used, in what proportion, etc.

LETTER SIZES

The size-of-lettering requirements refer to the height of the letter and only apply to information text on the label (such as ingredients, product description, manufacturer address, etc.). These requirements do not apply to brand name, logos, and other artwork of "marketing" nature.

Prescribed letter size is a compromise between prominence deserved and availability of space on the label.

Different minimum letter sizes may be prescribed for different text items on the label, with items of major prominence having to be larger than others. Usually, the larger letter sizes are allowed to vary in relationship to the surface area of the main panel of the label, which is taken to mean the part of the label where the brand name appears in greatest prominence.

Here, note should be taken whether the particular country's food laws make special allowances for labeling all required information on the small bottle caps of beverages filled into generic bottles with embossed labels (see Chapter 3).

An absolute general minimum letter size is also often prescribed, below which a letter size is not acceptable. This minimum is set to address all instances or items in which the legislation may not be altogether clear about and which were not covered specifically in the regulations. This minimum size is commonly 1 mm height.

Letter size requirements may also be related to the proximity of text in certain descriptive wordings or phrases, where a proportion between sizes would be stipulated (e.g., in "low-calorie diet drink," the "low-calorie" part could be prescribed as at least half the letter size of "diet drink").

IDENTIFICATION

Full product and manufacturer identities are of paramount importance.

The beverage in the package needs to be identified using a name or a description. These must be true descriptions of the beverage and must be precise enough to distinguish it from other products with which it could possibly be confused by the public.

Some such names and descriptors may be prescribed by regulation, but reasonably worded ones will usually be acceptable. Common examples of these are "diet drink," "sports drink," "fruit nectar," "natural spring water," etc. Even plain and simple "soft drink" may, for example, be used to describe a cola or lemonade beverage.

The manufacturer's name and address must appear on the label. Multifacility companies may be permitted to use a common head office address for all of their factories' products. Beverages produced or filled by an outsourced contractor must state the latter's details. House-branded products must have the seller's details. If a beverage is packed in concentrated form for later dilution by the consumer, details of the dilution or preparation instruction must be clearly indicated on the label.

PROHIBITED STATEMENTS

Food laws forbid many types of statements on the labels of foods, most of which would also apply to soft drinks. These statements may be in the form of words and phrases but also include pictorial representations, marks, and symbols.

Some key prohibited statements.

Prohibition of such statements can be found in diverse sections of the legislation and are mentioned in the text of regulations pertaining to a specific subject dealt within a particular section. The following are the more all-encompassing categorical prohibitive statements on which food laws generally stand very firm:

- A label of a soft drink may not bear an endorsement or recommendation by a medical or dental practitioner or any other person engaged in supplementary health services.

The medical profession usually prohibits this.

- A label of a soft drink may not bear an endorsement or recommendation by an organization (other than a religious organization), unless the label clearly indicates that the product is to be used in accordance with the directions of the organization.

As an example, a diabetic organization may recommend a certain sugar-free beverage, but the onus is on the diabetic consumer to consume it in a manner prescribed by the organization. The soft drinks company should not be held responsible for any mishaps if the consumer does not comply with this.

During my entire career, I shied away from such endorsements on my company's sugar-free products for the simple reason that I am not a medical doctor and cannot take the responsibility involved in diabetes matters.

- A label of a soft drink may not bear any claims that the product has health-giving properties.

This is a "tricky" item. It has to be studied in conjunction with legislation pertaining to medicines, drugs, and related substances.

- A label of a soft drink may not bear any claims indicating that the product has any healing or curing properties or any other medicinal, therapeutic, or prophylactic properties.

This is also a "tricky" one, as above.

- A label of a soft drink may not claim that the product is free from a certain substance if all other beverages of the same type are free of that substance.

This is to prevent unfair promotion of one's products (and confusing the consumer) by claiming, as a hypothetical example, that the lemonade product is "fat-free" — all lemonades are fat-free.

- No statement that is prohibited on a soft drink label may appear in any manner in an advertisement for that soft drink.

This is a corollary of the principle, sometimes applied to food labeling legislation, that advertising in any form is a kind of labeling activity.

- A label of a soft drink may not have any reference to government legislation or to these legislation authorities.

INGREDIENTS LIST

Food laws require that all ingredients of a soft drink be listed on the label. The format and positioning of this ingredients list may vary from country to country, but the general principles are outlined below.

A key section of the label.

INGREDIENT NAMES

The ingredients are usually listed by their commonly accepted names or chemical terms. However, the best way to name an ingredient is to use the name that may appear in a schedule list of a regulation dealing with that particular type of ingredient. By doing so, there would be no possibility of going wrong with the name to be used.

Some countries' food laws are lenient and allow for, by means of applicable specific regulations, an ingredient to be named by a generic category name based on its specific function in the beverage. Thus, citric acid and malic acid may be listed as "acidulants" or "acidity regulators." Other category names could be "colorant," "stabilizer," "thickening agent," etc.

On the other hand, the countries of the European Union are required to follow the name of the ingredient (or category name) with their standard ingredient code number (known as the "E number") in brackets. Thus, for example, E300 is the E number of ascorbic acid (or vitamin C).

Lists of E numbers are commonly available. It is wise to keep lists of these numbers for reference, especially for companies intending to export soft drinks to the European Union countries, as the labels will have to include these E numbers.

Some specialty ingredient names need to be followed (or preceded) with a prescribed category term. An example of this is "sodium benzoate (preservative)" or "acesulfame-K (nonnutritive sweetener)." Such requirements will normally be found in regulations dealing with the specialty ingredient.

ORDER OF INGREDIENTS IN LIST

In most food laws, the names of the ingredients are required to be listed in descending order of their weights present in the beverage. This order can easily be established from the master formulation document of the product.

In soft drinks, water would obviously be first on the list. In the case of carbonated soft drinks, this is normally listed as "carbonated water."

Ingredients contained in the beverage in relatively minute quantities, such as vitamins, mineral salts, and other micronutrients, are often allowed to be listed at the end of the list in any weight order, provided that these ingredients are listed in the nutritional information table that would probably be required in any case. (For more information, see the "Nutrition Information" section below.)

"CARRYOVER" INGREDIENTS

It often happens that an ingredient (or more correctly put, a food additive) that has added ingredients is used in the formulation of a soft drink. A typical example would be a fruit juice concentrate ingredient that was preserved with sulfur dioxide (SO_2) at 1500 ppm. When added to the beverage formulation, this could result in a "carryover" of a few ppm of SO_2 into the final beverage. This small amount of SO_2 is not in any way intended to serve as a preservative in the beverage. Most food laws recognize that this is a case of carryover. They would not require the sulfur dioxide to be included in the ingredients list.

The same principle applies to other food-additive types of ingredients, such as flavorants containing alcohol as a solvent, essential oils containing antioxidants, powdered colorant blends containing maltodextrin as a bulking agent, just to name a few.

SPECIAL LISTINGS

There are two ingredients often used in soft drinks that need special mention with regard to the ingredients list on labels.

Tartrazine, colorant.

The first is the colorant tartrazine (C.I. 19140, EEC No. E102, certifiable as FD&C Yellow No. 5). It is often used in drinks requiring a yellow to orange coloration. It was established that

tartrazine can present an allergy problem to a small percentage of the population. Therefore, if permitted, tartrazine is required to be specifically listed by name in the ingredients list. This is especially applicable if the food laws of the country allow food colorants to be generically listed under the category name of "colorants."

The second ingredient is the intense sweetener aspartame (E951). This ingredient is a source for the amino acid phenyla-lanine. Although nutritionally it is considered as an essential amino acid, a small percent of the human population needs to avoid high intake of this amino acid due to a genetically inherited disease called phenylketonuria (PKU). In this disorder, the sufferer of PKU cannot metabolize the phenylalanine, which accumulates in the blood to potentially harmful levels.

Aspartame, intense sweetener.

If present in the beverage, aspartame in the ingredients list needs to be somehow linked to a clear statement in close proximity to the list that warns the consumer that it is a source of phenylalanine. (In South Africa, the aspartame is listed with an asterisk (*) that refers to an ingredients list footnote "contains phenylalanine.")

SOFT DRINKS IN VENDING MACHINES

Some food laws may address the labeling issue of soft drinks sold in vending machines. The basic principle is that unless the individual beverage containers are clearly visible and their labels sufficiently legible to prospective customers, there might well be a requirement to somehow present the labeling information to the consumer.

This principle could also apply to beverages sold to the public through fountain dispensers.

These items have been mentioned by way of "splitting hairs." I have yet to see a vending machine or fountain dispenser that displays all the labeling information required on the labels of the same product sold in normal bottles or cans.

THE WORD "NATURAL"

Food laws can be very strict when it comes to misleading information on soft drink labels. The use of the word "natural" in conjunction with a soft drink's name, brand name, or description of these is specifically addressed by the food laws of most countries. They prohibit the use of this word to describe any soft drink that was processed in any manner.

The only soft drinks that this word "natural" could possibly be applied to are the natural spring or mineral waters bottled or canned directly from their natural sources.

Freshly squeezed juices could also qualify for the "natural" description.

Furthermore, the word "natural" is also usually prohibited for describing a soft drink that contains any ingredient that is not present in it in its natural form. The reverse is also applicable. A soft drink that has had any ingredient removed from it that is present in the drink in its natural form may not be described as "natural."

This again applies mainly to spring and mineral waters as well as to unprocessed single-strength fruit juices.

CLAIMS ON SOFT DRINK LABELS

A "claim" in relation to a soft drink can be defined as any written or graphical descriptive matter that is brought to the attention of the public referring to the characteristics or properties of a product. It should be noted that as labeling legislation often applies to advertising of any sort, this definition would be extended to any statement or communication, written or verbal, in the media and on billboards, that refers to the characteristics and properties of a soft drink.

Soft drinks of various types are placed in the market with labels bearing claims that aim to attract the attention of target market consumers to the properties and possible benefits of the particular type of drink. The following is a brief presentation of the more common claims encountered in the soft drink market and the legal labeling implications.

PROHIBITED CLAIMS

Some prohibited claims were mentioned at the beginning of this chapter in the "General Presentation" section. In addition to these, food laws usually prohibit a claim or any implication that a soft drink has special properties, when other similar drinks possess the same properties. For example, it would be prohibited to claim that a soft drink has had its water specially treated. Most, if not all, soft drink producers practice water treatment in their manufacturing processes.

Sometimes an ingredient of nutritional nature is added to a soft drink formulation for pure technical or sensory reasons. A typical case would be ascorbic acid (vitamin C) added as an antioxidant. Because of this, it would not be acceptable, for example, to place a flash "vitamin C added" or something similar on the label without a nutrition information table reflecting this "vitamin enrichment."

NUTRITIONAL CLAIMS

Claims related to nutritional benefits are the most common in soft drinks.

The most frequently encountered claims for soft drinks are those related to nutritional issues. As explained in the next section of this chapter, a nutritional claim will require, by legislation, clear-cut nutrition information relevant to the claim made. Each category of claims, such as "low calorie," "enriched with," "high energy," "no sugar added," etc., is usually dealt with in dedicated category-specific regulations, either in those of the labeling legislation or other subject-specific food laws.

Whatever the nature of the claim, the regulations will normally address the essential nutrition science background details of the subject so that not much can be misinterpreted as to what is required in the prescribed nutrition information for the label. (In fact, this background information could sometimes be used as "textbook" information for the novice nutrition scientist.)

The following is a brief listing of the more common nutritional claims found in our industry:

Reduced energy: For this type of claim, the regulation will stipulate the maximum energy content allowed as a percentage ($X\%$) of the energy content of a similar drink for which no such claim is made. In other words, a low-energy cola should not have more than $X\%$ energy content over that of a regular sugar-sweetened cola beverage. This $X\%$ can vary from country to country, but 50 to 80% would be a reasonable figure.

Diet/low energy: For this claim, the regulation will stipulate an absolute maximum energy content in the beverage. This could be as low as 30 kJ per 100 ml of beverage in ready-to-drink form.

Slimming claim: Not many soft drinks specifically, in so many words, claim to be slimming aids and will assist in weight reduction or weight control. However, the mere wording of "diet" in a product description could be taken to indicate this. Therefore, if a "slimming" claim seems to be implied, it would be required to make a statement on the label to the

effect that the product is "only effective as part of an energy-controlled balanced diet," or something similar. The regulation will usually have a well-worded prescribed statement to be used on the label.

Added/enriched: If it is claimed that a soft drink is enriched or fortified with one or more nutrients (such as vitamins, protein, minerals, and trace elements), it will require a detailed nutrition information section on the label with respect to such a claim. This nutrition information issue is discussed in the next section of this chapter.

Diabetic claim: Some food laws may make provision for a diabetic claim on applicable foodstuffs and stipulate the requirements, which include regulated parameters of "readily absorbable carbohydrates," "glycemic index," or other complex terminology related to the physiology of sugar metabolism in humans. However, most food laws strictly prohibit any diabetic claims on foodstuffs inclusive of soft drinks. This is for good reasons, of which the basic one is that we are not medical doctors, to whom such matters should be left. Suitable soft drinks may well be endorsed by diabetic organizations, but it is the responsibility of the consumers to ascertain that an endorsed product is suitable for its consumption by them. It is this author's considered opinion that soft drink manufacturers should totally refrain from labeling any claim of a diabetic nature on their products.

No sugar added: This is a complicated issue in food legislation. It all depends on how "sugar" is defined in the food laws of the country. This kind of claim is usually associated with fruit juice products, where it implies that the inherent natural sugars of the fruits (monosaccharides and disaccharides other than sucrose) are the sole sweetening agents in the beverage. This claim could also be misinterpreted by the less-aware consumer that the product is sugar-free, and hence, it is construed to mean the low-energy "diet" type of drink. This would not be a great disaster, but it could be if the consumer was diabetic. This "no sugar added" claim should be carefully addressed in conjunction with the food laws of the country concerned.

Other claims: There are many other types of nutritional claims on labels for a great diversity of soft drinks, such as sport recovery drinks, energy-boosting beverages, and health-providing herbal iced teas, to name a few. The general guideline here, in the absence of precise specific labeling legislation, and other applicable general food legislation, is to ensure that any such claims can be scientifically substantiated.

NUTRITION INFORMATION

Soft drinks were originally produced to serve one main purpose, namely, refreshment. Over the years, due to consumer demand and special niche marketing opportunities, many versions of the original beverages were developed to cater to specialty markets that focused mainly on claimed nutritional benefits for the consumer.

First were the sugar-free beverages that targeted the ever-growing market of weight-conscious consumers. These were the so-called diet drinks. In the last few decades, the soft drink market has literally been swamped with a multitude of beverage types that claim to offer the consumer diverse nutritional benefits.

The labeling requirements of such beverages are prescribed by food laws. Most countries are strict in this respect. Whatever the particular claim is, a nutrition information section in tabular format is usually required on the label. This table must contain specific data in respect to the particular claim made for the product. Each country's food laws prescribe its well-defined format for nutrition information presentation on labels. Table 8.1 and Table 8.2 illustrate examples of what such nutrition information sections could look like.

The nutrition information table on the label is linked to the claim.

TABLE 8.1
Nutrition Information — Low-Energy Diet Drink

Nutrition Information		Per 100 ml Beverage	Per 330 ml Beverage
Carbohydrate	g	0	0
Protein	g	0	0
Fat	g	0	0
Energy	kJ	5.9	19.9
	kcal	1.4	4.7

TABLE 8.2
Nutrition Information — Vitamin-Enriched Sports Drink

Nutrition Information		Per 100 ml Beverage	Per 250 ml Serving	% RDA[a] per 250 ml Serving
Energy	kJ	120	300	
	kcal	28	71	
Carbohydrate	g	7.5	19	N/A
Protein	g	0	0	N/A
Fat	g	0	0	N/A
Sodium	mg	24	60	N/A
Potassium	mg	4	10	N/A
Calcium	mg	10	25	3
Phosphorous	mg	14	35	4
Vitamin A	:g R.E.	8.4	21.0	2
Vitamin E	mg αT.E.	0.5	1.3	13
Vitamin C	mg	24.0	60.0	100
Vitamin B_6	mg	0.16	0.40	20
Folic acid	:g	16.0	40.0	20

Note: R.E. = retinol equivalent; T.E. = tochopherol equivalent; N/A = not applicable.

[a]RDA for adults and children over 10 years old.

Some examples of nutrition infor-mation table layouts.

In Table 8.1, the layout is for a diet drink that is claimed to be low in energy content or to be a low-calorie drink. The table contains information relevant to the claim; hence, the content of the three main energy nutrient categories — carbohydrates, proteins, and fats — must be listed. The total energy contributed by these, being the key information relevant to the low-energy claim, must also be listed in the table. (Energy units listed depend on those used in the particular country. It is advisable to list both unit types, kilojoules and kilocalories, to cater to the product export potential).

The values presented are for 100 ml of beverage, which is the commonly accepted standard reference quantity throughout the world (that is, in countries using the metric system). The table also has the values for a 330 ml quantity, this being the can content of the labeled product. The inclusion of this column in the table is often of voluntary nature. The 100 ml column is mandatory.

Table 8.2 is for a sports drink with a vitamin-enriched claim on the label. The nutrition information table is more complex than the previous one. It must contain the macronutrients (carbohydrate, proteins, and fats) and energy data. It must also contain the vitamins and electrolyte content as well as an indication of how much these represent as a percentage of the recommended dietary allowance (RDA).

Note that the nutrition information table lists the data for 100 ml as well as for a recommended serving of 250 ml. The latter is, in this case, mandatory. It is the guideline consumer consumption quantity for the claimed nutritional and sports performance benefits of the product.

> The established RDA values for vitamins, minerals, and other micronutrients are usually contained in authoritative schedules in annexes of the labeling regulations. Most countries use universally accepted RDA values established by recognized world health and nutrition organizations, though sometimes differences between countries do crop up.

These two examples of a nutrition information table required on a label are relatively simple and straightforward. When the product is much more nutritionally orientated and the claims are more numerous and specifically focused, the tables could become more complex (and will occupy much more space on the label).

At the end of the day, it can be said that labeling legislation in respect to nutritional claims in soft drinks is there, first, to instruct the manufacturer on how to go about providing the relevant information to verify claims for the prospective consumer. Second, the legislation aims to prevent misleading and incorrect information from appearing on the label of the product, whether this is done unwittingly or deliberately.

Labeling legislation aims at providing true and accurate information to the consumer.

> Persons involved in the labeling of soft drinks are advised to acquaint themselves with the subject of nutrition information.

LABELING OF PRODUCTS FOR EXPORT

When a company plans a launch of a new soft drink product, a label is designed and created. Much time and work normally goes into this process. After the launch, if the product is successful, export to markets often becomes a possibility. It also can happen that the label is found to be incompatible with the food laws of the targeted export country.

If the target country has a different official language than that of the exporter, there is no real problem, as a new label in that language will need to be designed in any case. However, if the language is common in both countries, a new label design becomes an unnecessary expense. This is even more pronounced when the label is on a metal can product — new cans have to be designed and produced.

It is, therefore, a good rule for companies involved with exports to other same-language countries to design their labels in such a way as to adhere to both countries' food laws. This implies that one has to be familiar with other countries' food

A small tip to exporters.

laws, or, at least, that they must be available for study by the prospective exporter. This is merely an expense-saving tip for a prospective soft drink exporter.

CHAPTER REVIEW

The labeling of soft drinks, as for all food products, serves many purposes. A main one is that it enables the consumer to make an informed choice. For this purpose, the information on the label should be true, accurate, and as understandable as possible by the consumer. Labeling legislation is aimed at achieving these objectives. In this chapter, the attempt was made to address the main technical issues involved in global aspects of soft drink labeling food laws.

9 Syrup Making — The Heart of the Process

THE SYRUP PROPORTIONING SYSTEM

This chapter deals with the subject of the syrup-making stage in soft drink manufacture. It, therefore, ostensibly deals only with those final beverage-filling operations in which prepre-pared concentrated syrup of the product is blended, at the filling machine, with treated water in a prescribed water-to-syrup ratio.

Syrup-to-water proportioning is mainly used in the carbonated soft drinks industry.

This blending operation is effected by a piece of equipment called a syrup proportioner (or blender). It may vary in design, from a simple pump with a manually adjustable piston stroke to very sophisticated units consisting of computerized flow rate regulators. Whatever the design, the principle is the same. The flow is set to deliver the prescribed amount of syrup to that of the treated water. The resulting water and syrup blend is then thoroughly mixed in-line on a continuous basis, is carbonated, and is delivered to the filler bowl for packaging into bottles or cans. This system, in which concentrated syrup is first produced and thereafter mixed with treated water at the filling point, has always been, and still is, the main one used in the carbonated soft drinks industry.

I visited many carbonated soft drink operations, big and small, all over the world. Most, if not all, produce their products in this manner. On the other hand, with the exception of the larger international soft drink corporations, I have not come across many smaller still beverage manufac-turers that use the syrup proportioning system for their final beverage products. Such manufacturers prepare their final beverages in tank batches of bulk final beverage in ready-to-drink (RTD) form, which is then delivered to the filling machines for final product packaging. I will return to this subject of syrup versus bulk RTD a little later in this chapter.

It would seem that this chapter is only applicable to carbonated soft drink manufacture. This is not altogether true, because when preparing RTD noncarbonated beverages, a syrup-making stage of sorts is still involved. Concentrated syrup is first made up in a tank and then diluted with treated water in the same tank to final batch volume at a specified final beverage Brix. The reader is requested to bear in mind that though the focus of this chapter is on carbonated soft drinks, much of the subject matter is applicable to bulk preparation of RTD still beverages as well.

WHY IS SYRUP PROPORTIONING USED?

This question can be answered in two ways, depending on how one looks at the question. If the question is really asking why this system is, in particular, used for carbonated soft drinks, I have a theory that may serve as an explanation for this.

Syrup proportioning may well have its roots in early soft drink history.

Historically, carbonated soft drinks developed in the late 19th century in the American drugstores, where people could find refreshing drinks made from diversely flavored syrups dis-pensed and mixed into glasses of carbonated water (see the "Introduction" of this handbook). These drinks were known as the "soda fountain" beverages that became a rage in the U.S.

Mass production of soft drinks in bottles copied the way the bever-ages were prepared at the drugstore soda fountain.

Some drugstore owners saw the business opportunities involved and began supplying the customers

with the drinks manually filled into bottles so that they could be taken away for drinking at home. Proving to be a great success, some entrepreneurs recognized the business potential in mass producing the bottled beverages in factories. Thus, the first bottling plants came into being.

My theory is that when the machinery and processes were designed for these first bottling plants, the designers copied the ways the beverages were prepared in drugstores. A small amount of concentrated syrup was dispensed into a bottle, carbonated water was added, the bottle was capped, and the liquid was mixed by shaking or inverting the filled bottle a few times. Not only was copying the manual drugstore process the logical and reasonable thing to do, but also processes and equipment to prepare and fill carbonated RTD final beverage into bottles did not exist at the time, even if someone had thought about going that way in mass producing the drinks.

Syrup making became the standard process for carbonated beverage production. Even as gradually more sophisticated machinery and processes developed, the syrup-making stage remained an integral but separate part of the production sequence on which basis these new processes and equipment were designed. This principle has lasted to this present day, and most of the modern, highly sophisticated carbonated beverage filling equipment is still designed on the syrup proportioning principle.

This was one way to answer the original question of why syrup making and proportioning it with water at the filler is found in carbonated soft drink operations only. Obviously, if there were no advantages in this system historically, it would have been abandoned for the RTD beverage filling system. Before dealing with these advantages, I ask for the reader's indulgence for my going into a little more history of the carbonated soft drinks industry development related to syrup-making aspects.

A LITTLE BIT OF HISTORY

Not many readers of this chapter are going to be familiar with what is discussed in this small section of the chapter, as it concerns the "dinosaur age" of carbonated soft drink history and will no doubt reveal that I am some sort of dinosaur myself. But then, the dinosaur can be a fascinating subject, and I hope that the reader will find some interest here.

I mentioned earlier that when carbonated soft drinks were first produced in factories, the processes and equipment were designed to copy how the drinks were prepared at the local drugstore soda fountain. There, a measured dollop of flavored syrup was squirted into a bottle, and then the bottled was filled with carbonated water (soda water). The bottle was firmly sealed with a cap, and the contents were mixed, usually by inverting the bottle a few times until the syrup was evenly dispersed in the water. The beverage was then ready for drinking whenever the customer chose to open the bottle and do so.

The post-mix filling system is a replica of the drugstore soda fountain process.

By saying that this process for mass production was "copied" is no exaggeration. In principle, the factory process truly followed the drugstore procedure. The flavored syrup was prepared in bulk in a suitably sized tank. When ready, it was pumped to the filling machine for filling into glass bottles. At the machine, there were two filling bowls. The first bowl contained the syrup pumped over from the holding tank. The filling valves of the syrup bowl were designed to deliver a fixed precise volume of syrup to each of the bottles as these revolved around with the bowl. This "dollop" of syrup was called the "syrup throw" for the product and was set at a volume for a specific bottle size. At a 4:1 water-to-syrup ratio for a 250 ml bottle, the syrup throw would have been 50 ml in volume. The consistency and accuracy of the syrup throw for each of the few filling

valves could be checked by periodically physically measuring it (or a bit later on by checking the Brix of the final beverage produced).

After receiving its syrup throw, the bottle would proceed to the second filler bowl, which contained carbonated water. There it was filled with the water (usually with a certain amount of foaming), and then immediately afterwards, at a capping station, it was sealed with a cap of some sort that hopefully prevented the escape of any of the original gas in the beverage. (The crown cork, still used today in some carbonated soft drink operations, was soon invented to address this gas retention in the bottle issue.)

As the sealed bottles came off of the capping line, they were manually packed into a wooden crate of suitable size. This crate was fitted firmly into a "tumbler" — a device that was manually rotated so that with a few gentle spins, the case of bottles was inverted several times, and complete mixing of syrup and carbonated water was effected. To check this, a line operator would sample a bottle, turn it upside down, and observe the liquid for "syrup tails" (or trails — I seem to have forgotten which term was used). If the syrup was not fully and properly mixed with the water, and being colored and of thicker consistency than the water, tails (or trails?) of colored syrup would clearly be seen in the beverage. If these were observed, the case would be sent back for a few more tumbles.

I have a tale to tell about these tails — at the end of the chapter.

This type of beverage-filling process, a precise reproduction of the drugstore soda fountain procedure, was called the "postmix" filling type to differentiate it from the later, more modern "premix" operation. The postmix operation receives its name from the fact that syrup and carbonated water are mixed into final RTD beverage after the filling operation. (In the premix operation, the syrup and carbonated water are mixed into the diluted final beverage form before the filling operation.)

Postmix filling machines are now obsolete and are mainly found in museums. However, the term "postmix" is still used today to designate syrups used in fountain dispensers, where carbonated water and syrup are separately but simultaneously dispensed into the customer's glass or cup. These fountain dispensers have adjustable syrup throw devices to accommodate the syrup flavors with different water-to-syrup ratio requirements.

ADVANTAGES OF THE SYRUP-MAKING SYSTEM

The previous brief excursion into carbonated soft drink history was intended to support my theory that syrup making in carbonated beverages operations is a result of the historical development of equipment and processes.

Filling equipment design and fabrication for the carbonated soft drinks industry developed tremendously. Today, we have fillers of extremely high speeds, with all types of sophisticated physical and electronic controls for syrup proportioning, water deaeration, product cooling and carbonation, empty and filled

Preparing a concentrated syrup as a separate step in final beverage production has its advantages.

bottle inspection, etc. Most of these designs are based on the fact that syrup, and not RTD beverage, is delivered to the filling system. Apart from the historical fact, there must be a reason why the carbonated soft drinks industry continued with the principle of separately preprepared syrup being proportioned at the filler and did not take the route of preparing bulk RTD beverage for direct filling as the final product. There are a few reasons for this that will be briefly pointed out below.

Tank Size and Storage Space Costs

Cost savings in tank size and storage space are a main advantage.

In order to explain the advantage in tank storage space and other related costs, let us consider a simplified numerical example. Imagine a medium-size bottling plant that fills about 100,000 liters of final beverage per day and does this by preparing bulk RTD in manufacturing batch sizes of 20,000 liters each. It theoretically would require $5 \times 20,000$ liter tanks to contain the day's planned filler production. (This is not altogether true, because in practice, fewer tanks could be used. As one is emptied, it could be quickly cleaned and used for preparation of another batch, while a second tank is being used for filling. This is a valid argument, but it would apply to a syrup-making scenario as well, and the argument would thus be canceled out. So, let us stick for example purposes to the $5 \times 20,000$ liter tank scenario.)

In a syrup-making scenario, the plant that used a 4:1 water-to-syrup proportioning ratio system would only require 5×4000 liter tanks for the 100,000 liter daily filling volume. Not only would the tank-holding space cost be reduced to about 20% of that of the bulk RTD scenario, but also the cost of the tanks would be significantly decreased. Also, many other related cost avoidance items could be enumerated, such as reduced labor, power, staff, and materials costs incurred in preparing smaller batches and in cleaning and sanitizing much smaller equipment. Also, there could be lower-cost ancillary equipment, such as agitators, pumps, pasteurizing units (if required), etc. These are just a few of the cost-saving items that come to mind.

I would hazard a guess that the cost savings of a syrup-making system would far exceed, especially in the long term, the cost of the water-to-syrup proportioning equipment, which would in any case normally be included in the overall price of the entire filling unit. The same water-to-syrup proportioning unit would also serve, at no extra cost, any expansions in the daily filling program (unless of course a complete new filling line becomes necessary). All that would be required is an extra one or two 4000 liter tanks that more than likely could be fitted into the current available space in the syrup room. This would be yet another cost-saving item. This cost-saving issue is one of the advantages of the syrup-making system when compared to the bulk RTD filling system.

Versatility

Concentrated syrups provide flexibility in filling planning and operation.

I estimate, very roughly, that the preparation of a 4000 liter syrup batch would take about a quarter of the time of that of an equivalent 20,000 liter bulk RTD beverage batch. This increases the versatility in daily or even weekly production scheduling and operations for the filling section. Batches of syrup could be prepared with relatively short notice periods, and new unplanned batches could quickly be arranged or banked upon to meet unforeseen circumstances.

Syrups could also be prepared for the next day's filling, as syrups are more resistant to spoilage and general deterioration than bulk RTD beverage and may be stored, in most cases, for up to 24 h prior to use in filling. The versatility principle could figuratively be simply explained by saying that it is much easier to juggle small apples than large ones.

Product Integrity

High Brix syrups are more resistant to microbial spoilage during storage prior to filling.

Syrups designed for the commonly used 4:1 to 5:1 water-to-syrup ratios are in the region of 50 to 60°B range. With such high solids contents, they are fairly resistant to microbiological growth due to their osmotic pressures' disruptive effect on the microorganisms' cell structures. Bulk RTD beverage, on

the other hand, in the 9 to 13°B range is a most favorable media for microorganism growth, especially while contained in the contamination-vulnerable holding tank. This higher resistance to spoilage is not only an advantage in itself but it also allows for longer storage time for syrups, especially in the case of lengthy filling operation breakdowns.

This brings us to a special case in favor of syrups over bulk RTD beverage. In some countries, such as the U.S., carbonated soft drink bottling and canning plants purchase their preprepared syrups from outside sources. These are delivered to the plant by road tankers, pumped over to holding tanks, and used virtually the same or next day in filling operations. This would not be economically viable for "single-strength" bulk RTD beverage. Of more importance, this would not be a wise idea due to the microbiological spoilage risk involved.

OTHER ADVANTAGES

The previous three claimed advantages of cost savings, versatility, and superior product integrity are ample enough to favor the syrup-making system over the bulk RTD beverage system. There are still other advantages of a second-level nature which, when combined, would add up into further significant support for the syrup-making operation. I will mention a few of these in passing without any lengthy elaboration:

- Any processing errors or defects (taste, sweetness, sourness, color, cloudiness, etc.) are magnified and are, thus, easier to detect and correct, "before it is too late."
- A quantity error in weighing out an ingredient, e.g., an excess of sugar, citric acid, or even of a flavorant, can be quickly remedied by preparing another small "compensatory" syrup batch to be mixed with the faulty one, thus bringing the particular ingredient back into line. (This could also be done with bulk RTD, but the time-to-tank-space factor could be restrictive.)
- Most carbonated soft drink companies run lucrative fountain sales businesses that require syrups for the fountain outlet operations. These can be drawn off regular syrup batches and need not be specially prepared in the relatively small volumes required.
- By far the greatest advantage of syrup making is the fantastic sensory experience one enjoys when entering a syrup room — the wonderful, intensified tangy aromas of the concentrated syrups are simply out of this world — just kidding for a change.

IN CONCLUSION

In this section of the chapter, I attempted to explain why carbonated soft drinks usually use the syrup-making and water-to-syrup blending option as opposed to filling preprepared bulk RTD final beverage. It also outlined the various advantages of the syrup system.

Why many still beverage companies use the bulk RTD filling option I cannot really explain. I have, on several occasions, asked colleagues who transferred from carbonated soft drinks to still beverages companies why they do not go over to the syrup-making system. The responses have usually been shrugs of the shoulders and responses of "that's the way things are." I hope one day to find a reasonable explanation. There most probably is one, only I have not looked far or deep enough into the matter.

Having concluded this aspect of syrup making, we can now proceed with the subject matter of syrup making in carbonated soft drink operations. It has a place in this handbook, because, after all, this category of beverages makes up almost 50% of the global volume of soft drink sales.

SYRUP-MAKING TECHNIQUE

In order to standardize the terminology used in this chapter and to address some primary premises on which this chapter is based, the following items need to be clarified:

- The syrups discussed in this chapter, unless specifically indicated otherwise, refer to those prepared with the natural sweetener sucrose alone (cane sugar or beet sugar). This is not to say that syrup making with other natural sweeteners, such as high-fructose corn syrup (HFCS) or invert sugar, is vastly different. The differences in operational aspects are virtually the same, but I wish to avoid falling into scientific inaccuracy traps by not distinguishing between some of the subtle technical differences between sucrose and these other natural sweeteners that may exist when they are used in syrup making.
  - Sucrose will be referred to as "sugar" for the simple reason that this is how the operators on the floor of the bottling or canning plant commonly call it. There is no need to always use the chemical notation for this sweetener.
- Syrup making in this chapter refers to the operation that takes place on-site in a carbonated beverage manufacturing facility. It does not refer to the operation in an outsourced syrup manufacturing facility from which the syrup is delivered in bulk to the beverage factory by tanker. Though in principle these should be similar operations, this chapter focuses on the in-house syrup making of a regular carbonated beverage bottling plant.
- The site in the bottling plant in which all syrup making is carried out will be referred to as the "syrup room" (even though in some larger carbonated soft drink operations this can be more of a "hall" than a "room").

GENERAL PROCESS OUTLINE

Simple syrup preparation.

Figure 9.1, a simplistic schematic representation of the syrup-making process, outlines the standard syrup-room equipment and process flow of the system. A measured amount of treated water is pumped into the tank (1), and the agitator is started. The prescribed amount of sugar is added to the treated water and allowed to mix in the water for some time, until it is completely dispersed and dissolved in the water. The resultant sugar solution is commonly called "simple syrup" and will be referred to as such in this handbook.

The simple syrup is then pumped through a polishing filter (2) to a second tank (3). Filtering the simple syrup through the polishing filter is a standard requirement aimed at removing any foreign matter, such as black carbonized specks that are commonly found in even the best grades of sugar. The pore size required of the polishing filter depends on the general quality of sugar used and is usually in the 5 to 20 μm range.

Adding the beverage base ingredients.

To the transferred filtered simple syrup in a second tank, the other beverage formulation ingredients are added in a prescribed manner and sequential order. The total complement of formulation ingredients, excluding the sugar (and the carbon dioxide gas later added at the filling machine), form what will be called the "beverage base" for that particular formulation.

Topping up to final volume with treated water.

The beverage base ingredients are mixed well into the simple syrup by the tank agitator until they are completely dissolved or dispersed in the syrup. The agitator is then stopped, and more treated water is added to bring the total liquid quantity in the tank up to the final volume prescribed for the syrup batch. This volume determination can be performed by using a calibrated dipstick or sight glass. (Load cells can also be used if such a luxury can be justified and afforded.)
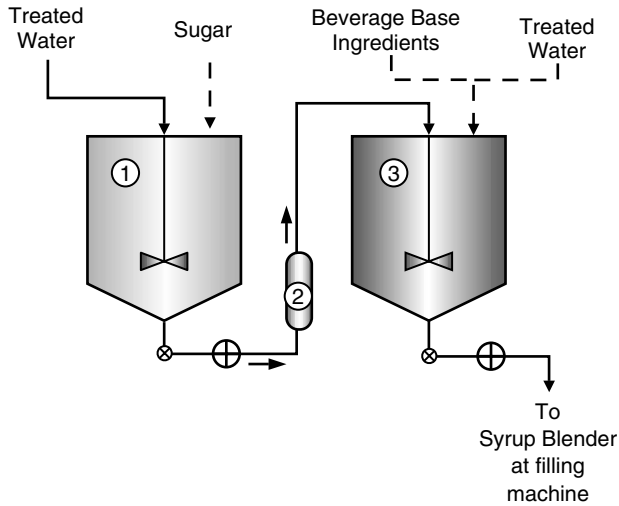
FIGURE 9.1 The standard syrup-making process.

After topping up with the treated water to the final batch size volume, the agitator is restarted, and the syrup is mixed for approximately 10 to 15 min. The agitator is stopped, and the syrup is allowed to deaerate for 1 to 2 h. At this stage, the syrup can be referred to as final syrup, as it now contains all the required components and is at the prescribed volume for the batch. It is ready for use in filling at the bottling line, provided, of course, that it passed all the required quality control (QC) tests.

Deaeration and final quality control testing are conducted before releasing for filling.

This operation of final syrup preparation was referred to in the title of the chapter as the "heart" of the overall carbonated soft drink manufacturing process. I called it so, because it is in this final syrup preparation stage where all of the beverage's key components are measured out, added, and mixed into the syrup in the correct manner. It is the stage in which the prescribed quality parameters for the final beverage are built into the product and checked for conformity. Well-prepared final syrup will offer the filling line no problems in filling final beverage as far as can be related to syrup quality. Good final syrup will make a good final product. The final syrup can be likened to a cake mix. A cake will flop, regardless of correct oven conditions, if the cake mix was not prepared correctly.

WORKING MODEL OF FINAL SYRUP PREPARATION

Throughout this chapter, for discussing the syrup-making technique, I will make use of a mockup lemonade beverage formulation as a working model. For convenience sake, I chose the formulation volume of this lemonade final beverage as 10,000 liters. The formulation and control standards for the 10,000 liters of this relatively simple lemonade product are given in Table 9.1. The data in Table 9.1 normally form part of an official authoritative document containing the manufacturing instructions for the final syrup preparation. These will be referred to as the final syrup mixing instruction (or mixing instructions, for short).

TABLE 9.1
Lemonade Formulation Working Model

<table>
<tr><th colspan="3">Final Syrup Formula</th></tr>
<tr><th>Ingredient</th><th>Unit of Measurement</th><th>Quantity</th></tr>
<tr><td>Treated water</td><td>Liters</td><td>680.000</td></tr>
<tr><td>Sugar</td><td>Kg</td><td>1021.340</td></tr>
<tr><td>Sodium benzoate</td><td>Kg</td><td>3.000</td></tr>
<tr><td>Citric acid anhydrous</td><td>Kg</td><td>12.000</td></tr>
<tr><td>Lemon–lime flavor</td><td>Kg</td><td>1.000</td></tr>
<tr><td>Treated water to final volume</td><td>Liters</td><td>As required</td></tr>
<tr><td>Final volume</td><td>Liters</td><td>1666.667</td></tr>
</table>

Controlling Standards

Water-to-syrup ratio: 5:1

Final syrup volume: 1666.667 l

Final beverage volume: 10,000 l

Specification	Syrup	Final Beverage
°Brix at 20°C	50.50 ± 0.20	10.00 ± 0.15
Carbonation (gas volumes)	—	4.00 ± 0.20
Acidity (as % citric acid anhydrous m/v)	0.72 ± 0.02	0.120 ± 0.02
Sodium benzoate (mg/l)	1800	300

Syrup-room equipment and how it is used can vary from plant to plant. For the purpose of this exercise, we will assume that treated water is measured out by a flow meter and that the final volume of syrup in a tank is measured by means of a calibrated sight glass connected to the syrup tank. Using this lemonade working model as a typical example, we will now proceed to discuss, step by step, the key issues of the syrup-making technique.

SIMPLE SYRUP

The first syrup prepared is called simple syrup, as it contains only sugar and water.

A quantity of 680 liters of treated water is metered out into a 2000 liter simple syrup tank, and the agitator is started. The required quantity of 1021.340 kg of granular sugar is then added to the treated water. This is usually done through a suitably sized screen in order to remove any foreign matter (sometimes referred to humorously in our jargon as "nuts and bolts") or caked sugar in large pieces. The latter, if present, needs to be crushed and added back to the tank in order to attain the target Brix of the final syrup. (Alternatively, the caked sugar can be replaced with other free-flowing sugar.)

The mixing time to completely dissolve the sugar depends on its granular size, the water, and ambient temperatures. Roughly, this should not take more than half an hour. The quantity of treated water stipulated in this mixing instruction is

such that the formulation quantity of sugar dissolved in it will result in a simple syrup around 60°B at approximately 1324 liters in volume. This will allow for the addition of about 343 liters treated water that is required for dissolving some of the beverage base ingredients; rinsing out flavorant containers; flushing out the simple syrup tank with water; and, most importantly, for topping up to the final target volume of the final syrup, 1666.667 liters, at 50.50°B. If more treated water was used in this first step of simple syrup preparation, there might not be "space" for these additional quantities of treated water.

Many a novice in syrup making sometimes ignore strict adherence to the stipulated treated water quantity in the mixing instruction. After adding the beverage base ingredients, rinsing out containers, etc., they find themselves in the embarrassing situation of having overshot the final syrup volume mark of 1666.7 liters. What needs to be done in such cases is another story.

As the first quantity of treated water is critical, it should be measured out with some degree of accuracy. The prescribed quantity of 680 liters should not be exceeded. However, it is permissible to use a few liters less than this amount, as it will not make any difference. The final syrup will be topped up, in any case, with some treated water to the target final volume.

When all the sugar is dissolved, and after the simple syrup passed a few prescribed QC tests such as taste and appearance, it is ready for pumping over to the final syrup tank. This is where the main action takes place. Before proceeding with the steps in the final syrup preparation process, another item related to simple syrup preparation requires mentioning. This is the bulk simple syrup option.

BULK SIMPLE SYRUP

The simple syrup prepared as described above is for the single batch of final syrup required for the 1000 liters of lemonade beverage. For batches of final syrups of other beverage flavors produced by the bottling plant, this procedure would need to be repeated using other sugar quantities specified in the mixing instructions of these products. A simple syrup would need to be made separately for each planned final syrup batch. For each batch, the water would need to be measured and the sugar weighed and added to the simple syrup tank. This would also require a mixing time to dissolve the sugar. Quality control testing on each simple syrup batch would need to be conducted.

Technical management of carbonated soft drink operations long ago recognized the tedious repetition involved in individual simple syrup preparation for each relatively small final syrup batch. They were also aware of the time-consumption factor

involved in the preparation of these individual simple syrup batches. This was considered to be a nonproductive way of going about things. As a result, the bulk simple syrup concept was developed, and the classical, traditional way of preparing final syrups was changed.

The bulk simple syrup principle is as follows. Based on the plant's daily or weekly final syrup requirements, a suitably large syrup tank is chosen in the syrup room. For the purpose of our working model exercise, let us say this is a 10,000 liter tank. This tank is used for and dedicated solely to the preparation of 10,000 liters of simple syrup batches at 65°B. Using Brix/density tables, a simple syrup at 65°B works out to contain 0.855 kg dissolved sugar per liter.

For our working model of lemonade, we required 1021.340 kg sugar for the simple syrup preparation. If we had a preprepared batch of bulk simple syrup at 65°B, we could use it to obtain

this required 1021.340 kg of sugar. To calculate how many liters of bulk simple syrup would be required, the simple formula below would give us this figure:

$$\frac{\text{Liters Bulk Simple}}{\text{Syrup required}} = \frac{\text{Kg sugar required}}{\text{Kg sugar per liter Bulk Simple Syrup}} = \frac{1021.340}{0.855} = 1194.550$$

Therefore, in our lemonade working model, if we were on the bulk simple syrup system, all we would need to do is pump these 1194.550 liters of the bulk simple syrup through the polishing filter, into the final syrup tank. In fact, the bulk simple syrup could be prepared by filtering it through the polishing filter into a second 10,000 liter holding tank. This filtered bulk simple syrup could then be directly pumped into the final syrup tank and immediately used for the final steps of the process.

The bulk syrup batch does not need to be made exactly to the 65°B value. As long as an accurate value of the Brix is determined, the amount of liters for a batch of final syrup can always be calculated from the above equation. For the convenience of syrup-room management and operators, a table of kilograms sugar per liter versus Brix values in the range 64.5 to 65.5°B could be prepared from which the appropriate liters of bulk simple syrup required could be easily worked out.

Bulk simple syrup is a source of ready-made "liquid sugar" for numerous final syrup batches.

The advantage of the bulk simple syrup system is that there could always be an immediately available holding stock, in syrup form, of the sugar requirements for final syrup preparation. In our working model exercise, 1000 liters of bulk simple syrup would be able to supply the sugar for about eight batches of lemonade or other similar final syrups.

With adequate plant space and equipment, bulk simple syrup batches could be prepared in parallel with routine final syrup production operations so that no bottleneck out-of-stock situations would occur. Bulk simple syrup has considerable advantages over individual simple syrup preparation, the main ones being increased flexibility and efficiency in syrup-making activities. However, in our exercise, we will continue using the traditional simple syrup system.

FILTERING THE SIMPLE SYRUP

Simple syrup needs to be filtered, as sugar often contains foreign matter particles.

Regardless of whether simple syrup or bulk simple syrup is being used, it needs to be filtered before being transferred to a 2000 liter final syrup tank for further processing. This is because bulk granular sugar for industrial use, packed in 25 kg paper bags or in 1 ton pallet bags, often contains minute amounts of small foreign particles, of special note being the fine black specks of carbonized material (carried over from the refining processes at the sugar mills). Also, other particles, such as minute fibers, specks of paper material, etc., may be present in the bags. These particles do not present any real health hazard, but they are definitely not desirable in the final beverages, especially the black carbonized specks. The latter are very easily noticeable in a bottle of clear or light-colored beverage, even if it is a single speck. Most consumers will not be very impressed with the product and may consider such a bottle as an outright reject. The polishing filter used is of the wound fiber cartridge type, a full description of which can be found in Chapter 5.

After a batch of simple syrup is filtered, the polishing filter housing should be opened, and the cartridge should be inspected for fouling to establish what level of foreign matter is contained in the sugar. After a few such inspections, the level of cartridge fouling found will determine the frequency at which further inspections need to be performed.

After filtering all the simple syrup into the 2000 liter final syrup tank, the simple syrup tank is rinsed with a small amount of treated water that is pumped into the final syrup tank through the

filter to flush out any simple syrup remaining in the lines to the filter and final syrup tank. Let us say that 50 liters of treated water would be required for this operation. Therefore, we would end up with about 50 + 1324 = 1374 liters of syrup in the final syrup tank. This will allow us about 290 liters of additional treated water required later for dissolving the powder parts of the beverage base, rinsing out flavor containers, and topping up to a final syrup volume of 1666.667 liters.

ADDING THE BEVERAGE BASE INGREDIENTS

At this stage of the syrup-making process exercise, we are now sitting with about 1374 liters of simple syrup in the final syrup tank. The next step is to add the beverage base ingredients to the tank and mix them into the simple syrup. The agitator is therefore started.

The sodium benzoate must be the first ingredient added.

It is of extreme importance to note that the first ingredient to be added must be the sodium benzoate preservative powder. The reason for this has to do with the chemical properties of the preservative, which will be briefly explained.

> The actual preserving agent is benzoic acid. However, this material is sparingly soluble in water. Its sodium salt, sodium benzoate, is much more water soluble, which is the reason for using it, and not the acid, as the preservative material. When dissolved in water, the sodium benzoate dissociates and exists mainly in this dissociated ionic state. However, if the pH of the solution is lowered to about pH = 4.5 and below, the sodium benzoate molecule converts to its acid form, the benzoic acid molecule. Being much less soluble, the benzoic acid molecule remains mainly in its undissociated state. This undissociated molecule is the chemical entity that has the antimicrobial properties of the preservative.

If the sodium benzoate powder was introduced into the syrup after the citric acid was added, it would immediately be transformed into insoluble benzoic acid due to the lowering of the pH by the citric acid to well below pH = 4.5. This insoluble benzoic acid forms a thick, white, gelatinous precipitate that creates a milky-white cloud in the syrup as it is being mixed. Not only is this white cloud of gelatinous material undesirable, but also, more importantly, the gelatinous benzoic acid precipitate would not be properly dispersed in the syrup.

If the sodium benzoate is added as the first ingredient, it would, as explained above, dissolve and dissociate quickly and be finely dispersed, at the molecular level, throughout the entire syrup batch. When the citric acid is added afterwards and the pH is lowered, all the now well-dispersed sodium benzoate molecules would convert individually to the antimicrobial undissociated benzoic acid form. No gelatinous cloud would be formed, and the preservative would be very well dispersed in the syrup. This is the reason that, to avoid the forming of the white cloud, the sodium benzoate is the first ingredient to be added when preparing the final syrup.

> This is a cardinal rule that should always be remembered in final syrup preparation and is also applicable to another preservative, potassium sorbate, which is used in some types of still beverages.

The beverage base ingredients are added in a prescribed sequential order: sodium benzoate, citric acid anhydrous, and then the lemon–lime flavor. The sodium benzoate powder is first dissolved in about 25 liters of treated water (warm water, if possible, to aid dissolution). The solution is then poured into the tank through a screen of approximately 250 μm mesh size, in order to filter out any possible caked material, which should, as with the sugar, somehow be crushed and added to the tank. This screening procedure, applicable to all the ingredients used in final syrup preparations, is also, as mentioned before, aimed at identifying any "nuts and bolts" that could be in the ingredient containers.

Ingredients should be screened through a 250 μm sieve.

This same procedure is adopted for the citric acid powder. The liquid lemon–lime flavor is then poured into the tank through the screen. The flavorant container is thoroughly rinsed with treated water to salvage flavor adhering to the container bottom and walls. These rinses are added through the screen into the tank. The syrup in the tank is allowed to mix for about 15 min, and then the agitator is stopped. We are now ready to top up the syrup to the final syrup volume of 1666.667 liters. As the sight glass can only be read to an accuracy of about 2 to 5 liters, we will settle for a rounded off value of 1667 liters as the final volume and dispense with the decimal point.

THE SIGHT-GLASS PROBLEM

Sight glasses are sometimes used incorrectly.

Before proceeding to the next step of topping up the syrup to the final volume of 1667 liters, I will discuss an issue related to the use of sight glasses for determining the final volume marks to which syrups are topped up with treated water. In fact, it relates to any reading taken on a sight glass attached to a syrup tank as the device for determining volumes in the tank.

A sight glass is a narrow tube made of clear transparent material, usually glass, but another less hazardous material, such as acrylic polymer, Perspex™, or even rigid clear transparent plastic tubing, is preferred. The tube is fixed in an upright perpendicular position and is connected by a narrow pipe to the syrup tank outlet pipe (see Figure 9.2). Note that in the schematic drawing in Figure 9.2, the sight glass is presented out of scale in diameter size for illustrative purposes. Initially, the sight glass is calibrated in the following manner. The connecting valve A is turned into open position with valves B (for sight-glass drainage) and C (for delivery of syrup to the filling machine) closed off. By means of an accurate certified flow meter, an initial volume of water (e.g., 100 liters) is pumped into the syrup tank. Some of the water entering the tank will flow through the connector pipe and into the empty sight glass, where its level will be noted. Usually, the sight-glass tube will be partially encased in a protective metal casing. This level is marked off on the casing as the 100 liter level of the tank.
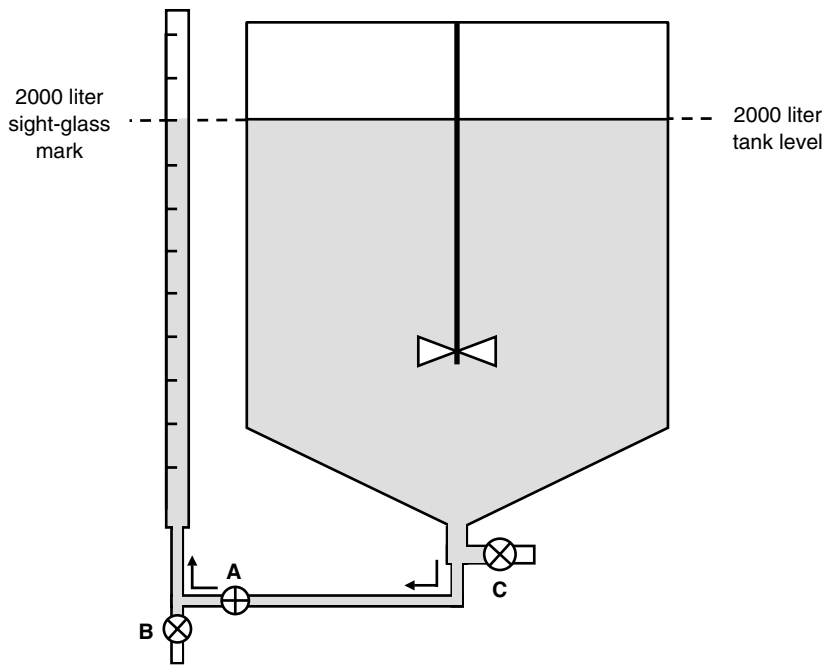
FIGURE 9.2 The syrup tank and sight glass

Consecutive 100 liter volumes are individually pumped into the tank. After each additional 100 liters volume is added to the tank, the level of the water will rise to a higher level in the tube. This is marked off on the sight-glass housing as the accumulative total volume of water in the tank. Thus, the second mark will be at 200 liters. This procedure is repeated until the highest required volume level is reached in the tank, e.g., 2000 liters.

This will result in a sight-glass housing graduated with twenty, 100 liters marks along the length of the sight glass. With a tape measure, the intervals between these 100 liter graduations can be measured and subdivided into lower volume units, e.g.,

How a sight glass works.

10 liter graduation marks. The size of these subdivision graduations would depend on the required operational accuracy for syrup level measurements as well as on the degree of accuracy at which a regular syrup-room operator could clearly visually distinguish them. This then would be a calibrated sight glass ready for use in the syrup room. It can now be used to determine liquid levels in the tank.

A sight glass works according to a simple physics law that many of us probably learned in high school in a demonstration using the famous Pascal vases. The law says that when interconnected vessels are filled with a liquid, the levels of the liquids will be at the same height, regardless of the shape or size of the vessel.

In our syrup-room scenario, the final syrup tank and the sight glass are the two interconnected vessels of different shapes and sizes. When the tank and sight glass are interconnected by opening valve A, syrup from the tank is allowed to flow into the sight glass. According to this law, the levels in both the tank and the sight glass will be the same.

The hydrostatics principle of the Pascal vases applies only if the liquid in the two vessels is the same, as was the case of the water with which the sight glass was calibrated. However, if the two vessels contained two different liquids with different densities, the same-height levels principle would not apply. This is because the heavier liquid would exert a greater hydrostatic

For a correct reading, the sight glass and the tank must contain the same liquid.

pressure and, in effect, push the lighter liquid up to a higher level than that of the heavy liquid.

This is the sight-glass problem to which this section of the chapter is dedicated. Usually, during a level measurement in syrup preparation operations, the sight glass will contain the same syrup liquid as that in the tank that is being measured. If afterwards some more water is added to the tank and mixed into the syrup (e.g., for topping up to final volume), the syrup will be diluted. Its Brix will drop and so will its density. If the connecting valve to the sight glass is open (or will be opened later, it makes no real difference), some of this new lower-density syrup will flow into the sight glass and raise the level therein. There is virtually no mixing taking place in the sight glass other than that due to a negligible amount of diffusion at the interface between the new low-density syrup at the bottom of the tube and the original higher-density syrup above it. To all intents and purposes, the syrup in the sight-glass tube can be taken to be at its original Brix and density, as before the water was added to the tank. This density is higher than that of the syrup in the tank to which water was added.

This end result implies that the level of the heavier syrup in the sight glass will be lower than that in the syrup tank. Therefore, a sight-glass reading of this level as being that of the syrup in the tank would be incorrect.

This end result would also be true of a case where instead of syrup in the tank as described in the previous example, there was water to which, for example, sugar was added for simple syrup preparation. If the treated water added to the tank was

The end result, briefly stated, is that we would have a case where the two vessels have liquids of different densities. The physics law of "same level height" will not apply.

measured by the sight-glass method, the latter would have water in its tube. After the sugar addition, the resultant simple syrup solution would, in the tank, have a much higher density than the water

in the sight glass. The level of the less-dense liquid in the sight glass would, as opposed to the previous example described, be at a higher level than the heavier liquid in the tank. Again, the tank volume reading taken from the sight glass would be erroneous.

If I managed to confuse the reader, then Figure 9.3 might be of some further assistance. Figure 9.3 shows three situations. In situation A, the tank and the sight glass contain the same syrup at a nominal Brix value of 55.0. The same-height level principle applies because the density is the same in both. The syrup in the tank is at the 1667 liter level and is also at the 1667 liter calibration mark on the sight glass. All is well, and there is no problem.

A sight glass containing syrup with a different density than that in the tank will not show the true level of the syrup in the tank.
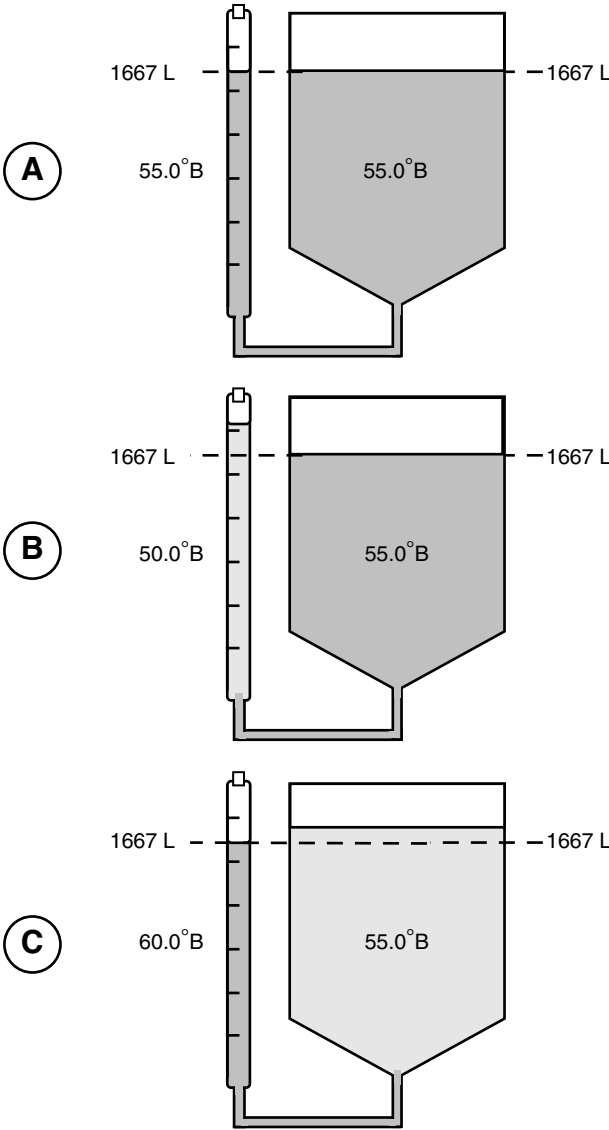
FIGURE 9.3 The sight-glass reading problem.

In situation B, the syrup in the sight glass is at a lower Brix value of 50.0. It is less dense and therefore lighter than the syrup in the tank. It will be pushed up in the sight glass to a higher level than the 1667 liter mark due to the greater hydrostatic pressure of the heavier syrup in the tank. (This is very much like a barometer, in which the mercury is pushed up when the barometric pressure increases.) Such a situation could occur when there is water in the sight glass when simple syrup is prepared.

In case C, the reverse is demonstrated. The higher syrup at 60.0°B in the Brix sight glass will push up the level in the tank syrup. This could occur in the case of topping up a syrup batch to final volume with added water to the tank — the 1667 liter level would be considerably overshot.

This sight-glass problem, which could now be called the "sight-glass error," is not always taken note of in syrup preparation operations. It leads to many incorrect final volumes and out-of-spec syrup Brix values, some of which can be serious. These could affect final beverage quality and could also be related to inexplicable variances in sugar, syrup, and final product yields.

In cases where the potential sight-glass error is taken into account, the syrup-room operators, in a topping up to final volume operation, follow the "golden rule," which should be stipulated in the mixing instructions in some wording or other saying, as follows:

The golden rule for sight-glass readings.

Before any sight-glass reading is taken, the sight glass must be closed off from the tank connection and its contents must be drained and then refilled with the syrup to be measured.

Topping Up to Final Volume

Returning to the lemonade final syrup preparation exercise, we reached the stage where all the beverage base ingredients were added to the simple syrup. In this process, some treated water was used and was also added to the tank. The syrup was agitated sufficiently to disperse the ingredients well in the syrup.

Topping up to final volume is one of the most critical steps.

It would seem that all that is left to do is simply top up the syrup in the tank with treated water to the final volume mark, using the 1667 level mark on the sight glass. However, this is not the case. We learned about the potential sight-glass error that must be avoided. How do we go about topping up the syrup to its final syrup volume of 1667 without falling into this erroneous sight-glass reading trap? There are several ways to do this, but they are all merely variations on the same theme as the one I would recommend here.

In our exercise up to this stage, we did not yet use the sight glass, so let us assume that we kept the connecting valve to the tank closed, and the sight glass is therefore empty. (If it contained some rinse water from a previous cleaning procedure, this should be drained and the drain valve reclosed.) The connecting valve is now opened, and the syrup is allowed to fill the sight glass. We then note the syrup level in the sight glass. We need this level reading in order to calculate how much topping up water will be required to reach the final syrup volume of 1667 liters.

Note: Whenever a sight-glass level reading is taken, the agitator in the tank must be turned off, because the mixing turbulence in the syrup tank will cause the syrup level in the sight-glass tube to bob up and down a few centimeters, making an accurate reading difficult. Also, the vortex that may be formed by the agitator will displace some of the syrup volume in the tank, thus raising the level in the tank as well as in the sight-glass tube.

Let us assume in this exercise that the sight-glass reading taken is 1434 liters. A simple subtraction calculation (1667 – 1434 = 233) indicates that we need to add 233 liters of treated water to reach the final volume of 1667 for this batch of lemonade final syrup. At this stage, we also take a Brix reading of the syrup in the tank. We find this to be 57.0°B. This Brix value is required for a purpose explained later in this section.

In our exercise, we have the luxury of treated water addition using a flow meter, so all that is required is to meter out this volume of water into the tank. Before doing so, we must decide whether we are going to leave the sight-glass connection opened with the tube still containing syrup or close it and drain the syrup from the tube.

It makes no difference what we decide, because the sight glass is going to be drained in any case at some later stage in order to confirm that the final topping up volume of 1667 was attained. This draining operation will be necessary, because the sight-glass tube will contain syrup with a higher density than that of the finally topped up syrup, to which the 233 liters of treated water was added. This will be true whether we leave the sight glass connected to the tank or we close the connecting valve.

This required draining operation was the conclusion of the sight-glass problem study in the previous section of this chapter.

We decide to leave the sight-glass valve open, if only for the simple logical reason of not needing to drain it twice — once at this stage and again for the final volume reading after the topping up with treated water. The agitator is now turned on, and the 233 liters of water is pumped into the final syrup tank. The sight-glass connecting valve is then closed, and the syrup is drained from the tube by opening the drainage valve.

Another point that needs to be noted here is that the syrup volume in the sight glass is part of the total syrup volume indicated. If the sight-glass tube is of a relatively large diameter, and if the reading is taken at the upper levels of the sight-glass tube, as is the case in the present topping up operation, then this syrup volume in the tube can be significantly large enough to warrant that the tube contents drained be added to the syrup in the tank. This is because its sugar content contributes to the syrup Brix specification, and of equal importance, sugar will not be wasted.

A full sight-glass tube, if wide enough, could contain about 10 liters or more of syrup. If this syrup is not added back to the final syrup tank, in a plant making a good few hundred batches of final syrups per year, this would amount to thousands of liters of high-Brix syrup that would be literally drained to waste.

The drained syrup is collected (in a clean bucket or similar stainless steel vessel) and added back into the syrup tank. The syrup is mixed for about 15 min more to disperse the added drained sight-glass syrup. The agitator is then switched off.

The next step is to verify that the syrup, now referred to as final syrup, is at the target final volume of 1667 liters and that it is also at the final syrup Brix target of 50.50°B ± 0.20°B. Following the golden rule mentioned before, the sight-glass connecting valve is opened to allow its tube to be filled with the final syrup from the tank. With the gush of syrup into the sight glass, the column of liquid in the tube will bounce up and down for a few seconds. When the syrup in the tube settles down and is motionless, the reading on the sight glass can be taken and recorded as the final volume of the final syrup.

If it is our lucky day, this will be very close to the 1667 mark. If we are still lucky, a Brix determination will result in a value within the prescribed specification tolerance range of ±0.20°B from the 50.50°B target value.

I made the above remark seemingly in a joking manner, but then someone famous once remarked that many a true word is spoken in jest. There is much that can go wrong in a final syrup preparation process that can affect the target of the process, which is a syrup batch at the correct final volume at the right Brix.

I will name a few of these that randomly come to mind:

- Incorrect indicated weight content of the sugar bags (if these bags are used as the main means of measuring the prescribed sugar weight)

- Faulty flow meter for the treated water measurement
- Calculation error when converting bulk simple syrup to sugar content
- Inaccurately calibrated sight glasses
- Incomplete homogenous syrup due to faulty agitation equipment
- Excessively high or low ambient temperatures affecting tank volumes due to metal expansion or contraction as well as their similar effects on treated water and syrup volumes
- Losses of syrup due to unnoticed leaks in pipe connections and valve seals
- Undrained treated water remnants at the bottom of the tank or in the piping lines after a cleaning operation
- The same as above for remnants of undrained syrup from a previous batch of the same product flavor

Most syrup-room operators and supervisors, especially veterans with years of experience, develop an eye for things that can go wrong with a syrup batch before it is topped up to final volume. Thus, most of the items mentioned above are usually detected early enough to take corrective actions to avoid defective final syrup preparation.

THE TOPPING-UP WATER AND FINAL BRIX CALCULATION

The most critical stage at which the syrup-making process is vulnerable to mistakes that are very difficult to correct is at the step of topping up the batch to the final volume. Overshooting

Final syrup is a high-cost item.

the prescribed final volume or arriving at the target Brix before reaching the final volume level are the most common threats involved in this step.

In our lemonade syrup exercise, we used a nominal batch final syrup volume of 1667 liters for a bottling run of 10,000 liters of final beverage. In a relatively small soft drink business, dumping of a substandard batch of this size of syrup would by no means be a considerable loss.

In large-volume soft drinks operations, the final volume batch sizes of syrups could very well be over the 20,000 to 40,000 liter level, especially for the high-sales-volume beverage brands. Dumping a defective batch of such volume magnitude is inconceivable. The sugar cost alone in such batch sizes could amount to as much as US$15,000. With the added costs of the other ingredients, especially the flavorants, this raw material cost could easily reach the US$20,000 level.

Recognizing the financial risk involved in incorrectly topped up final volumes, as well as the accompanying quality defects, many large soft drink organizations as well as some smaller ones use a final volume topping up procedure that could be called the "topping up to final volume Brix" method.

"Insurance" against incorrect topping up to final volume.

Basically, the principle of this method is to add treated water to the batch to roughly 100 to 200 liters below the prescribed final volume level for the syrup. An experienced syrup-room operator can roughly estimate this 100 to 200 liter lower level (even by the reading on a sight glass not containing the same syrup as is in the tank). When this level is reached, the incompletely topped up syrup is mixed thoroughly and checked for Brix. The exact level volume of the syrup is then determined (by draining the sight glass and then refilling it with the syrup in the tank).

Knowing this exact volume of syrup in the tank as well as having its Brix value, a simple calculation can be performed to establish how much more treated water needs to be added to

the tank's syrup to attain the target Brix of that particular syrup product. In fact, technical management of some companies using the topping up to Brix method prepare and supply the syrup room with individual tables indicating the additional water required. These tables may vary in their formats from company to company, but in principle, they are the same. They indicate the additional treated water volumes required at specified pre-topping-up syrup tank levels for different standard batch sizes based on the expected Brix values of the syrup at those pre-topping-up volumes.

In other words, using our lemonade syrup as an example, the table will show the syrup-room supervisor that for 1560 liters of untopped-up syrup at 53.10°B, he or she must add 100 liters of treated water to bring the syrup to the specification Brix value of 50.50°B ± 0.20°B. In most cases, if the syrup was prepared correctly, this indicated added water quantity will bring the batch very close, if not exactly, to the prescribed 1667 liters of final volume specification. In this lemonade topping up example, the final volume will be 1560 + 100 = 1660 liters, instead of the 1667 liters stipulated in the mixing instruction.

> The final syrup volume obtained by the treated water addition indicated in the table is the volume at which the final syrup is left at and later used in beverage filling — not the prescribed 1667 liters. This is why it is called topping up to Brix and not topping up to volume.

As mentioned before, the calculation to determine this volume of additional treated water required to attain the correct syrup Brix is relatively simple, and the tables can be prepared by using it. However, before demonstrating how this calculation is used, I wish to make one more comment about the topping up to Brix method.

I used this topping up to Brix method when working in or managing syrup-room operations (many years ago) as well as when compiling mixing instructions for syrup-room operations at present. In these mixing instructions, I used it with a slight modification, which I think could have an enormous advantage. My rationale is the following: Why perform the calculation at 100 to 200 l below the specified final volume of the syrup? Why not do the calculation at a syrup volume well below the target final volume mark?

If, arithmetically, a calculated figure of additional water does not bring the final volume reasonably close to the theoretical prescribed volume, this indicates that something is very wrong with the batch. With a calculation performed on a much lower pre-topping-up level, one has much more unused batch volume to play with for corrective action, if such is at all possible. My recommendation is to do the calculation on the syrup at the stage just after the addition of beverage base ingredients is completed. Below is the formula for this calculation and how it is applied to our lemonade syrup at the stage of completed beverage base ingredients addition.

> For the purpose of this calculation demonstration, I will remind the reader that at the stage we were at in the exercise, the following was the state of affairs:
>
> There are 1434 liters of syrup in the tank.
> This leaves a theoretical balance of 233 liters of water to be added to reach the final volume of 1667 liters of syrup at 50.50°B ± 0.20°B.
> The Brix reading of the syrup is 57.0°B.
> The sight glass contains the same syrup that is in the tank.

We will now, using these data, calculate how much additional treated water is required to bring this syrup to the target Brix of 50.50°B ± 0.20°B, regardless of what final volume will result from this calculation, as this is a topping up to Brix calculation and not a topping up to final volume calculation. The calculation is as follows:

$$\text{Liters additional water required} = V \times D \times \left(\frac{B}{TB} - 1 \right)$$

where

 V = volume of syrup in final syrup mixing tank = 1434;
 B = Brix of syrup in final syrup mixing tank = 57.0;
 D = D20 of syrup in final syrup mixing tank (at Brix = 57.0) from tables = 1.26797; and
 TB = target Brix of final syrup in final syrup mixing tank = 50.50.

By entering these values in the formula, we will calculate the required treated water topping up volume in liters. The calculation is as follows:

$$\text{Liters additional water required} = 1434 \times 1.26797 \times \left(\frac{57.00}{50.50} - 1 \right)$$

$$= 1818.3 \times (1.1287 - 1)$$

$$= 1818.3 \times 0.1287$$

$$= 234 \text{ liters}$$

Therefore, 234 liters of water are required for topping up to a final volume at which the Brix of the syrup will be 50.50°B. This final volume will then work out at 1434 + 234 = 1668 liters. This agrees with the theoretical and specified 1667 value.

How does this calculation provide "insurance" against incorrect topping up to final volume?

What does this tell us? It tells us that all is well with the syrup-making process up to this stage. The sugar content is correct, and our final volume will be only 1 liter above the theoretical 1667 liter mark. If it was about 5 liters over or under the theoretical volume of 1667 liters, it would tell us that something is slightly amiss, but the syrup could still possibly be released to production for bottling without serious adverse effects on the final beverage quality.

If it was much higher or lower, then something very serious is wrong. We could then, without yet topping up the syrup to any final volume, investigate the matter. We could, for example, taste the syrup as a reconstituted RTD beverage at the final beverage Brix specification of 10.00°B and see if we could detect an unusual acidity or flavor level. We could test the syrup for acidity content — perhaps the citric acid was not measured out correctly and is the cause of the syrup being higher or lower in solids content than it should have been.

A thorough methodical investigation would usually reveal the cause. If revealed, the batch could, in most cases, be corrected within the ample 234-odd liter "space" to final volume. In conclusion, the topping up to Brix method gives us a little bit of insurance against the likelihood of preparing Brix-defective final syrups. This could sometimes happen by "blindly" adding topping-up water to the prescribed final volume.

RELEASING THE SYRUP TO PRODUCTION

After topping up to final volume, samples are taken for specified quality testing. It is recommended that two samples be taken — one from the top of the tank and one from the bottom. This is

Last checks before releasing a batch for filling final beverage.

to confirm that the syrup was mixed homogenously. A Brix test with identical results for both samples will do this. If the Brix results are significantly different, i.e., more than 0.1°B apart, the syrup should be given a 10 min mix with the agitator, and then another two samples should be tested.

If results still differ, then the cause must be found. Many times this difference in results is due to improper sampling of the bottom sample. The sampling point is often at the end of a lengthy piece of piping from the bottom of the tank. It can contain incompletely mixed syrup trapped in the piping on which the agitator had no mixing effect. The solution to this problem is simple. About 20 to 30 liters should be drained out into a vessel before sampling, and the drained syrup must be returned to the tank. This should be a standard procedure before sampling from the bottom of a tank.

Another test, which is highly recommended, is the standard beverage test. From the sample tested for Brix, 50 ml of syrup is added to 250 ml treated water (the 5:1 water-to-syrup ratio) in a 300 ml clear bottle. The bottle is shaken to mix the water and syrup into a (noncarbonated) final beverage. This is tested for taste and appearance, and any other prescribed tests are completed using this sample. This final beverage sample can also be tested for Brix to confirm the target Brix chart that may be provided for the filling operation (see Figure 6.2).

Having passed the prescribed QC testing, the final syrup is allowed to stand for approximately 2 h to allow it to deaerate. After deaeration, the final syrup can be released to production for filling final beverage. In general, final syrup may be stored for 24 to 48 h prior to bottling, depending on its "sensitivity" grading. Juice-containing syrup, for example, is considered highly sensitive (to microbial growth) and should be used within 24 h after preparation. Our lemonade syrup may be kept up to 48 h, but the sooner it is used, as for all final syrups, the better.

SIGHT GLASS VS. DIPSTICK

Which volume measuring device should be used?

In syrup making, taking accurate level readings of the syrup in tanks is an essential part of the process. In our described lemonade syrup exercise, we used a sight glass to measure these syrup volumes. We came across the phenomenon of the sight-glass error. In order to address this issue, seemingly tedious time-consuming draining and refilling of the sight glass was required. What alternative syrup-quantity measurement equipment could be used in the syrup room?

An ideal alternative would be to have the tank on load cells. Not only can a load cell be much more accurate and easier to read, but it also measures in mass and not volume. This makes life even easier for the syrup maker, as there would be no need for volume-to-mass conversion calculations often required in the syrup room.

Load cells are much more costly than sight glasses and are considered a luxury by most soft drink companies. However, when affordable, the load cell is probably the best quantity measurement device for the syrup-making process.

The dipstick is commonly used as an alternative to the sight glass.

An alternative measuring device, the dipstick, has been and is still sometimes used as the cheapest and simplest device for measuring syrup levels in tanks. The dipstick is a long flat strip of stainless steel suspended from the tank manhole or top rim into the syrup. It is initially calibrated by means of a water flow meter, in much the same way as a sight glass, into liter-volume graduation marks cut into the metal. By means of these marked graduations, the level of the syrup, into which it has been "dipped," can be read by the syrup adhering to the metal, much like when testing the oil level in a car engine. When topping up syrup to a certain level in the tank, the target graduation is keenly visually observed. When this mark is reached, the topping-up treated water pump is stopped. Sometimes, a strip of clean food-compatible material (such as a rubber band) is fixed around the target graduation to improve the visual observation, especially in large-size tanks, the inside of which can be quite dark.

Why have I preferred to use a sight glass in our lemonade syrup-making exercise? Sight glasses and dipsticks have advantages and disadvantages. It is up to syrup-room management to decide on the device that suits their conditions and requirements. These advantages versus disadvantages are discussed briefly below.

With the dipstick, one does not have to deal with the sight-glass error, which seems at first to be a great advantage insofar as the tiresome draining and filling of the sight-glass tube is concerned. However, use of the dipstick also involves some tiresome tasks. Before each dipping measurement, it has to be wiped clear of the syrup in which it was previously suspended, again, much like what we do when checking the oil level in the engine of a car, and for the same reason — to make sure there are no misleading syrup marks on it. In a small tank, this is no problem. But, when it comes to measuring syrup in a 30,000 liter tank, the dipstick becomes a heavy cumbersome piece of metal.

Also, with such a tank size, when checking the syrup level in a topping-up exercise, the target level graduation cannot always be seen clearly. This again involves a repetitive hauling out and dipping in series of actions to avoid overshooting the mark as the syrup level slowly rises to the final volume graduation. With a sight glass, all that is necessary, after the single draining and refilling exercise, is to stand by and watch as the level slowly rises in the tube, stopping it at the target graduation.

Large tall tanks require a long dipstick, and it often bends slightly, due to metal fatigue, from the stress of its suspended weight. Such bending obviously skews the initial calibration, leading to incorrect level readings. The only occasion when a sight-glass calibration can become analogously skewed is if the tube used is made from rigid but pliable plastic tubing.

On occasion, a dipstick, especially a large, long, heavy one, can be inadvertently dropped into the tank by the operator while the agitator is on. This can result in a situation of a dipstick wrapped around the agitator. This can also happen if the dipstick gets dislodged from its suspension point on the tank because the turbulence of the agitated syrup is strong. Not only is the unwrapping of the dipstick from the agitator a nasty task to perform, but also the situation may cost the company a new agitator shaft and probably a new motor as well.

A sight glass does not mean by its name that the tube is always made of glass. As a good manufacturing practice (GMP), the rule is that no glass equipment, utensils, etc., should be allowed in the processing areas of a syrup room for the obvious hazard reason attached to accidental shattered glass particles. This applies to sight glasses as well. Therefore, the tubes must be of alternative, nonhazardous, clear transparent material such as types of hard acrylic polymer, polycarbonate, Perspex, or plastic hosing.

When syrup-room operators handle a dipstick, operators' hands will necessarily touch places that will come in contact with the syrup. Although meticulous hand washing is mandatory in the syrup room, such handling of equipment coming into direct contact with product is definitely a potential health hazard to be avoided.

Sight glasses are prone to microbial contamination if they are not drained, cleaned, and sanitized after every batch production. However, as the sight-glass tube is often used as part of the circulating piping of the tank's clean-in-place (CIP) system, it is usually kept in sanitary condition. The above-mentioned advantages and disadvantages of these two syrup-room volume-measuring devices would lead me to a simple general conclusion as to which one to use in a soft drink syrup room.

Dipsticks should be used for small tanks. Sight glasses should be used for large tanks.

BULK RTD PREPARATION

It was already mentioned that many soft drink operations do not use the syrup-proportioning system when filling final beverages. In these operations, final beverage in RTD form is prepared in bulk in a holding tank from which it is transferred to the filling machine when required.

The process for preparation of bulk RTD is, in essence, the same as that of syrup making. The main difference is that the simple syrup with added beverage base ingredients is topped up to a prescribed final beverage volume at the target Brix of the beverage. To all intents and purposes, bulk RTD preparation can also be considered as a syrup-making process.

A TALE OF SYRUP TAILS

In the section in which I delved a bit into the history of carbonated soft drinks and syrup proportioning in old filling machines of the postmix type, I indicated that I have a personal story to tell on this subject. In fact, I was only recently reminded of this story at a retirement farewell dinner of an old friend of mine from the soft drinks industry. At the end of the dinner, after we had a few glasses of wine, a few of us veterans started telling amusing stories of the silly mistakes we made during the courses of our technical careers. One of my friends asked me to tell the story of my quality audit visit to a small, out of the way bottling plant many years ago. At first I did not know what he was referring to, but he soon refreshed my memory with the two-word prompt, "syrup tails." It all came back to me very clearly.

I had just returned to work after a 6-month break backpacking around South America. Things had changed a bit, and I was asked to take up the function of a "traveling chemist," who, among other things, performed the yearly routine quality audits at company franchise bottlers.

In consideration that I was a bit out of touch with things after sailing down the Amazon and crossing the Andes several times, my boss gave me a small backwoods plant as my first assignment. (I suppose he also thought that any damage I might cause would only be to this small independent bottler, and the embarrassment to the company would be minimal.) Apart from performing the routine 2-day audit, it was the function of the traveling chemist to assist the plant with any technical problems it may have. I was, therefore, very eager to prove myself in this new function.

After the brief meeting with the plant owner, I proceeded to the factory production area to start my audit. As I entered the small bottling hall, I found myself facing a conveyor belt transporting filled bottles exiting the filler bowl unit. Even from the distance I was looking from, I recognized the brand and flavor being filled from the color of the beverage in the bottles, but something immediately looked terribly wrong to my trained eye. The liquid in the bottles had the right color, but only halfway up the bottle, above which it diminished in intensity toward the neck, where it was almost clear and colorless.

I approached the conveyor and removed one of such bottles for closer inspection. Not only was the liquid almost completely colorless at the neck, but it also had numerous streaks of color that swirled around as I handled the bottle. As I had never seen such a sight before, I suspected that something was terribly wrong with the product being filled. I shouted to the filling line supervisor to immediately stop the machine. He did so without any hesitation (traveling chemists wielded a lot of power in those days) and came over to inquire what the commotion was all about.

I showed him the bottle and asked for an explanation. He looked at me in wonderment, studied me for a few seconds, and then smiled. He said that there was nothing wrong with the product in the bottle because, simply he added, stressing this word, the bottle had not yet been through the "tumbler." On hearing the word "tumbler," I realized in a flash of embarrassment that I was holding a bottle of product filled on a postmix machine. It contained syrup and carbonated water but had not yet been through the case tumbler that mixes the two into the finished final product. What I observed in the bottle were the famous tails of colored syrup that were not yet properly mixed into the water. In my eagerness to do my job, I completely forgot that this small backwoods plant was using an ancient postmix filler. I somehow completed the quality audit but tried to avoid visiting that plant again for the rest of my career.

CHAPTER REVIEW

The system of preparing concentrated syrups for subsequent dilution at the filling machine into final beverage is mainly practiced by carbonated soft drink operations. The dilution of the syrup is achieved by accurate water-to-syrup proportioning equipment. The syrup-proportioning method has definite advantages over filling final product from bulk RTD preparations.

Syrup making is the process in which the main attributes of the final beverage are built into the product. If the process is not performed correctly, this can lead to substandard quality of final product and excessive losses to the company. The key factor in the process is that of attaining the correct final batch volume at the specified Brix value. Accurate weighing out of ingredients and volume measurement are, therefore, essential. The syrup-making technique was discussed in a detailed exercise using a mock lemonade final beverage formulation as a working model.

10 Microbiology — All about the "Bugs"

GENERAL CHAPTER OVERVIEW

Microbiology is the science that studies living organisms of microscopic size. These are called microorganisms, and most of them are so small that they are invisible to the naked eye. In order to see individual microorganisms, each must be viewed through a microscope.

The study of microscopic organisms.

Microorganisms are classified scientifically into numerous diverse groups such as what we commonly call bacteria, yeasts, molds, algae, and viruses, to name a few. There are so many groups and subgroups that the study of each of these is a science on its own. Thus, bacteriology studies the bacteria; mycology deals with the fungi to which group the yeasts and molds belong.

The soft drink industry mainly concerns itself with bacteria, yeasts, and molds. To give even an elementary comprehensive scientific description of the complex biological nature of these microorganisms is far beyond the scope of this handbook. This chapter will, however, attempt to discuss the impact that these microorganisms have on soft drinks, how we handle microbiological matters, and where applicable relevant scientific background is required, this will be briefly described.

A MATTER OF TERMINOLOGY

The term "microbiology," its adjective and adverb derivatives, "microbiological" and "microbiologically," are sometimes considered as unnecessary lengthy tongue twisters. In the soft drinks industry circles, an abbreviated term "micro" has long ago been invented when referring, in speech, to microbiological issues. Thus, a micro lab means the microbiology laboratory, a micro survey is a study of the microbiological conditions in a plant, and a micro-tested sample indicates that a sample was tested microbiologically. I will, therefore, often use the term "micro" in this chapter, for the reader's benefit as well as for my own convenience.

THE MICROBIOLOGIST IN THE SOFT DRINKS INDUSTRY

It was indicated that microbiology is a complex science. This is not to say that other natural or physical sciences are less complicated. What is meant is that micro in the beverage industry, as in all other food industries, is mainly concerned with

A qualified microbiologist is an asset in a soft drink company.

sampling and testing products and processes for evaluation of quality integrity. For correct sampling, testing, and evaluating of results, there are certain basic disciplines and procedures peculiar to micro that are essential for ensuring legitimacy of results and for meaningful interpretation thereof. A technical background in microbiology science is usually required to understand the reasons for these disciplines and procedures. It will also be required to correctly interpret testing results and to decide on necessary action to be taken, when applicable.

This required scientific background is usually not within the ambit of the regular technical management staff of a soft drink factory, whose members are, in most cases, graduates of chemistry

or other related sciences. Even qualified food scientists and technologists, who complete some courses in micro during their education, do not always have all the background knowledge and practical experience of a qualified microbiologist.

So it seems that a qualified microbiologist is a good person to have for any soft drink operation that engages in in-house micro activities. This person, usually at the junior management level, does not need to do all the work him- or herself. Subordinate staff can be trained to do most of the workload, but the microbiologist is there to keep an eye on things, to advise senior management, and to develop and enhance micro-related systems.

> This section, with its issue of micro's esoteric nature and advocating the need for in-house qualified microbiologists should not be seen as an indication of any academic snobbery on my part, for the simple reason that I am not a qualified microbiologist. In my odd 30-yr involvement in the soft drinks industry as a food technologist, I learned much about micro. However, in all cases of perplexing unsolved micro-related problems (and there have been quite a few such problems), I always found it wise to consult with a qualified food microbiologist, whether an in-house person or someone at an outside consultancy laboratory. My reasons for considering micro as a specialized science, as much as it is related to quality control in the soft drinks industry, may become clearer to the reader as we progress through this chapter.

> Notwithstanding all the above, I do surprisingly have one criticism of microbiologists in the soft drinks industry. Often, microbiologists are employed for general junior quality control (QC) management positions. I often found that such persons have serious technical knowledge gaps in basic and general food technology issues, such as sensory evaluation, product development, food-processing principles, factory equipment, and so forth. These people can acquire such knowledge with time and experience. I am referring mainly to young microbiologists employed immediately after graduation or those with very little practical industrial food-processing experience. Still, they are not to blame — it is the employers that should be blamed — for thinking that a microbiology qualification is an equivalent of food technology, chemistry, and biochemistry, etc., qualifications that are much more suitable for the positions to be filled.

WHAT IS MICRO ABOUT?

To answer this question, it will be necessary to learn a little about microorganisms, their characteristics, and the potential damage that they can cause in any food industry, not only in the soft drinks industry. In fact, the soft drinks industry should consider itself somewhat fortunate, as the micro hazards are not as pronounced as those in the meat or fish food industries, for example. Even the dairy industry has micro problems much greater than our own.

MICROORGANISM GROWTH

Microorganisms "grow" by multiplication and not by increasing in size.

Microorganisms are usually microscopic single-cell living organisms. Very much like us, they need nourishment in order to survive and grow. A bacterium or yeast cell does not really "grow" in the sense that it increases its size as a tree does. Rather, it grows a little and then immediately reproduces by splitting into two new "young" cells. These, in turn, grow a little also, and then, within a matter of hours or even minutes, these each split again into two, and the process is repeated until the resultant multitudes of microorganisms virtually run out of food.

The first thing to distinguish in micro terms is that "growth" means multiplication and not increase in size.

This doubling-up type of growth by microorganisms is reminiscent of the well-known story about an ancient Chinese emperor who granted a favored advisor the wish that payment for his well-done job should be the following: a grain of rice

placed on the first square of a chessboard, two grains on the second square, four grains on the third square, eight on the fourth, and so on throughout the remaining squares of the 64-square chessboard. This is a doubling-up operation, and the emperor was astonished to find that in the end he owed his advisor enough rice to cover the entire area of China.

This is what happens with bacterial growth. Bacteria split every few hours, and if allowed to do so, after 24 h, they would reach astronomical numbers from a single cell. In spite of their microscopic sizes, given enough time, this colony of bacteria could in theory cover the planet. Fortunately, this does not occur in real life for two reasons.

Microorganisms can double their numbers in a matter of hours.

One is that they run out of nutrients essential for their continued growth. But even before that, another phenomenon can take place. As living organisms, their life processes create toxins that they secrete from their cells into the surrounding medium in which they are growing. When their numbers reach a certain level, the concentration of these toxins is so great that they literally kill themselves off. This is called the autotoxic effect. To put it simply, they die in their own bodily wastes. However, there is little comfort in this autotoxic effect phenomenon, because usually the microorganisms do enough damage before they reach this stage.

WHAT IS THE DAMAGE?

Microorganisms, like bacteria and yeasts, obtain their nutrients essential for life and growth from the surrounding medium in which they exist. They do this by diffusing these nutrients into their bodies through their cell membranes. Thereafter, the nutrients are metabolized into all the materials required for cell building and growth by multiplication.

Microorganisms are a threat to human health.

Microorganisms, especially bacteria, are usually associated with human illness and disease. These are caused by the bacteria doing damage of different types to the human body, some of which are as follows:

- Secretion of toxins (poisons) into the body tissues and organs
- Interference with normal vital body organ function and biochemical reactions
- Physical damage to body tissues
- Disruption of body internal environment regulating systems

These types of bacteria are called pathogenic bacteria or pathogens, and as such, are of concern to any food-processing operation, as their products could contain and transmit the microorganisms to consumers.

Not all microorganisms are harmful. Some are even useful to humans.

Before proceeding to the damage caused in the soft drinks industry, a special note should be made that of the thousands of species of known microorganisms, relatively few are pathogens. Many exist without doing harm to man or beast, and a few types of microorganisms are actually beneficial to mankind. As an example, all humans contain intestinal bacteria, which help with digestion of our food. Many plants rely on soil bacteria for their growth. Molds are used in preparing antibiotics, such as the famous penicillin. Of course, mention should be made of those special strains of yeasts, which in addition to helping us make bread and cakes, also provide us with the wide array of fermented beverages that many of us so enjoy.

In the soft drinks industry, we are concerned mainly with two categories of microorganisms: bacteria and the yeasts and molds. Bacteria, as a rule, do not cause much damage to soft drink products. Their presence is checked for mainly as an indication of how well the plant is kept in sanitary condition.

In soft drinks, we are mainly interested in bacteria, yeasts, and molds.

If they are detected in unusually high numbers, it means that either we are introducing them by

means of our raw materials, mainly water, or that we are not cleaning our processing equipment clean enough. It can also mean that there are other sources of contamination that were not addressed fully, such as airborne contamination from the nearby environment.

Yeasts and molds are the main causes of product spoilage.

Whatever the source of high bacteria levels in the product or on equipment or in the air, though their presence does not do much damage to the soft drink operation, it does mean that pathogenic bacteria may also be present, and that is a major concern. Yeasts and molds are the reverse to bacteria as far as the soft drinks industry is concerned. They do not usually cause any serious diseases, at most only some slight health discomfort. They do, however, cause product spoilage.

Soft drinks, with their 8 to 13°B sugar content make for an excellent growth medium for yeasts and molds. When the product contains juice or other additives with nutritional value for the microorganisms, this only enhances the favorable growth conditions.

By metabolizing the sugar in the drink, they virtually carry out a fermentation process, which at high enough levels often imparts a repugnant taste or a rotten smell to the product. This process is generally referred to as product spoilage and is the main damage that these microorganisms cause in the soft drinks industry. A spin-off of spoilage is that in clear drinks, the yeasts sometimes impart a cloudy appearance to the beverage in the bottle as well as a layer of sediment at the bottom of the package. Mold spoilage can often be accompanied by suspended filamentous bodies in the beverage, often referred to as "floaters" in QC jargon.

The main potential damage that can be caused by yeasts and molds is general product spoilage, which, in turn, results in consumer rejection. Rejection is based on unsightly visual observation before the package is opened as well as on taste and odor rejection after opening the package. Yeasts and molds do not normally cause any serious diseases, but if a spoiled product is consumed, it could possibly cause nausea and stomach problems in some cases, as is often alleged in consumer complaints of spoiled product.

GENERAL CHARACTERISTICS OF MICROORGANISMS

The three main microorganism groups that concern the soft drinks industry are, as mentioned, the bacteria, yeasts, and molds. They all share common attributes as far as how they are tested for in the micro laboratory and the actions taken to prevent contamination in the factory and products. However, a brief description of the special characteristics of each group is given below.

BACTERIA

Bacteria are very small single-cell organisms of about 0.2 to 2.0 μm in size and are only reasonably visible when seen through a microscope at 1000 and higher magnification (Figure 10.1). They are generally classified by their shapes into four main groups:

- *Cocci*: Round shaped; often linked to each other in chains or clusters
- *Bacilli*: Straight, rod-shaped organisms
- *Vibrios*: Resembling bent rods
- *Spirilla*: Having a twisted spiral shape

To clearly see bacteria with an optical microscope, the bacteria need to be color stained.

Even at high power magnification in the optical microscope, there is a need to color them with a special stain, called Gram stain, to see them more clearly. This method of staining leaves the bacteria a dark blue to purple in color or with a light-red tint. Therefore, bacteria can also be classified according to the Gram stain they retain — Gram-positive for the dark-blue col-
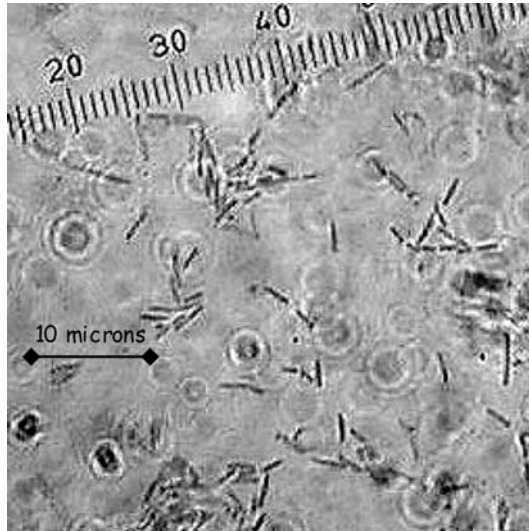
FIGURE 10.1 Rod-shaped bacteria. (Original immersion oil magnification × 1000.)

oration and Gram-negative for the light red coloration. This staining attribute is often used as a key distinguishing parameter in bacteria identification.

Bacteria exist in almost every environment conceivable, in the air, water, and soil. They live in the bodies of animals and plants. They are found on all parts of the globe, from icy polar wastelands to the hot tropical jungles, in the sea, in rivers, and in barren deserts. In fact, there are some scientists who support

Bacteria are found almost everywhere on the planet and in almost all environments.

the theory that life began on Earth from bacteria carried to our planet in cosmic dust particles from outer space. (It is strange that most supporters of these theories do not try to explain how these alleged bacteria developed on whatever outer space source they originally are supposed to have come from.)

Most bacteria depend on oxygen for life, and these are called aerobes. However, some species can live without oxygen and are called anaerobic bacteria or anaerobes. Some aerobes, when oxygen becomes scarce, can convert to "anaerobic mode." When

Bacteria could be considered the hardiest of all life forms.

living conditions become unfavorable, many bacteria are capable of changing their delicate cell membranes into thick walls of highly resistant material. The bacteria become inactive but remain alive in this state, called bacterial spores, until favorable conditions return, upon which the dormant spore becomes active again. In the spore state, the bacteria are also highly resistant to extreme temperatures and harsh physical or chemical conditions.

Bacteria display the ability to mutate into different strains of the same species, which show higher resistance to unfavorable conditions to which its predecessor strains were vulnerable. From the above, it would appear that bacteria represent one of the hardiest and resilient life forms on our planet. It is no wonder that the battle against diseases caused by these microorganisms is an ongoing affair.

Coliform bacteria are tested as an indication of potential pathogen presence.

In the soft drinks industry, disease-causing bacteria, called pathogens, are not frequently encountered. This is because soft drink products do not normally contain all the essential nutrients for rapid and favorable growth, as do other food industry products, such as meat, fish, dairy, soups, sauces, etc. However, add

juice, vitamins, minerals, proteins, plant extracts, etc., to a soft drink, and its vulnerability to bacterial infection and growth will increase considerably.

We still need to be on guard for bacterial contamination in our products, because if bacteria are present in equipment or in products, it can mean that pathogens may be present as well. This is of grave concern, because, though they are inactive and in small numbers, they can be transmitted via our products to consumers and can become a health hazard.

Pathogens can find their ways into the plant and products through raw materials, such as the raw water, from the air in the surrounding area entering the factory, as well as from other sources. In order to address this highly unlikely but still possible potential health hazard of pathogens, we perform a standard test to check for a special group of bacteria called coliforms. In particular, we check for a species called *Escherichia coli* (or *E. coli* in micro jargon). These bacteria are found in the intestinal tracts of animals and humans. Their presence indicates that either there is a sewerage contamination of the water being used, that there is a contamination from the feces of pests in the plant (mice, rats, or even birds — not to mention the stray alley cat) or simply that workers are possibly not washing their hands properly after visiting the toilet.

The presence of coliforms in samples tested means that there could be other specific pathogens present for which we are not specifically testing. Action must be taken discover the exact source of contamination and to eliminate it.

Note: Another potential source of pathogens in the factory can be from sick workers or workers with infectious skin ailments.

Though not all that common, there are some types of nonpathogenic bacteria that can cause spoilage to our products. For these, we check with a test called total count that will be described later. This tests for a broad spectrum of bacterial types and, again, indicates the sanitary state of the plant and the possibility of contaminated raw materials such as water, sugar, and others.

YEASTS

Yeasts are single-cell microorganisms belonging to the fungi group of organisms, which also includes mushrooms, toadstools, and molds. They are usually larger than bacteria, reaching up to about 10 μm in length. Yeasts can grow by cell division like bacteria, but more commonly they multiply by the process of budding, in which the cell wall swells up into a "bud" and eventually breaks off into a new individual cell (Figure 10.2). Yeast cells are found almost everywhere in nature and are usually transported from place to place by air.

Soft drinks containing natural sugars are ideal for yeast growth.

Unlike bacteria, yeasts find naturally sweetened soft drink products ideal for growth, as sugars and other carbohydrates are the yeasts' main source of nutrition. They ferment the sugar into alcohol or other substances releasing carbon dioxide gas. In certain species of yeast, this attribute is widely used commercially in wine making, beer brewing, and in preparation of almost all other alcoholic beverages. Yeasts are also used in bread making, where the released carbon dioxide leavens the bread.

From the soft drinks industry point of view, the yeasts present the greatest product spoilage menace. Yeast-contaminated beverage will usually taste foul and smell rotten. A fermented product can, upon opening its seal, gush out forcefully due to the pressure buildup from the carbon dioxide released into the package during the fermentation process. When excessive, this pressure can result in "blown up" cans and burst bottles. The prevention and elimination of yeast contamination of plant equipment and products is an ongoing activity in the soft drinks industry. The daily testing for yeast presence in samples of all flavors produced is usually a standard requirement of the QC system. The most common primary source of yeast infection is from airborne contamination by yeast spores. For this reason, a basic quality standard in the industry is that soft drink factories should not be established in close proximity to nearby brewing and baking industrial operations.
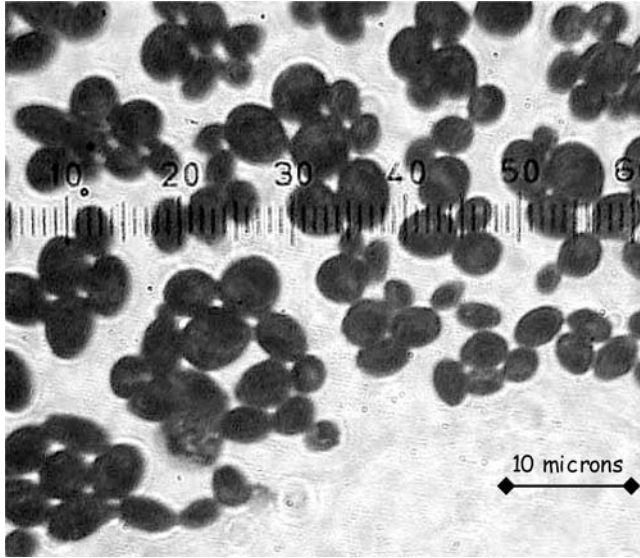
FIGURE 10.2 Yeast. (Immersion oil magnification × 1000.)

Other contamination sources can be from established yeast growths in plant equipment and sites that are inadequately cleaned and sanitized. Yeast-contaminated raw materials can also serve as sources for infection.

MOLDS

Molds also belong to the fungi group of organisms. A mold starts it life cycle as a single microscopic cell spore. Usually airborne, it settles on a favorable growth site and rapidly develops into a network of fine long filaments called hyphae. These grow into a tangled mass of intertwined threads forming the mold body, called the mycelium (see Figure 10.3 and Figure 10.7, item B).

Molds usually grow as a network of fine threads.
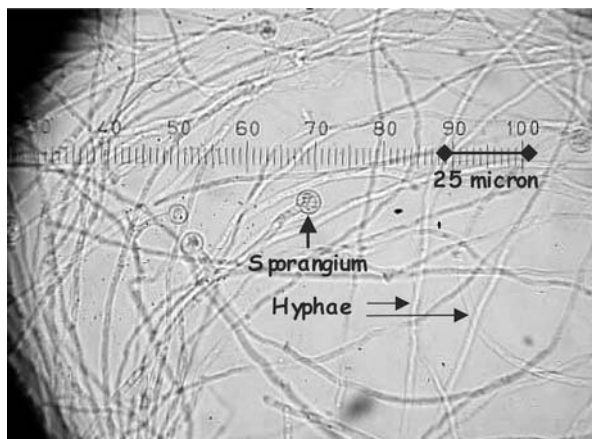
FIGURE 10.3 Mold mycelium. (Magnification × 1000.)

The mycelium grows in size, soon becoming visible to the naked eye as the cobweb-like mold body. At the tips of some hyphae, fruiting bodies called sporangia develop, in which spores are produced for further propagation of new molds. (Most of us are familiar with such mold bodies on stale bread or rotten fruit, the colors of which depend on the mold species.) When ripe, these sporangia split open and release the new spores, which are dispersed by wind or water to new growth sites.

Mold growths in beverages can be very unsightly.

Molds thrive on a large variety of organic substances. Certain species, like yeasts, find sugar-containing beverages very favorable growth sites. They can also cause product spoilage due to fermentation and other enzymatic processes. By far the greatest negative effect on the product, and hence on the potential consumer, is the presence of very unsightly mold body masses in a beverage. These can be in the forms of single large threadlike masses or many smaller ones suspended in the beverage, the latter having been mentioned before as "floaters" in soft drink QC language. These often appear slimy, and this only adds to consumer displeasure.

Like yeasts, many mold species are beneficial to humans, such as those used in many types of cheeses to give characteristic tastes and odors. The antibiotic penicillin was originally derived from a specific species of *Penicillium* mold. Notwithstanding these and other benefits that may be derived from molds, in our industry, they, like the yeasts, are extremely unwelcome due to the product spoilage damage they can do, to the company and brand image damage that can be done, and to financial loss that can be incurred. Molds and yeasts are tested for in a standard test called the yeast and mold test, which will be described later in this chapter.

MICROBIOLOGICAL TESTING

The micro test is used to determine the presence or absence of microorganisms in a sample. The result of the test is the micro count — the number of microorganisms per sample volume, e.g., 10 per 100 ml. As individual microorganisms are not visible to the naked eye, it would not be possible to actually see these 10 microscopic-sized cells in the 100 ml of sample. So, how would we be able to count these 10 microorganisms? Two main testing methods are employed in the soft drinks industry to perform these micro counts, the principles of which are briefly outlined below.

MEMBRANE FILTRATION METHOD

Individual microorganism cells are not visible to the naked eye.

This method is based on the principle of filtering the liquid sample through a very thin membrane made of cellulose material. This membrane has very fine microscopic pores, the diameters of which are much smaller than the sizes of the microorganism cells that are being tested for. Thus, during the filtration of a prescribed volume of sample, any cells present in the sample are trapped individually on the relatively large surface area of the membrane.

The membrane is then removed gently from the filtration equipment and placed on an absorbent pad in a petri dish. This pad was previously soaked with a nutrient broth (also called a nutrient medium), the composition of which is specially formulated for assisting growth of the specific type of microorganisms being tested for. The membrane placed on the pad is gently tapped to make it stick to the pad. The petri dish is then covered and transferred to an incubating oven set at a temperature favorable for the growth of these kinds of microorganisms. The dishes are allowed to stay in the oven for a prescribed number of hours or days.

Single cells are allowed to grow into individual visible colonies that can be counted.

What happens in the oven is as follows. A single microorganism cell that was retained on the membrane will, through the porous membrane, absorb the nutrient medium below it on the pad and start to grow, i.e., to multiply into more cells. As

they are more or less fixed in place on the nonliquid surface of the membrane, the multiplying cells will not be able to move away from each other. As time goes by, the number of cells increases to such an extent that at the site of the original single cell, they soon become visible to the naked eye as a small round "colony." Depending on the type of microorganism, these colonies can be flat or domed, shiny or dull, and of different colors. After the prescribed period of incubation, the colony may reach a diameter of up to 1 mm, and it will be clearly visible to the observer.

This colony-forming process will occur with each single trapped cell on the membrane that can use the nutrient medium for growth. The number of colonies present on the membrane will, therefore, correspond to the number of individual microorganism cells originally present in the volume of sample tested.

> When reporting a micro count, e.g., 10 per 100 ml, most laboratories will express this figure as 10 CFU per 100 ml (CFU standing for colony-forming unit). This is a more sophisticated way of indicating that the count is based on colonies of microorganisms observed and not on a direct microscopic observation of single microorganism cells.

A slight variation of this membrane filtration method uses nutrient agar set in the petri dish instead of the adsorbent pad with added medium. The membrane filter is then placed directly onto the surface of the agar. The colony-forming process on the membrane is the same as that for the adsorbent pad method.

Figure 10.4 through Figure 10.7 show photos of membrane filters with colonies from a bacteria total count test and from a yeast and mold test using the nutrient agar method. In Figure 10.4, the designations A, B, and C indicate the petri dish, the agar medium, and the membrane filter with colonies, respectively. The same is shown in Figure 10.6. Figure 10.5 and Figure 10.7 show magnified sections of the membrane in order to enable the reader to see more details.

Notice in Figure 10.5 that the bacteria colonies are small, flat, and very shiny. This is characteristic of bacteria colonies. Notice in Figure 10.7(A) that the yeasts have a matte appearance (sometimes called dulled), and most of the colonies are domed in appearance, also characteristic of most yeast colonies. Item B in this photo indicates a mold mycelium with its typical fuzzy cobweb-like appearance.

With different nutrient media and incubation temperatures, different microorganisms can be grown selectively.
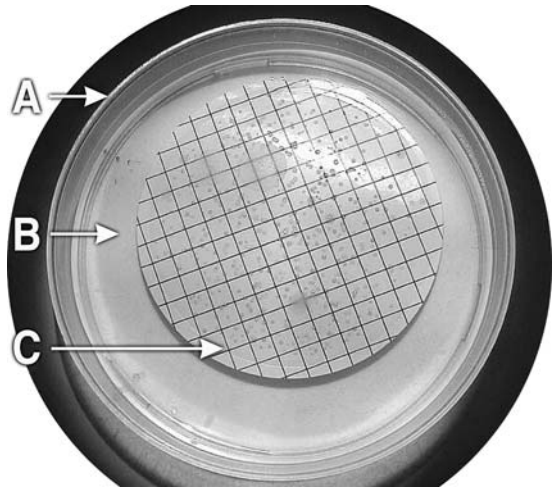
FIGURE 10.4 Membrane of total count with bacteria colonies.
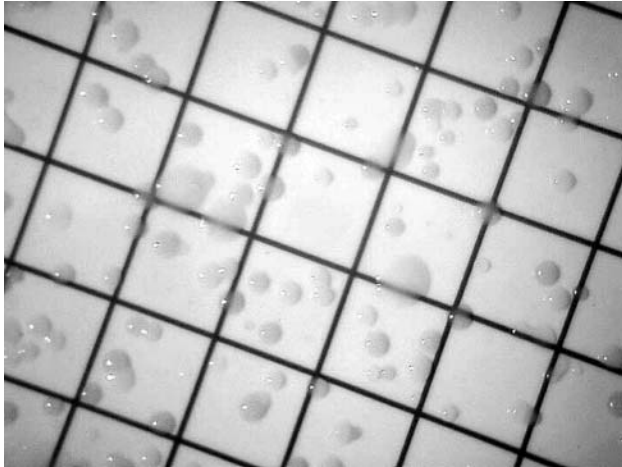
FIGURE 10.5 Magnified section of total count membrane.
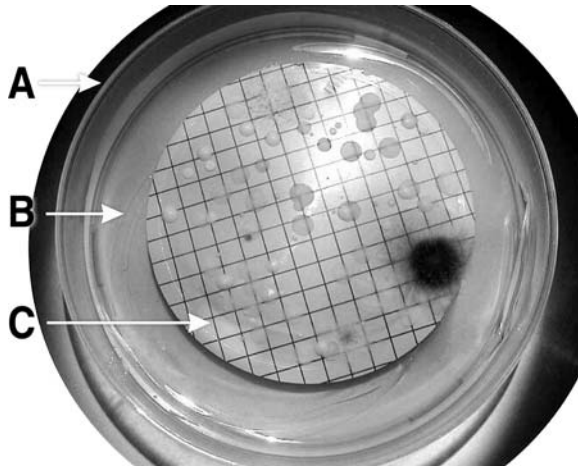
FIGURE 10.6 Membrane of yeast and mold count.
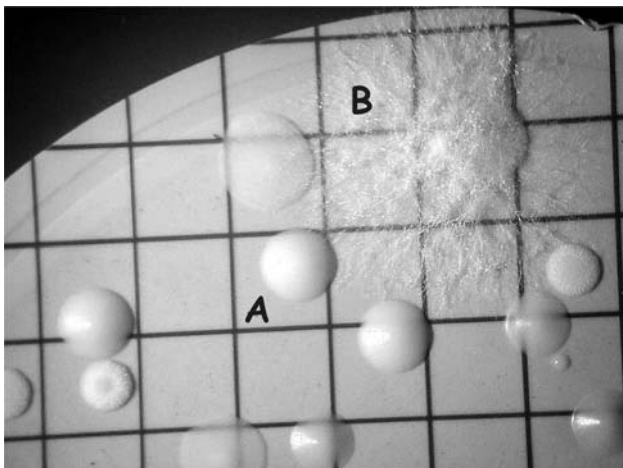
FIGURE 10.7 Magnified section of yeast and mold membrane.

We must remember that the number of colonies on a membrane filter represents only the number of microorganism cells that favored the nutrient medium as a growth source and that found the incubating oven temperature favorable. There may have been other cells trapped on the membrane that did not grow because either the nutrient medium composition was not suitable or the incubating temperature inhibited or retarded their growth.

This is an important aspect of the membrane filtration technique, as with differently formulated nutrient media, one can selectively test for different groups and types of microorganisms. The medium can also be designed to selectively totally inhibit the growth of certain types of microorganisms. For instance, if we want to test for particular types of bacteria that are acid resistant, an acidified nutrient media will inhibit the growth of bacteria not resistant to acidic conditions. Only the bacteria we are interested in will form colonies. The incubating temperature can also be a type-selective mechanism, e.g., yeasts and molds grow at lower temperatures than bacteria.

There are literally hundreds of specialized nutrient media available from suppliers of microbiological testing materials and equipment. Invariably, a particular test method for a type or group of microorganisms will prescribe the nutrient medium suitable for that test. It will also prescribe the optimum incubating period and temperature. In this way, we are able, with some skill and luck, to test for many different types and groups of microorganisms that are of particular concern or interest to us at a certain time or in a specific problem-solving investigation.

I mentioned the words "with some skill and luck," because in the above description of the membrane filtration method, I did not touch on all the numerous micro-related disciplines, prerequisites, and techniques required in microbiological testing procedures that need to be adhered to for meaningful results. These include, among many others, items such as aseptic sampling, sterilization of equipment and materials, bug-free working stations, serial dilutions of heavily contaminated samples, control samples, nutrient media preparation, repeat testing for validation of results, and many other items. These will be touched upon briefly later in this chapter.

From the photos displayed, it can be seen that colonies can be counted and results reported as so many organisms per volume of sample. However, sometimes a membrane contains so many colonies that it is virtually impossible to count them, even with a mechanical device called a "colony counter." Not only can there be too many colonies, but also they may be attached to each other and literally form a single continuous "carpet" of microbiological growth. In such a case, there are two options to take. If an estimated count is needed, then the other sample is taken and diluted with sterile water in a serial manner to obtain 1/10, 1/100, and 1/1000 dilutions. These are again tested, and the counts are multiplied by the dilution factor to obtain the final true result.

This is not always necessary, because if the count exceeds a specified maximum, then it is reported as too numerous to count (TNTC), and it is a "fail" result. The serial dilution method is only performed to get an idea of exactly how high the count is and how bad the contamination.

Membrane filtration is the most common method used in our industry. Its advantage is that it allows for large volume samples to be used, as even the entire contents of a 2 liter bottle can be quickly filtered with the vacuum pump used in the method. However, there are soft drink products that may contain *Membrane filtration is the most popular micro testing method.* ingredients that clog the membrane quickly and require prolonged filtration periods. Sometimes the membrane becomes so clogged that the filtration cannot be completed. This is often the case with fruit juices and drinks containing fruit juice. The pulp content of some juices clogs the small pores of the membrane and renders the filtration of large volumes impractical.

The one option is to reduce the size of the sample, but herein lies a tricky problem. A smaller-size sample may not always give as true a picture of the actual micro content as that of a larger-size sample. This applies even more so if the sample contains a very low level of contamination.

Also, take a case where the specification calls for less than 10 colonies per 20 ml of sample. If a juice sample volume is reduced to 2 ml, then the specification becomes, by simple arithmetic, less than 1 colony per 2 ml. If under normal conditions you would have obtained a 5 colony per 20 ml count, which is a "pass" result, with the 2 ml sample volume you cannot physically obtain the ridiculous equivalent of 0.5 colony per 2 ml sample count. However, if you are unlucky and obtain a single colony, which is quite possible, your result is 1 colony per 10 ml, which in turn is equivalent to 10 colonies per 100 ml — your result is a "fail." That is definitely not fair.

Pour Plate Method

This method can be used as an alternative to membrane filtration.

A second alternative is to use the pour plate method. For this method, the nutrient medium is supplied in the form of a nutrient agar powder. In other words, it is a mixture of the nutrient medium and agar.

The required nutrient agar for all planned tests is mixed with water in a suitable container and sterilized according to the supplier's preparation instructions. The nutrient agar container is then placed in a water bath at about 45°C. At this temperature, the nutrient agar will stay in liquid form. When used, it will not destroy any microorganisms in the samples to be tested.

A measured volume of sample (2 to 5 ml) is placed (by pipet or measuring scoop) into a petri dish. To this petri dish is added about 20 ml of the nutrient agar, and the cover is placed back on the dish. The agar in the dish is then gently swirled to both mix the sample into the agar and spread it in a thin layer around the entire petri dish. Care must be taken not to splash the agar onto the sides and cover of the dish. The nutrient agar in the petri dish is allowed to cool and solidify into its typical rigid gel form. The dish is transferred to the incubation oven and kept at the prescribed temperature for the required period. As in the membrane filtration method, single microorganism cells will grow into observable colonies on the surface of the thin agar layer. Some colonies will be observed embedded inside the agar as well. These are formed from cells situated inside the gelled agar. All visible colonies are counted.

As mentioned before, the disadvantage of the pour plate method is that by using small sample volumes, the counts are not as accurate as those of the membrane filtration method. In order to improve this accuracy, samples with an expected count of 30 to 50 per ml should be used. Larger sample volumes can also be used, but they should not be too large, as they will dilute the nutrient agar and impair its gel-setting properties.

A second disadvantage of the pour plate method is that the growth of aerobic microorganisms embedded in the agar will be hindered due to the lack of oxygen. The thicker the agar layer and the deeper the microorganisms are embedded in it, the more pronounced this effect would be.

Notwithstanding the disadvantages of the pour plate method, it is still used for suitable purposes. It is also less laborious than the membrane filtration method, as it does not require individual equipment sterilizing steps (as will be described later in the chapter) and a sometimes-prolonged filtration step for each test. Also, it may work out to be less expensive, as the specialized equipment for membrane filtration involves an initial capital expenditure cost.

Thus, with respect to which method should be used, membrane filtration versus pour plate, I suppose the old horse-racing adage would apply: "different horses for different courses."

For convenience sake, this chapter will focus on the membrane filtration technique in micro testing.

Note: Historically speaking, before the advent of filtration membranes, presterilized petri dishes, and other sophisticated accompanying equipment and techniques, one way in which general microbiological testing was performed was with agar and nutrient media

that was poured into a plate and allowed to solidify. The samples for testing were streaked or smeared onto the agar plate on which the colonies then developed. As a result, the process of streaking the agar plate with the tested sample attained the term of "plating the sample." This term has survived to present day, and we still talk of "plating" the membrane filter when we place it in the petri dish, when, in fact, no real plating process is involved. We even go so far as to refer to our results as "plate counts." The reader is requested to bear this in mind when the "plating" of membrane filters is mentioned.

FUNDAMENTALS OF MICRO TESTING PRACTICES

This chapter has occasionally referred to disciplines, procedures, and prerequisites that are distinctive to the science of microbiology and are essential for meaningful micro testing. Before proceeding to outline the details of membrane filtration testing, a brief generalized review of these items is considered necessary.

Micro testing must avoid external contaminations that would render the test invalid.

The primary aim of micro testing is to obtain results reflecting the true contamination status of the sample or object tested. In order to achieve these correct meaningful results, microbiological contamination of samples and testing equipment from external sources must be minimized, if not eliminated, during the entire testing procedure. As we know, microorganisms are found almost everywhere in our working environment — floating in the air, present in materials, and settled on equipment and on our bodies. They are even contained in our breath. Should such microorganisms be allowed to find their way into our test samples, testing materials, and equipment, the results of our micro testing could be seriously distorted. The results would not only be biased toward higher counts but also could indicate the false presence of microorganisms in the sample. Such results could also mistakenly indicate types of microorganisms of which the sample in reality is completely free.

An error of opposite nature should also be avoided in the micro testing technique. Microorganisms inherent in the sample must not be destroyed or rendered inactive during the testing procedure. This would obviously skew the results in the opposite direction to that mentioned before.

In order to prevent, or at least minimize, this error-introducing factor, materials and equipment must be rendered sterile when used in testing. Furthermore, aseptic conditions and procedures must prevail in each step of the test, from sample taking to final colony count on the membranes.

Below is a brief outline of the items involved in maintaining the micro testing system as free as possible of these above-mentioned error-introducing factors.

THE MICRO LABORATORY

The micro lab should be physically detached from the general QC laboratory. Entrance should be restricted to unauthorized persons. Traffic in the laboratory should be minimized as far as practical.

If possible, the laboratory should contain a laminar flow cabinet in which the membrane filtration activities are performed. The cabinet unit, in essence, supplies a flow of microorganism-free air to the working space and is maintained under positive pressure. This prevents permeation of potentially contaminated outer laboratory air into the cabinet. An autoclave of suitable capacity should be available for sterilizing applicable materials, laboratory equipment, and glassware. If equipped with an air conditioner, this should be switched off during micro testing work.

Lab-Testing Glassware and Materials

All glassware to be used in micro testing should be sterilized before using it in tests. These should be suitably wrapped in kraft (brown wrapping paper) and autoclaved at 120°C at 15 psi pressure for 15 min. Most of the traditionally used glassware, such as petri dishes, pipettes, syringes, sampling bottles, etc., is readily available in presterilized disposable plastic equivalents from microbiology supply companies. These are relatively inexpensive, especially when purchased in bulk quantities as is necessary for micro testing in a soft drink factory. They are the preferred equipment in most companies, and we will assume they are used in the methods described in this chapter.

Sterile water should be prepared by autoclaving distilled water in 20 ml glass McCartney bottles. This sterile water is required for sample dilution and rinsing, swab sampling (to be discussed later in the chapter), and most importantly, for use as blank control samples in membrane filtration testing. Filter membranes and adsorbent pads for nutrient media are also nowadays purchased in bulk in presterilized formats. Nutrient media need to be sterilized by autoclaving according to the manufacturer's specific instructions.

Sampling from Sample Points in Processing Equipment

Proper aseptic sampling is essential for meaningful micro testing results.

Usually, samples of water, syrups, and product taken for micro testing from processing equipment are drawn from specially situated sampling valves, stopcocks, or taps. The small valve end normally contains some product that was standing there for some time and could already be contaminated with microorganisms from the surrounding air. Therefore, before drawing the sample, the valve should be opened for a few seconds and the product allowed to drain out to waste, thus removing the suspect product. The valve is closed, and the tip of the valve is then flamed for a few seconds with an alcohol burner (or a small portable low-pressure [LP] gas burner).

This flaming kills any microorganisms on the outside of the valve that may be drawn in while taking the sample. It also kills any remaining contaminants in the inside of the valve pipe. However, this flame treatment will also kill any microorganisms in the sample to be drawn at that stage. Thus, another few seconds of draining of this product are required in order to draw off a representative sample of the product. It will also cool the still-hot flamed valve that otherwise may also destroy some of the microorganisms in the sample taken, if any are present. After this draining, the valve is again closed, and the product in it is ready for sampling. The sample is then drawn off into an empty sterile sampling bottle, which also has to be flame sterilized according to the method described in the next section.

This seemingly laborious finicky sampling procedure is absolutely essential to ensure proper sampling and meaningful plating results. (There, I used the "plating" term discussed previously.) This sampling technique is applicable to any micro sample taking from a sampling point in stopcock, valve, or tap form. Adhering to this or any other similarly effective procedure is part of the "discipline" element mentioned that is a prerequisite for correct and proper micro practices. There are no shortcuts or alternatives. Occasionally in investigations of high micro counts and serious contamination problems, it is revealed that original results were due to improper sampling techniques.

As a general rule, testing of a sample should be performed as soon as possible after it is drawn. However, in practice, especially in operations where dozens of samples are taken daily for "en masse" testing, this is not always possible. In such cases, the samples should be stored under refrigeration until tested to retard any additional microorganism growth, particularly in excessively contaminated samples.

Flaming of Sample Bottles

Whenever a sample of liquid for micro testing is to be transferred into a sampling bottle, another "finicky" but essential flaming sterilization procedure must be practiced as follows. Assuming that the sampling bottle is of the screw-cap McCartney bottle type, the bottle is held in the left hand, and the cap

Flaming is a key step of any aseptic sample-handling procedure.

is loosened with the right hand (but not removed altogether yet). The screw-cap is grasped by curling the little finger of the right hand around it and pressing it firmly against the palm of the right hand.

The bottle now is twisted by the left hand, and by turning it in the appropriate direction (clockwise), the bottle is freed from the cap, which is still retained by the curled right little finger. (This curled little finger trick allows the rest of the right hand to be used for other purposes, such as opening and closing the sampling valve.) While holding the freed sampling bottle in the left hand, its threaded mouth can be passed quickly through the flame of the alcohol burner a few times. Roll the bottle in the fingers so that the entire threaded mouth area is flamed. This is necessary to destroy any microbial contamination that may have developed in the exposed area between cap and bottle threads.

The sample is then carefully transferred into the bottle. When this is completed, the mouth area of the bottle is again flamed. This is done to destroy any contamination of the bottle mouth from the surrounding air during the minute or two period of drawing the sample. It also incinerates any product that may have splashed onto the outside of the bottle mouth (which often happens to the best of us). The splashes of product, especially if it is a syrup or final beverage, could well serve as growth sites for microorganisms during a lengthy delay in actual testing. (Samples are often taken and stored overnight for testing the following day.) These would only increase the risk of external contamination during testing.

The bottle is then recapped in a reverse action of opening it — the sample-containing bottle, held in the left hand, is engaged into the threads of the cap still held firmly by the curled right pinky finger, and it is twisted and turned until securely sealed. This procedure is obviously modified accordingly for left-handed operators. It is a matter of dexterity but is easily learned with a little practice and experience. It may also be modified for personal convenience, as long as all of the contamination prevention risks in sample transfer into the bottle are addressed.

This same bottle-flaming procedure, with applicable modifications and steps, is also conducted when pouring the sample out of the bottle into the filtration apparatus (to be described soon). It is also used, with appropriate modifications, when pouring out a micro sample from an actual beverage bottle. Care must be taken at all times not to overflame the glass bottle mouths, as cracking of the entire bottle could result.

Again, this finicky sort of procedure must be adhered to diligently. It is a basic given between professionals that it was performed correctly — and if not, your professional reputation and perhaps even more will be at stake.

Blank Control Samples

During the numerous steps of micro testing, from sampling through plating and eventual reading after plate incubation, there is always the possibility that external contamination occurred that could render the results as meaningless. Sources of such

"Blank" sterile water controls are a "must" for every testing session.

contamination are numerous, such as from the surrounding air in the laboratory and from ineffective sterilization of nutrient media, petri dishes, pads, or membranes, of filtration equipment, and of sterile water for sample dilution and rinse.

In order to monitor the sterile conditions of materials, equipment, and general testing practices, control blank samples are tested in every micro testing session. This blank control (referred to as a blank) is performed with sterile water, which is filtered, plated, and incubated in the same way that the samples are tested. A blank is performed for each different nutrient medium used in the testing session.

A blank test should have a zero colony count to render it as a valid control for the test session. If it does, for some reason, show a count of a few colonies, a decision must be made as to whether all the other plate counts of the same test category are to be accepted or declared invalid. Depending on the type of microorganisms and the number of colonies involved in the blank sample, it is sometimes possible, with having similar previous experience in such cases, to attribute the blank's few colonies to the result of a one-off incident of surrounding air or procedural contamination. In such a case, one could, with some reservations, accept that the testing session was conducted satisfactorily and that the results are valid. If the blank controls display heavy growth of colonies, the test results of the entire session should be discarded and the contamination source determined.

Duplicate blanks are "insurance" against some tricky situations that could arise.

It is recommended to do the blanks in duplicate. If only one blank is performed and if it is accidentally damaged or soiled, e.g., by dropping it during or after the incubation period, then the entire session results could become unusable, especially if it contained samples of more than just routine nature. However, with two blanks, one would still have the second as a control sample.

Duplicate blanks also serve another purpose. If one of the two blanks has a low colony count and the other is perfectly "clean," then more than likely the contamination in the first one is due to an unfortunate one-off type of contamination, as mentioned above. If both blanks are heavily contaminated, then there would be no doubt that such contamination is not of a one-off trivial nature. The results of the session must be discarded, and the contamination source must be identified and eliminated from further testing sessions.

DUPLICATE PLATES

If workload and time allow, duplicate plating of each sample is highly recommended.

The preparation of duplicate plates per sample, i.e., two separate filtrations for the same sample, is highly recommended. Plate count results are usually only finally determined after several days of incubation in the oven. If only one plate is prepared and for some reason it is accidentally spoiled and rendered useless, it would take another few days to obtain the missing results from a repeat test. With two plates per sample, this situation can be avoided if one of them remains intact and countable.

Furthermore, with duplicate plating, each one should have more or less the same counts of the same microorganism colonies. If this is not the case and one of the duplicates is significantly different in count or colony type to the other, then something is seriously amiss with the micro testing technique involved. This should be investigated.

In practice, especially in large soft drink manufacturing operations, the numbers of daily micro samples could very well be of such quantities that duplicate plating can become an excessive workload on the laboratory staff. In such cases, single plates per sample could be sufficient for the routine daily samples. On the other hand, duplicates should be the general rule for specifically critical micro testing, such as for consumer complaints, micro surveys, and problem investigations.

Some professionals may disagree with my "single plate per sample" recommendation for routine testing mentioned above. My rationale in going along with one plate per sample is that in a large plant, many different product brands and flavors are run on several filling lines. Daily, a large number of different samples would necessarily be taken for routine testing. The prime aim of micro testing is to determine the sanitary condition of the plant's equipment, the contamination levels of the raw materials, and the general overall influence of environment and processing practices on the final products' micro status.

The numerous different samples taken are from products that are, in most cases, processed with the same factory equipment. Most of the raw materials are common to all products (treated water, sugar, acidulants, preservatives, colorants, etc.). The final beverages at all stages of production are processed by the same labor force and are exposed to identical environmental conditions in the factory. From a micro testing point of view, all of these numerous samples could already be considered duplicates of each other.

From that same micro point of view, the only real difference between each brand and flavor is in the flavor components (and possibly in one or two unique brand-specific components, if present). If any of these unique brand- and flavor-specific ingredients is contributing to product contamination, this would soon be picked up in the micro testing of the single-plate samples of such brands and flavors. This would also apply to any brand- or flavor-specific plant equipment, processing site, and workforce practice that may be a source of contamination in the final beverages of these brands and flavors. In effect, in a large operation where numerous different samples are taken for micro testing, the single micro plates prepared for each sample are, in a sense, already duplicates of each other.

MISCELLANEOUS MICRO TESTING PRINCIPLES

The following are a few additional basic principles for correct and effective micro testing:

- Windows, if present in the micro laboratory, should be closed during testing sessions.
- The workbench surface should be periodically cleaned by wiping with a cloth dampened in ethanol.
- Hands should be thoroughly washed before and during each test session.
- Certain clothing, such as long sleeves, ties, etc., should be avoided, as these could contaminate equipment.
- Exhaling directly onto sterile equipment should be avoided. Talking during testing should be minimized.
- The lips of sterile petri dishes are not necessarily sterile, as they are handled by the operator during the testing procedure. Contact with these by sterile equipment must be avoided.

By far the most important factor in successful micro testing is attention to detail. This is true of all laboratory activities, but in micro testing, this aspect takes on a very special meaning.

THE MEMBRANE FILTRATION METHOD

Membrane filtration equipment comes in various sizes and shapes. Some are made of glass components and others of stainless steel. For the purpose of this method description, we will use a stainless steel version. We will also use flaming as the in-between steps sterilizing method for the larger filtration components, as opposed to immersion in boiling water, which is also commonly used.

The method described below, in the text format of an instruction document, is a generalized one and can be modified to suit the operator's preferences as well the specific stipulations that may be required by a particular soft drink company's quality assurance authority.

Detailed step-by-step description of a typical membrane filtration procedure.

1. Place on the workbench an amount of sterile petri dishes equal to the number of samples to be tested plus an additional two petri dishes for blank controls for each nutrient media type to be used in the test session.
2. Mark each petri dish with a label identifying the sample to be tested.
3. Flame a fine forceps in a Bunsen burner (or alcohol burner), and use it to remove a sterile adsorbent pad from its container and carefully place it in a petri dish, lifting the petri dish cover as little as possible to do so. Repeat this for each of the petri dishes, flaming the forceps between each pad removal.
4. Lift the lid of a petri dish just high enough to inject the required amount (±2 ml) of the applicable nutrient medium onto the adsorbent pad, ensuring that it is soaked enough to allow good adherence of the membrane filter to be added later in the test. Do not oversoak the pad, as excess medium could cause unwanted spread of colonies on the membrane.

MEMBRANE FILTERING AND PLATING

A disassembled view of a typical stainless steel filtration apparatus setup is given in Figure 10.8 and will be referred to in this method description. Before proceeding with the filtration, allocate a dedicated area of the workbench for flaming equipment, away from the general working area, that contains a beaker of 95% alcohol for use in swabbing filtration equipment.

1. Secure the filter base (E) into the mouth of a suitably sized vacuum flask (H) by means of the attached rubber bung (G). The vacuum flask may need to be supported by a retort and clamp to stand securely due to the weight of the filter base. Ensure that the filter base valve (F) is in the closed position.
2. Flame the forceps, and remove a sterile filter membrane (D) applicable to the test from its container. Place this on the porous material at the top of the filter base. Ensure that the membrane is well centered on the base. The membrane will stick to this base as it would be damp from a previous filtration (or initial rinsing) process. (Note that this base does not have to be repeatedly sterilized, as any microbial contamination on it, if present at all, will only grow on the underside of the membrane and cannot pass through the membrane pores to its upper surface.)
3. Using the hands, swab the inside surface of the filter funnel (C) with a cotton wool bud soaked in alcohol. While swabbing, squeeze the cotton wool so that some alcohol drips out onto the surface. By swirling the funnel, disperse the alcohol over as much area of the funnel inside surface. While still holding the funnel, with the other hand, flame a suitable sized tongs, and grasp the swabbed funnel with the tongs. Release the funnel from the hand, and holding it with the tongs, allow any excess alcohol to drip to waste.
   a. Flame the still-alcohol-wet funnel in the burner. Be careful of the sudden flame that will be created. Twist the funnel around with the tongs for a few seconds so that the flame covers most of the funnel surface. The flame will soon cease, as all the swabbed alcohol is burned.
   b. Hold the funnel for a few more seconds to allow it to cool. When cool enough (this can be tested by a gentle finger touch of the outside surface), manipulate the funnel with the tongs so that it settles and fits onto the filter base supporting the membrane. With the attached clamp (not shown in Figure 10.8), secure the funnel firmly on the filter base.
4. Using the sample bottle flaming technique described in an earlier section, transfer the required volume of sample into a flamed stainless steel scoop of applicable size, and then tip the measured quantity of sample into the filter funnel.
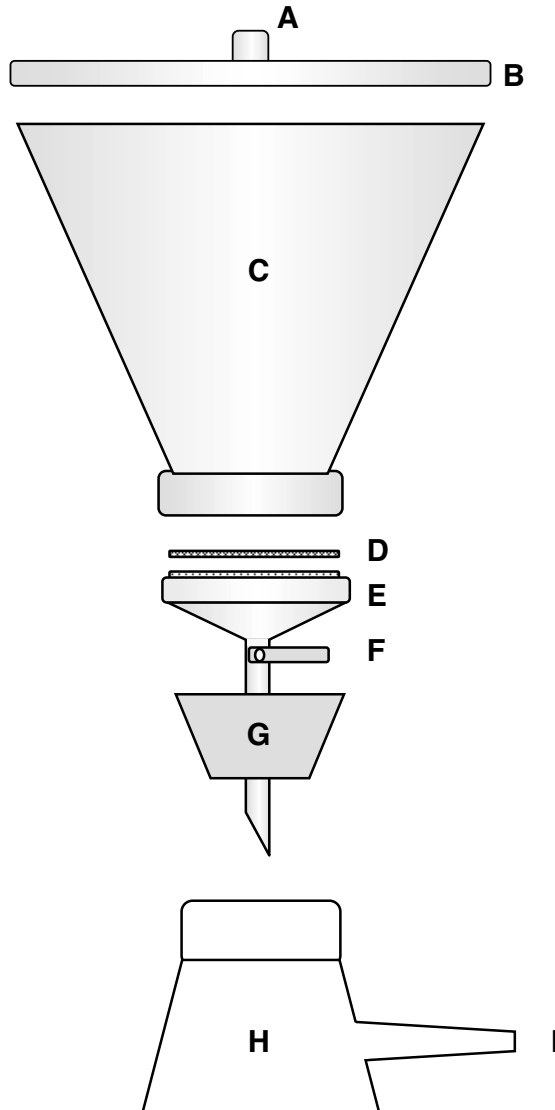
FIGURE 10.8 Membrane filtration apparatus.

5. With a bud of cotton slightly wet with alcohol, quickly swab the entire inside area of the funnel lid (B), and cover the funnel firmly. Take care that no liquid alcohol is present on the lid to drip into the funnel.
   a. Ensure that the filter lid has a cotton wool plug inserted tightly in its air inlet (A). (This cotton wool plug will filter out any microorganisms contained in the air that sucked into the filter funnel when the vacuum pump is activated in the filtration process.)
6. Connect the flask to the pump with vacuum piping from its outlet (I). Open the filter base valve and start the vacuum pump. The sample will filter through the membrane and then through the porous section of the filter base into the vacuum flask.
   a. Close the valve, lift the lid just high enough to quickly aseptically transfer about 20 ml of sterile water from a McCartney bottle. Replace the lid, open the filter base valve

to allow the water to rinse out the funnel and membrane. Allow the vacuum pump to operate another few seconds, close the filter base valve, and then switch off the pump.

7. Release the funnel clamp and remove the funnel from the filter base. With flamed forceps remove the wet membrane and carefully place it on the adsorbent pad in the applicably marked petri dish. Tap the membrane gently in a few places to ensure that it is firmly stuck to the wet pad.

8. Repeat steps 2–7 with all the samples as well the blanks for each of which 20 ml of sterile water is used as the "sample."

INCUBATION OF SAMPLES

After filtration and plating of all sample is complete, transfer the petri dishes to the incubation ovens at temperatures and periods indicated as follows:

Total count: 35°C for 72 h
Yeasts and molds: 28°C for 48 h
Coliforms: 35°C for 24 h

Separate ovens should be used for each microorganisms group. If only one incubator is available, maintain the temperature at around 30°C. Petri dishes should be placed in the oven in upside-down, inverted position. In the up-right position, condensate that will form on the petri dish cover will drip down onto the membrane surface. This would disrupt the expected single detached colony growths.

COLONY COUNT

After the prescribed incubation period, count the colonies on each membrane, and report the values as the number of CFU per volume of sample filtered. If a sample dilution was used, multiply the count by the dilution factor. If it is physically impractical to count the colonies due to excessive numbers of colonies, report this count as TNTC.

DISPOSAL OF COMPLETED TEST MATERIAL

All petri dishes with pads and membranes should be autoclaved to kill off all growths. Thereafter, these should be effectively incinerated so as to prevent any further microorganism growth at whatever waste dumping site they will eventually land up in. This practice should be considered as an obligation to the community, because intact nutrient media-soaked pads could be ideal growth sites for pathogenic bacteria present in the surrounding environment.

MICROBIOLOGICAL SPECIFICATIONS

Specifications for micro counts in the soft drinks industry may vary slightly from company to company. Table 10.1 lists some of the recommended basic micro specifications for water, raw materials, and products in a soft drink plant.

MICRO TESTING OF FACTORY EQUIPMENT

In addition to testing waters, raw materials, and products, there is a need to determine the sanitary condition of factory processing equipment. The equipment is continuously exposed to micro contamination, both internal and external, from products, sur-

Micro surveys are periodically performed to determine the sanitary conditions of plant and equipment.

TABLE 10.1
Recommended Microbiological Specifications

	Micro Specification (Colony-Forming Units per Volume/Weight)			
Item	Coliforms	Total Count	Yeasts and Molds	Sample for Test
Raw water	Zero per 100 ml	Less than 500 per ml	N/A	From suitable sampling point
Treated water	Zero per 100 ml	Less than 25 per ml	N/A	From suitable sampling points after carbon filter
Granular sucrose	N/A	Less than 200 per 10 g	Less than 10 per 10 g	10 g dissolved in 100 ml sterile water
Liquid sucrose	N/A	Less than 200 per 10 ml	Less than 10 per 10 ml	10 ml from suitable sampling point
High-fructose corn syrup	N/A	Less than 200 per 10 ml	Less than 10 per 10 ml	10 ml from suitable sampling point
Simple syrup final syrup	N/A	N/A	Less than 5 per 5 ml	5 ml from suitable sampling point
Final beverage	N/A	N/A	Less than 10 per 20 ml	20 ml from final beverage container
Empty container	N/A	Less than 50 per container	N/A	±20 ml sterile water added to container and swirled around
Containers' rinse water	Zero per 100 ml	Less than 25 per ml	N/A	From suitable sampling point
Filler rinse water	N/A	N/A	Less than 10 per 100 ml	Sample of final rinse water in filler clean-in-place (CIP) procedure

rounding air movements, and operator handling. If not cleaned and sanitized effectively, equipment can become growth sites for microorganisms, which in turn can infect waters, raw materials, syrups, and final products. Periodic factory micro surveys are conducted. The results reflect on the effectiveness of standard cleaning procedures and identify problem areas requiring attention.

MICRO SWABS BY MEMBRANE FILTRATION

The most common and effective method of taking micro samples from equipment and structures is by the swabbing method. This is performed by dipping a sterile cotton wool swab (very much like an ear-bud in structure) in a 20 ml McCartney bottle

Micro swab taking is the most common survey method.

of sterile water and then rubbing the surface of the object to be tested with the swab. The swab is then dropped into the bottle of sterile water, and the bottle is recapped.

The bottle is marked with an identification of the piece of equipment sampled and taken for membrane filtration testing in the normal manner. Before filtering the sample, the bottle with the swab is shaken vigorously to disperse most of the microorganisms present into the sterile water. The entire contents of the bottle are then tipped into the filtering funnel, for membrane filtration that follows. The membrane is plated and incubated in the regular manner for the period required. Results are reported as micro counts of colonies per equipment sampled.

The piece of equipment could be a filling valve, the entire surface of which was swabbed. The count is then reported as per the single valve tested. In another case, an area of a syrup tank wall, e.g., 10×10 centimeters, is lined out with a marking pen, and this area is swabbed. The result is then reported per 100 cm^2. The swabs are tested for applicable microorganisms types expected in

the particular piece of equipment, e.g., a filler valve would be tested for yeasts and molds, whereas a treated water valve would be tested for coliforms and total count.

ATP Bioluminescence Assay

ATP bioluminescence assay is a sophisticated micro count method based on the firefly's ability to produce its glowing cold light.

Another method for testing the sanitary condition of factory processing equipment is by ATP bioluminescence. This is a sophisticated method developed in recent years and is based on the chemical reaction to which the firefly beetle owes its name. Briefly, this is explained as follows.

ATP (adenosine triphosphate) is a key chemical in energy storage and production reactions in all living organisms — animals, plants, and microorganisms. In the firefly, by means of luciferase, an enzyme that acts on a chemical luciferin in the firefly's body, the chemical energy stored in the ATP in the cells is converted to light energy. This light produced is called bioluminescence and is commonly referred to as "cold light." The amount of light given off is directly proportional to the amount of ATP available in the reaction. This reaction principle was scientifically copied to measure the ATP present in organic matter. By means of a sensitive light-measuring device, the luminometer, this quantity of light can be measured even at very low levels.

Advantages and disadvantages of the method.

Thus, if we took the micro swab sterile water that contains some microorganisms and subjected the water to the luciferin light-producing reaction, we could measure the amount of ATP present in the microorganisms. The light produced is measured in arbitrary-type units called "relative light units" (RLUs). By calibrating the luminometer in RLU values equivalent to different levels of equipment contamination (determined by conventional micro plating methods), one could determine the level of contamination in a swab sample. The ATP bioluminescence method has a great advantage or disadvantage, depending on how one looks at it.

In the luciferin reaction, it does not make a difference if the organic matter is alive or consists of dead cells. The ATP is present in both and will be detected. Thus, any dead microorganisms and any other nonliving organic material collected on the swab from the sampling site will also be detected and contribute to the bioluminescence produced. This, therefore, does not give us a pure microorganism count. This method is nonspecific in that it does not identify the groups or types of microorganisms present in the sample.

On the other hand, in the ATP method, the luminometer will tell us the level of combined contamination on the equipment — the living microorganisms and the organic matter that was not cleaned off. The latter could well serve as a growth site for more microorganisms. In essence, it reflects the sanitary condition of the equipment in the factory, whether this is microbial in nature or not. An added advantage is that the results of a complete ATP bioluminescence test can be obtained within hours, if not minutes, after sample taking.

This can be very useful as a support micro testing tool, but it should not replace conventional plating methods.

The ATP bioluminescence method can be an important support tool for micro surveys in the soft drink factory. It should also be noted that in our industry, we do not normally process animal or plant material that could land up as nonliving ATP-containing contamination on equipment. The probability of any nonmicrobial organic material contaminating our equipment is very low, so a luminometer reading would usually be, in effect, a genuine microorganism count.

Though relatively expensive, commercially available ATP bioluminescence assay kits, inclusive of the light-producing chemicals and luminometer, are being used by many soft drink operations. In fact, I think that handheld portable luminometer kits are already available that can read contamination levels directly on the equipment without the need for any swab-taking procedures. Even

with all the sophistication, convenience, and speed of this method, ATP bioluminescence should not be considered as a total replacement of conventional plating micro testing.

PRESERVATIVES

One could normally ask why there is all this "fuss" about microorganisms and microbiological spoilage if we put preservatives in our beverages. Will the preservatives not kill off any microorganisms present in the beverage in any case?

The answer is that in food products the commonly used preservatives are not bactericides — they do not kill off the microorganisms. Sodium benzoate and potassium sorbate, the preservatives most used in soft drinks, are bacteriostatic agents. These are chemicals that stop further growth of any microorganisms already in the beverage. The preservatives only chemically disrupt the cell multiplication process in the microorganisms — they do not actually kill them outright.

> If we were to put preservatives into foods that literally kill the microorganisms, such as chlorine, iodine, carbolic acid, and all other types of bug-killing disinfectants, they would probably kill us as well, if we consumed those foods.

Therefore, in spite of the presence of preservatives in beverages, we must still strive to keep micro counts at minimum levels and eliminate the possibility of pathogenic microorganisms being present in our products. This is because when consumed, any microorganisms in the beverage, freed of the preservative's growth-inhibiting effect and given the chance, could possibly start multiplying again in our bodies.

Again, a question could be asked why beverages become spoiled by microbial growth when the preservatives should keep them in check. I do not have a pat answer to this particular question. I think that the answer lies in the initial microorganism load of the beverage, in that the preservative, in the concentration levels in beverages allowed by food laws, can only cope with certain contamination levels and not more than that. Also, probably the spoiled beverage was subject to some special growth-favoring circumstances, such as air leakage into the bottle or can, higher than normal storage temperatures, etc.

As microbiologists are fond of saying, perhaps the spoilage microorganisms were of a "strain" resistant to the preservative. In this respect, I have a short story to tell.

> As a consultant, I was studying a problem of the typical kerosene- or petroleum-like off-odor in a client's beverage due to the formation of 1,3-pentadiene in the drink. I was vaguely familiar with this uncommon but known diene off-odor phenomenon in soft drinks and decided to search the Net for more information. Much to my amazement, there was a world of information on the Net about this subject. The gist of it all was that there are microorganisms, mainly molds (and some yeasts), that when under pressure from the preservative potassium sorbate, "detoxify" this preservative by converting the sorbate into the ineffective diene molecule, with the resultant off-odor.

> The problematical product being investigated was preserved with potassium sorbate, and subsequent microanalyses by specialist outside laboratories identified the contaminating microorganisms as a species of Trichoderma mold. My own literature search indicated that other species of Penicillium molds as well as some yeasts species could also convert the preservative into its ineffective diene form.

> What this story is trying to say is that microbiology is indeed a tricky subject, as mentioned at the beginning of this chapter. Here we not only have a microorganism that is not affected by a well-known food preservative, but it literally eats it up. There just do not seem to be any hard and fast rules in this science.

CHAPTER REVIEW

As a food industry, soft drink companies have a public obligation to eliminate health risks for the consumer by reducing microbial contamination in their products and ensuring that their products are free of pathogenic bacteria. Reduction of this microbial contamination is achieved by adhering to high standards of water and raw materials quality, by maintaining effective hygiene standards, and by continuously micro monitoring the processes. This also helps to achieve a low incidence of product spoilage. In turn, this means that not only are added spoilage-related costs avoided, but also the images of the company's products are enhanced.

This chapter has been a brief incursion into the somewhat esoteric complex science of microbiology and the part it plays in the soft drinks industry. There is still an outstanding micro-related subject to elaborate upon in this handbook, namely biofilms. It is a subject of singular interest, and a short chapter is specifically dedicated to the issue in this handbook.

11 Syrup Shrinkage — Splitting Hairs?

Syrup shrinkage is a phenomenon with which not all soft drink manufacturers are familiar. If indeed aware of it, many manufacturers tend to ignore it and carry on with their operations as if it did not exist. Truly enough, syrup shrinkage seems to have no significant impact on quality, cost, or any other key aspects of the soft drink business operation.

So, perhaps we can justifiably disregard syrup shrinkage as a factor in the soft drink manufacturing process and consider it an item of academic interest — a pedantic matter of "splitting hairs." I will leave this as a decision for the reader to make after completing this chapter.

WHAT IS SYRUP SHRINKAGE?

The phenomenon of syrup shrinkage, as its name implies, is encountered in syrup-making operations. It therefore applies mainly to the carbonated soft drinks industry, where final beverage is usually prepared by proportioning preprepared concentrated syrups with treated water at the filling machine. Syrup shrinkage can be likened to the often-used paradoxical saying of one and one not being equal to two.

In a 4:1 water-to-syrup proportioning ratio, as an example, where 4 liters of water and 1 liter of syrup are mixed, one would expect the resultant mixture of final beverage to be 5 liters. This, in fact, does not happen. The total volume of the two mixed liquids will be slightly less than the expected 5 liters volume. The shortfall in the expected volume is of a relatively very low order (and this is possibly the reason it is not actually picked up in water and syrup mixing operations in the factory, or even in the laboratory).

I have yet to find a recorded and documented detailed scientific explanation for this in the soft drink technical literature. I have, however, been given a verbal explanation by one of my many past mentors in the soft drinks industry upon which I base the following explanation.

When a water-soluble solid dissolves in water, its molecules disperse in the intramolecular spaces available between the water molecules. Thus, the resultant solution occupies a total volume slightly less than the combined original volumes of the water and the solid material. This happens when we dissolve sugar in water to make a syrup solution — and there is nothing very strange about this.

Syrup shrinkage is due to the intramolecular spatial arrangement between solvent and solute, which is water and sugar in syrups.

When we now take the syrup solution and mix it with more water, the dissolved sugar molecules in the syrup behave in the same manner, as did the solid sugar ones, and occupy some intramolecular spaces between the new water molecules. Thus, the 1 liter of syrup and the 4 liters of water shrink a little bit in their combined total volume and do not make up the full expected 5 liters of volume. Hence, the term "syrup shrinkage" comes about. The reader may well not accept this somewhat crude explanation. I will, therefore, proceed with a more scientific explanation involving a little bit of math (and some of the basic Brix/density/mass/volume theoretical principles I hope the reader is by now familiar with from some preceding chapters in this handbook).

SYRUP SHRINKAGE EXPLANATION

Syrup shrinkage can be explained by mathematical calculation.

For the purpose of this calculation demonstration of syrup shrinkage, I will use as examples syrups for two nominal final beverages, lemonade and orange. We will assume that for each product the formulation and filling instruction calls for a 4:1 water-to-syrup ratio and that the final beverage volume expected is 1000 liters. Table 11.1 gives a step-by-step calculation of the resultant volumes of final beverage for each flavor. With regard to the format of the table, the following should be noted:

- The first column, "Item," contains the item calculated or used in a calculation.
- The column "derived from" indicates how the item was arrived at.
- The "Ref." column provides a letter that identifies the item.
- Brix values are presented as percentage values.
- The operator (/) indicates division.
- The "×" indicates multiplication.

TABLE 11.1
Syrup Shrinkage Calculation

Item	Derived from	Ref.	Lemonade	Orange
Syrup volume (liters)	1000 × 1/5	A	200	200
Syrup Brix (as percentage)	Given	B	45.70%	52.60%
Syrup D20	Density tables	C	1.20524	1.24297
Syrup mass (kg)	A × C	D	241.048	248.594
Syrup solids (kg)	B × D	E	110.159	130.760
Water volume (liters)	1000 × 4/5	F	800	800
Water D20	Density tables	G	0.99717	0.99717
Water mass (kg)	F × G	H	797.736	797.736
Beverage mass (kg)	D + H	L	1038.784	1046.330
Beverage Brix (as percentage)	E/L × 100	J	10.60%	12.50%
Beverage D20	Density tables	K	1.03957	1.04750
Calculated beverage volume (liters)	L/K	M	999.244	998.883
Expected beverage volume (liters)	4:1 water-to-syrup ratio	N	1000.000	1000.000
Difference from expected volume (liters)	N − M	P	0.756	1.117
Percent difference from expected volume	P/N × 100	Q	0.08%	0.11%
Average percent difference for both beverages		R	0.1%	

SHRINKAGE CALCULATION

We will proceed through the details of each step:

Step 1: The syrup volume required to achieve the 1000 liters of final beverage target at the 4:1 water-to-syrup ratio will be one fifth the final beverage volume, which is equal to 200 liters.

Step 2: The lemonade and orange syrups have given Brix values of 45.70°B and 52.60°B, respectively. After being mixed in the 4:1 water-to-syrup ratio, these will result in a lemonade final beverage at 10.60°B and an orange at 12.50°B. (This will be verified in a later step.)

Step 3: The syrup D20 (density at 20°C) value is obtained from standard sucrose solution density tables (see Appendix 1).

Step 4: Syrup mass (weight) is its volume multiplied by its D20.

Step 5: Dissolved solids in the syrup are calculated as Brix multiplied by mass (by definition of Brix — percentage dissolved solids in a solution on a mass for mass basis).

Step 6: The water volume at 4:1 water-to-syrup ratio will be four fifths of 1000 liters, which is equal to 800 liters.

Step 7: Water D20 is derived from the density tables and is the "magic figure" 0.99717 first mentioned in Chapter 1 of this handbook.

Step 8: The water mass is equal to volume × 0.99717.

Step 9: The final beverage mass (L) is the combined masses of syrup (D) and water (H).

Step 10: The final beverage Brix is, by definition, the total dissolved solids as a percentage of the total final beverage mass (L). All the dissolved solids come from the syrup and are given in item (E) of the table. Therefore, the Brix value for the beverage will be $E/L \times 100$.

Step 11: The D20 values for the lemonade and orange final beverages are obtained from the density tables using their respective Brix values.

Step 12: This is the critical step in the calculation, whereby the resultant volume of the mixed 200 liters of syrup and 800 liters of water is calculated. To calculate this value, the final beverage mass (L) is divided by the final beverage D20 (K) (according the basic formula volume = mass/density).

From the calculation results in the table, the resultant volume of the lemonade works out to 999.244 liters instead of the expected 1000 liters of volume (N). For the orange, this works out at 998.883 liters instead of the expected 1000 liters of final volume. Herein lies the syrup shrinkage phenomenon.

Step 13: The difference for the lemonade is 0.756 liters short of the 1000 liters, whereas for the orange, it is at 1.117 liters. From this, we can see that with a higher syrup Brix (or higher final beverage Brix), the syrup shrinkage is greater.

Step 14: In percentages, these volume discrepancies are 0.08% and 0.11% for lemonade and orange, respectively.

Step 15: As lemonade is a typical low Brix beverage and orange a high Brix beverage, we can for convenience purposes average the syrup shrinkage percentage factor as 0.1% shortfall from the expected volume in a 4:1 water-to-syrup ratio mixing operation.

DISCUSSION OF CALCULATION

Before proceeding with a discussion, there may be a reader or two who will argue that as the D20 values play a key role in these calculations, could they not be erroneous and therefore cause these volume discrepancies? The answer to this question is simple. These density versus Brix values in the tables were compiled from meticulously controlled laboratory testing procedures. In my 30-odd years

of using such tables, they never let me down as far as practical or theoretical Brix/density and volume/mass calculations or applications were concerned. I have as much trust in these tables as the trust one has in any established technical tables, such as Celsius-to-Fahrenheit temperature conversion tables, temperature correction tables for refractometric Brix readings, alcohol percentage versus density tables, just to name a few such tables that food technologists use daily as tools in their profession.

The pivotal point to be made with regard to the syrup shrinkage phenomenon is that there is no physical loss of syrup or final beverage involved — nothing has gone down the drain, and no money has been lost to the company. What happened is as follows. The final volume of a syrup batch for eventual final beverage filling is often formulated without taking syrup shrinkage in consideration. As a nominal example, for 1000 liters of final beverage in a 4:1 water-to-syrup ratio, the batch size of the syrup is designed as 200 liters (as in our calculation demonstration). The shrinkage factor, averaged in our calculation at 0.1%, will not enable production to physically obtain their 1000 liters of yield target.

WHAT IS THE IMPACT OF SYRUP SHRINKAGE?

Ignoring the syrup shrinkage phenomenon will skew production yields statistics.

As mentioned before, there is actually no physical loss of syrup or of final beverage. All that happens is that there is a slight shortfall in the expected final volume of the final beverage. What then is the impact of syrup shrinkage in the soft drink manufacturing operation? Members of production management are always under pressure to achieve the company's established beverage yield targets in filling operations. An accepted maximum loss of beverage from syrup during filling operations in filled product cases is around 0.5%. Standard losses of product are expected from start-up operations, filler and other equipment breakdowns, overfilled bottles or cans and other on-line rejects, sampling by QC, syrup remnants in piping between the syrup room and the filling hall, etc.

Now, to include an unavoidable loss due to syrup shrinkage of 0.1% to this allowed 0.5% production loss is simply not fair to production staff, especially if they are on a production yield incentive bonus scheme. This is 20% off the allowed loss figure. Not only is it not fair, but also, a regular production operator, not being aware of the syrup shrinkage factor, will sometimes try to "stretch" the syrup to overcome this unavoidable "loss." By doing so, the operator will be slightly but perhaps significantly impairing the quality of the final beverage.

The 0.1% shrinkage shortfall may at first seem trivial and negligible. However, consider a medium-size soft drink operation producing 20 million liters of beverage per year. The 0.1% shrinkage shortfall would be equivalent to 20,000 liters of final beverage per year. How is the production manager going to explain this added relatively huge yearly shortfall in yields to his financial director, who will naturally but incorrectly assume it is product lost "down the drain"? So then, what is the solution to this "nuisance-value" problem? The solution is very simple.

The syrup batch size for a prescribed volume of final beverage must be designed to include the syrup shrinkage factor.

Thus, in our lemonade and orange beverage examples, the final volume of the syrup batches should be a little over 200 liters. Table 11.2 is a replica of the previous table, with calculation columns of these new 200+ liter syrup batch volumes included for comparison. For the lemonade, a syrup batch volume of 200.652 liters will result, after proportioning with water, in a final beverage volume of 1000 liters. For the orange, a batch size of 200.941 liters will be necessary to achieve a 1000 liters of final beverage volume.

TABLE 11.2
Syrup Shrinkage Calculation Comparison

Item	Derived from	Ref.	Not Corrected for Shrinkage		Corrected for Shrinkage	
			Lemonade	Orange	Lemonade	Orange
Syrup volume (l)	$1000 \times 1/5$	A	200	200	200.652	200.941
Syrup Brix	Given	B	45.70%	52.60%	45.70%	52.60%
Syrup D20	Density tables	C	1.20524	1.24297	1.20524	1.24297
Syrup mass (kg)	$A \times C$	D	241.048	248.594	241.834	249.764
Syrup solids (kg)	$B \times D$	E	110.159	130.760	110.518	131.376
Water volume (l)	$1000 \times 4/5$	F	800	800	800	800
Water D20	Density tables	G	0.99717	0.99717	0.99717	0.99717
Water mass (kg)	$F \times G$	H	797.736	797.736	797.736	797.736
Beverage mass (kg)	$D + H$	L	1038.784	1046.330	1039.570	1047.500
Beverage Brix	$E/L \times 100$	J	10.60%	12.50%	10.60%	12.50%
Beverage D20	Density tables	K	1.03957	1.04750	1.03957	1.04750
Calculated beverage volume (l)	L/K	M	999.244	998.883	1000.000	1000.000
Expected beverage volume (l)	4:1 water-to-syrup ratio	N	1000.000	1000.000	1000.000	1000.000
Difference from expected volume (l)	$N - M$	P	0.756	1.117	0.000	0.000
Percent difference from expected volume	$P/N \times 100$	Q	0.08%	0.11%	0.00%	0.00%
Average percent difference for both beverages		R	0.1%		0.0%	

CHAPTER REVIEW

Syrup shrinkage can be considered as a pedantic hair-splitting issue. However, I demonstrated that ignoring syrup shrinkage in product formulation and manufacturing instructions can be very unfair to production staff insofar as product yields are concerned. It can, by a kind of domino effect, also be the cause of some baffling variances in the accounts or administration departments of a company.

There is a far more serious reason to account for syrup shrinkage in formulations and manufacturing instructions, namely, scientific precision and technical integrity. Quality assurance management have a professional obligation to account for syrup shrinkage in the quality management system of a soft drink company. Even if syrup shrinkage is not built into the systems, at the least it should be acknowledged as an existing factor (even if it is considered as a "splitting-hairs" matter).

This chapter was included in the handbook for another reason altogether. This is to give the reader an opportunity to gain some "practice" with the entire issue of Brix/density/weight/volume interrelationships in soft drink technology matters. There are some more issues coming up in this handbook where these play a major role.

12 Carbonation — Putting in the Fizz

OVERVIEW

Carbonation is the process of introducing carbon dioxide (CO_2) gas into water or into a beverage. Soft drinks containing CO_2 are called carbonated soft drinks and are referred to as CSDs. This category of beverages makes up almost half of all world soft drink sales. When a carbonated drink is poured into a glass, the CO_2 gas in the beverage is liberated in the form of small bubbles that rise quickly to the surface, where they burst and release the gas. This also happens in one's mouth when drinking the beverage, causing the tingling, tickling effect typical of all CSDs.

The formation of gas bubbles in a liquid, technically referred to as effervescence, is what we commonly call fizz, sparkle, bubbles, and so forth. In nature, we find this effervescence in some spring waters containing CO_2 that was absorbed underground at high pressures. In some beers, the CO_2 present in the drink is solely due to the formation of the gas as a result of the fermentation process involved in the manufacturing of the product. Some wines, like champagnes, are called sparkling wines and are effervescent due to the CO_2, which is also formed by a fermentation step in the wine-making process.

In this chapter, carbonation refers mainly to the man-made effervescence resulting from the physical addition of CO_2 gas into water or beverage.

The effervescence in these beverages (natural spring water, beers, and wines) can, in a sense, be attributed to a carbonation process. In CSDs, carbonation is a man-made process of physically introducing CO_2 gas under pressure into the beverage (or into water with which the final beverage can be prepared). In this chapter, the term carbonation will, therefore, refer mainly to this physical process of adding CO_2 gas into water or into the beverage.

A LITTLE BIT OF HISTORY

The CSDs in the form of carbonated water, go back in history to the effervescent mineral waters from natural springs. Bathing in such waters was long believed to have health-giving results, and the waters were often considered as having curative powers as well. The natural conclusion was, therefore, that, when potable, drinking these waters would also result in a contribution to one's health. These carbonated mineral waters were sometimes called "seltzers," apparently after the name of the natural springs of carbonated water near a small German village called Niederseltsers.

An English scientist, John Priestly, first carbonated a glass of water artificially in 1767 by dissolving the gas formed from the fermentation process from a nearby beer brewery, in the water (not knowing at the time that it was CO_2 gas). A few years later, a Swedish chemist, Torbern Bergman, generated large amounts of CO_2 by treating chalk with acid. The path was opened that eventually led, in gradual steps, including CO_2 production from sodium bicarbonate reaction in acid solutions, through the gas production from dry ice CO_2 converters, to the modern CSD carbonation processing equipment using the huge bulk storage vessels of pressurized liquid CO_2.

During this development history, the idea arose to add sugar and flavors to carbonated waters. In the late 19th century, the soda pop industry in the U.S. was born. CSDs were mass produced in factories and filled into glass bottles. However, difficulties were encountered in retaining the CO_2 in the bottles due to the pressure created. Only after the crown-cap-type of closure was invented

in 1892 was the problem fully solved. This closure prevented the gas from escaping from the bottle, and it completely revolutionized the industry. This closure is still being used to this day.

The name "soda pop," first used in the U.S. for CSDs, apparently derived its name from the combination of two items: first, from the bicarbonate of soda (sodium bicarbonate) powder also used to make beverages fizzy; and second, from the popping sound of the CO_2 escaping when a crown closure was pried off the bottle of a carbonated beverage. Later, some people referred to CSDs as soda, while others called it pop.

In the last decade or two, bottled waters have become very popular and are the second biggest soft drink category in sales volume globally. Many of these natural subterranean waters products are artificially carbonated. Some even have mineral salts added, thus completing the circle that began with the original natural seltzer waters of many years ago.

CARBON DIOXIDE (CO_2)

Carbon dioxide is a natural gas. It is present in the air at a very low level of about 0.03% by volume. It is a vital substance to the plant kingdom for the process of photosynthesis, in which it is converted, using water and sunlight energy, into carbohydrates. These, in turn, serve as nutrients for the growing plant and help to build its main cellular structural component, cellulose.

Carbon dioxide can exist in three forms: gas, solid (dry ice), and liquid (under certain pressure levels). It has physical and chemical properties that render it ideal for the role it plays in carbonated beverages:

- It is a nontoxic, colorless, and odorless gas that does not impart any flavor to the beverage.
- It is nonflammable and presents no fire hazard when handled.
- It is soluble in water and dissolves easily in the beverage.
- Its solubility can be controlled by regulating the temperature and pressure relationship.
- In water, it forms a weak acid (carbonic acid) that gives the beverage its typical tart taste note.
- The carbonic acid can retard the growth of many common microorganisms.
- Carbonic acid easily releases CO_2 gas to create effervescence when the beverage is consumed.

The soft drinks industry is one of the largest markets for CO_2.

Carbon dioxide is produced in various industrial chemical processes, where it is often a by-product of sufficient volumes to warrant further processing into the purified product used in the soft drinks industry. This is most commonly supplied to the bottler in the pressurized liquid CO_2 form by specialist industrial gas-producing companies. This liquid CO_2 can be delivered in gas cylinders. However, in most reasonably sized soft drink operations, the liquid CO_2 is normally transported to the bottler's site and transferred into refrigerated bulk storage pressure vessels owned and maintained by the supplier. These liquid CO_2 plants on the bottler's site are designed to deliver CO_2 in its gaseous form when drawn off for production purposes.

Soft drink companies have strict specifications regarding purity and general quality of liquid CO_2. It is recommended to only deal with suppliers that can meet these specifications. A bottler does not normally have the equipment or the expertise for testing for specification details. However, some basic routine testing of CO_2 for taste, odor, and appearance can be performed. This is done by gently bubbling some CO_2 gas that is drawn from an on-line sampling source through a sweetened and acidified water solution simulating an average beverage product. After a specified time of dispersing the CO_2 in the solution, it is tested for taste, odor, and appearance against a control

solution. There should be no off-tastes or off-odors in the test sample, which should also be clear of any turbidity or foreign matter.

Also, to ensure the quality of the CO_2 used in production, bottlers may install in-line activated carbon cartridge filters. These would remove any taste or odor defects that could be introduced in the supply lines from the CO_2 vessels that were installed by the company.

CO_2 used in CSDs must meet very high purity criteria.

Impurities related to off-tastes and off-odors can be present in the CO_2, but this would be a rare occasion. However, one must be continuously on guard against such occurrences, as they can be costly to a company should defective final product reach the trade and the consumer. I think that effective, routine, on-line periodic quality testing for taste and odor would normally pick up such defects in time to prevent suspect stocks from going out into the trade.

GAS VOLUMES

Water at 15.6°C (60°F) and at 1 Atm of pressure will dissolve a quantity of CO_2 equal to its own volume. In other words, 1 liter of water at this temperature and pressure can absorb 1 liter of CO_2. At 15.6°C (60°F) and at 1 Atm of pressure, CO_2 has a density of 1.86 (air = 1.00). This means that at these conditions, 1 liter of water would contain 1.86 g of dissolved CO_2. At different temperatures and pressures, the volume of CO_2 capable of being dissolved in 1 liter of water will change. At temperatures below 15.6°C and at pressures above 1 Atm, there could be more than 1 liter of CO_2 dissolved in the water.

It has, therefore, become a practice to speak of the amount of CO_2 dissolved in a CSD in terms of how many CO_2 volumes it contains. These are called gas volumes, and they are the unit of measurement for the level of carbonation in a CSD. The relationship between temperature and pressure in the water

Carbonation levels in CSDs are measured and spoken of in terms of CO_2 gas volumes.

determines how many volumes of CO_2 it can dissolve. This is governed by somewhat complex physical chemistry principles known as the gas laws. To carbonate a beverage to a target gas volume, the beverage must be at a certain temperature. A corresponding pressure for that temperature must be applied in order to allow the required amount of CO_2 to be dissolved.

In a similar manner, to measure the amount of CO_2 in a bottled CSD or, in other words, to measure the beverage gas volume, the pressure in the bottle must be determined as well as the temperature of the beverage at the time of the test. By the gas laws principles, the volume (or weight) of the dissolved

The gas volume of a beverage is calculated from its temperature and pressure relationship.

CO_2 can be calculated. (Gas volume testing will be described in the following section of this chapter.) We do not need to perform such calculations, as the scientists have made life easy for us. Gas volume charts were prepared covering all the practical temperature and pressure values that could be encountered in soft drink carbonation testing. By looking up the temperature of the sample and the pressure measured in the bottle at the time of testing, a corresponding gas volume value is indicated.

Gas volume charts are available from suppliers of carbonation testing equipment. For interest sake, a small section of a nominal gas volume chart is given in Table 12.1 to give the reader an idea of how this works. (A full chart could take up a few pages in a book.) Looking at the gas volume chart section

A gas volume chart, or the electronic calculator equivalent, is required for a carbonation test.

in Table 12.1, one can see the interaction of temperature and pressure on the carbonation level in a beverage. If, for example, a gas volume test indicated a pressure of 30 psi at a beverage temperature of 10°C, the corresponding carbonation would be 3.6 gas volumes.

TABLE 12.1
Section from a Nominal Gas Volume Chart for Carbonated Soft Drinks

Temperature		Pressure (psi)					
		20	22	24	26	28	30
°Fahrenheit	°Celsius	Gas Volumes					
43	6.1	3.2	3.4	3.6	3.8	3.9	4.1
44	6.7	3.1	3.3	3.5	3.7	3.9	4.0
45	7.2	3.1	3.3	3.4	3.6	3.8	4.0
46	7.8	3.0	3.2	3.4	3.5	3.7	3.9
47	8.3	2.9	3.1	3.3	3.5	3.6	3.8
48	8.9	2.9	3.1	3.2	3.4	3.6	3.7
49	9.4	2.8	3.0	3.2	3.3	3.5	3.7
50	10.0	2.8	2.9	3.1	3.3	3.4	3.6

As the temperature values increase for a specific pressure column in the chart, the gas volume will decrease. For a specific temperature row, as the pressure increases, the gas volume will increase. This is in accordance with the CO_2 solubility properties discussed previously. The gas volume chart is needed for carbonation testing with manually operated testing equipment. Instead of using a chart, gas volume calculators are available in which the gas volume value is instantly displayed after manually entering the relevant temperature and pressure values into the instrument. Sophisticated computerized testing equipment is also available, with which the entire carbonation test is controlled electronically. There is no need for the chart or calculator, as the computer records the temperature and pressure data and calculates the gas volume, which is then displayed on the LCD screen of the instrument.

TESTING FOR GAS VOLUMES

The carbonation level of a CSD is a key sensory quality parameter. Frequent on-line gas volume tests are a "must."

The carbonation level is a key factor for the characteristic taste profile of the beverage. If it is too low, the beverage will be perceived as "flat." If it is too high, it will be considered too tart. In either case, the average consumer will very likely consider the beverage as of substandard quality. Therefore, it is essential to monitor the gas volume of product being filled at frequent intervals as part of routine online quality control (QC) monitoring.

The gas volume test should be quick, simple, and accurate. There are various types of gas volume testing equipment, from the simple classical equipment assemblies to the sophisticated computerized models now available from specialist suppliers. Basically, the methodological principles are identical in all testing equipment and have one aim: to measure the internal CO_2 pressure in the bottle or can and to determine the temperature of the beverage at the time of the pressure measurement. From these two values the gas volume of the sample can be established. The latter can be read off a simple gas volume chart or obtained from a gas volume electronic calculator.

In order to briefly outline the typical gas volume test method, I will use, for simplicity purposes, the "old-fashioned" classical testing equipment assemblies. A schematic drawing of this equipment is given in Figure 12.1. Item 1 in this drawing is the pressure gauge and bottle clamp assemblies
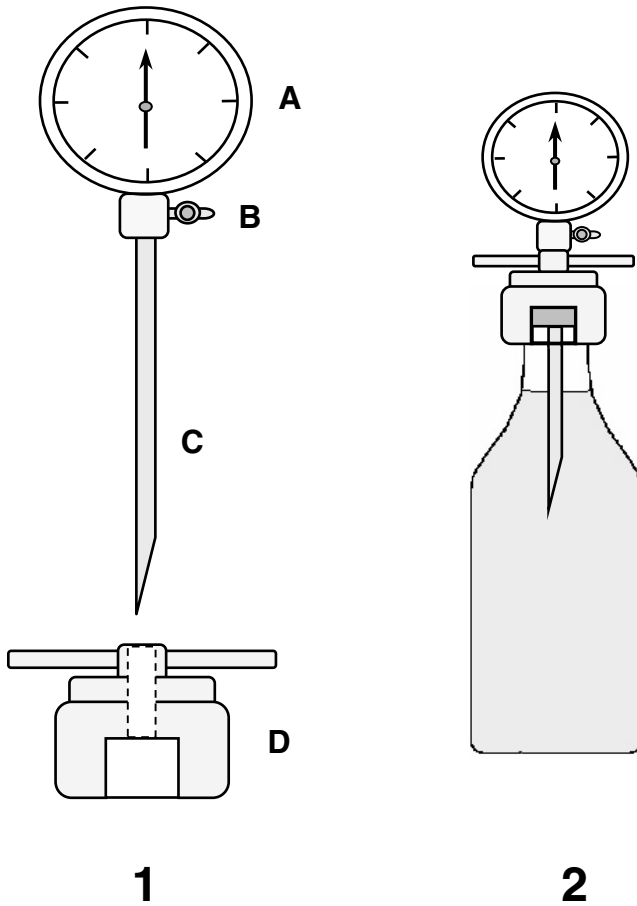
FIGURE 12.1 Gas volume test equipment.

used in the gas volume test. Item 2 shows the assembled testing equipment attached to a sample bottle during a gas volume test. The actual test of a bottled beverage involves a few simple steps, as follows:

Step 1: The sample to be tested must be allowed to stand a few minutes before the test in order to let the CO_2 pressure in the bottle and headspace to reach a steady stabilized equilibrium state (as the bottle may have been shaken or agitated while sampling and transporting it to the laboratory).

Step 2: The bottle clamp (D) is affixed to the neck of the bottle, and the clamp lever is screwed so that the base of the clamp, which has a thick disk of hard rubber, is pressed tightly against the top of the bottle cap.

Step 3: The snift valve (B) on the gauge assembly is closed tightly, and the piercing tube (C) is placed in the top opening of the clamp. The entire clamp assembly has a hollow central core through which the piercing tube is gently pushed downward. Before reaching the bottle cap, the tapered sharp point of the tube passes through a tight-fitting narrow hole in the hard rubber disk that is pressed against the bottle cap.

Step 4: When the piercing tube point reaches the bottle cap, it will be stopped, and the operator will know that the cap was reached.

Step 5: Holding the bottle and attached equipment assembly firmly with one hand and in an upright position on the workbench, the gauge assembly is pressed downward, using the other hand, with enough controlled force to pierce the bottle cap. (The force must be controlled to prevent the gauge assembly slipping down and knocking the clamp after piercing the cap. A hard enough knock could create a shock through the bottle that would cause the release of some of the CO_2 in the beverage into the stabilized headspace of the bottle. The additional released CO_2 could affect the test result, as the normal stabilized headspace gas will be removed before measuring the pressure in the bottle in the next step.)

Step 6: The clamp lever is now tightened a bit more to secure the gauge assembly in the clamp. The snift valve is opened to allow the pressure in the headspace to escape. It is then quickly turned back to the closed position.

Step 7: Holding the bottle and attached equipment assemblies in both hands, the bottle is shaken vigorously, while the needle of the pressure gauge (A) is watched. Shaking is continued until the gauge needle registers no further increase in pressure. The shaking releases the CO_2 from the beverage, and a gas pressure will develop in the bottle.

If the bottle is made of glass, it is advisable to cover the entire bottle with a safety hood or cloth in case the bottle bursts during the shaking operation. A bottle with a fine crack defect could burst, especially if the gas volume is unusually high in the bottle being tested. Using a shaking table is a common alternative to the manual operation, especially when numerous samples are tested at the same time.

Step 8: When the gauge ceases to register any increase in pressure, the shaking is stopped. The stop in pressure increase indicates that all the CO_2 was liberated from the beverage. The needle of the gauge will point to the highest pressure attained. This pressure value is recorded as P psi (or in whatever pressure units are being used).

Step 9: The snift valve is released gently (to avoid a spurt of pressurized product from the bottle), and the headspace gas is released until the gauge registers zero pressure.

Step 10: The equipment assembly is quickly dismantled from the bottle, and a suitable thermometer is suspended in the beverage through the pierced hole in the bottle cap. The temperature is recorded as T degrees Celsius or Fahrenheit.

Step 11: Using the P and T values from the test, the gas volume of the sample is determined from a suitable gas volume chart.

This then is a completed gas volume test, which can be performed in a matter of minutes by a skilled and experienced operator. The key requirements for a successful and accurate gas volume test are as follows:

- An accurately calibrated pressure gauge
- Avoidance of excessive bottle shaking or agitation before the test
- No air leaks in the clamp and gauge assembly equipment
- Avoidance of a hard knock on the bottle while piercing the cap
- An accurate thermometer

All the other various available gas volume testing equipment types and models basically follow the same above-described step-by-step procedure in one manner or another.

CARBONATING THE BEVERAGE

Most CSD operations use the system of water-to-syrup proportioning at the filling machine. In such systems, a liquid mixture of syrup and water is obtained at the target Brix of the final beverage to be filled. All that is needed to convert this liquid to final beverage is to carbonate it at the specified gas volume of the beverage flavor.

Carbonation of the beverage is done at the filling machine by regulating temperature and pressure to achieve the target gas volume.

Different flavors have characteristic carbonation levels. Colas, lemonades, ginger ales, tonic waters, and soda waters usually have high gas volume values between 3.0 and 4.0. Fruit flavors and cream sodas tend to have lower carbonation levels in the range of 2.5 to 2.8 gas volume. Sparkling mineral waters normally have gas volumes below 2.0.

To carbonate a specific final beverage at the filling machine, the production operators will know from experience to what temperature it must be cooled and at what pressure to feed the CO_2 gas into the liquid. If necessary, the operator will consult a gas volume chart and set temperature and pressure levels accordingly. For the higher gas volume products, the operator will normally work around a temperature of less than 10°C and at pressures around 30 psi or higher. Equipment capabilities and limitations may also influence the operator's chosen temperature and pressure settings.

The beverage to be carbonated can first be cooled in a separate cooling unit and then carbonated in a dedicated carbonator unit. Many filling machines have a unit called a carbocooler that does these two processes of chilling and carbonation simultaneously. After the cooling and carbonating process, the liquid, which to all intents and purposes is now actually a carbonated final beverage, is transferred to the filler bowl. The filler bowl is kept under CO_2 pressure for two main reasons.

First, the "head" pressure in the bowl keeps the dissolved CO_2 of the beverage in the liquid. Second, there is the matter of counter-pressure. Most fillers work on the gravity-filling principle — the beverage runs out of the bowl, by the force of gravity, through the filling valves, and into the bottles or cans. In order to achieve this gentle gravity-induced flow of liquid

"Counter-pressure" and "snifting" are two key principles in the operation of most CSD filler bowls.

from filler bowl into bottle, the pressure formed from the dissolved CO_2 in the bottle as it is being filled must be negated. If not, the bottle would, at a certain stage of its filling operation, contain enough CO_2 pressure to stop the inflow from the filler. Therefore, the bowl must contain a pressure equal to that in the bottle in order to allow for a free flow of beverage through the filling valve, into the bottle. This pressure in the filler bowl is the counter-pressure mentioned above.

Another issue related to the carbonation aspects of CSD filling is that of snifting. In order to provide the free gravity flow of beverage from the bowl into the bottle, the entire system of bottle, filler valve, and filler bowl must be "airtight" — it must be one continuous system without any leaks. For this purpose, the filler bowl operation is designed so that in a certain stage of its revolution on its axis, the empty bottle is raised upward, and its mouth is pressed firmly against the rubber cup of the filling valve, creating an airtight seal. However, as the bottle is slowly filled, the CO_2 in its headspace is compressed, and a stage arrives where it must be released from the bottle. This is to allow further filling and to prevent the bottle from bursting under the increased pressure. This removal of excess pressure is achieved by opening the snift valve of the filling valve, again at a certain stage in the cycle of the revolving bowl.

In all my years spent working in or visiting at bottling plants, I never ceased to marvel at the ingenuity involved in a CSD filler bowl operation. The two instances mentioned above, the snifting and counter-pressure devices, are but a few of many other instances of what I consider "mechanical wonders" involving the machining precision, timing, synchronization, and general engineering inventiveness that can be observed in a single rotation of a filler bowl unit.

CO₂ AS AN INGREDIENT STOCK ITEM

CO₂ is an ingredient, and, like any other, it needs to be controlled with respect to cost, yield, and inventory.

CO_2 is very much an ingredient as is sugar, flavor, preservative, or any other component of a CSD. As such, its inventory, usage, and yield statistics factors need to be monitored and controlled. At first it would seem that the few grams of CO_2 contained in a bottle or can of beverage is a negligible quantity and needs no special attention.

However, this is not the case. Consider the fact that a 1 liter bottle of beverage at 3.8 gas volume contains about 7.5 g of CO_2. A medium-sized CSD operation producing 20 million liter per year of such a beverage would use about 150 tons of CO_2 annually. An acceptable 10% overusage can be added to this in the form of losses in carbonation processes, counterpressure, line flushing, etc., making it 165 tons per year. Bulk liquid CO_2 prices vary considerably and depend on many factors, such as transport costs to the customer's site, consignment quantities, monthly off-take, etc. Whatever the final delivered CO_2 is, this 165 ton per year usage can amount to a significant sum that needs to be respected and controlled as far as CO_2 yields and variances are concerned. To calculate the beverage CO_2 content in a CSD container of a specific size, a formula is used:

$$\text{Grams } CO_2 = (\text{Gas Volume}) \times (\text{Container size in Liters}) \times 1.977$$

where 1.977 is the density of CO_2 at 0°C.

Data tables of CO_2 content in beverages at different gas volumes of various container sizes can easily be compiled from this formula, as per the example in Table 12.2.

TABLE 12.2
Weight of CO₂ (g) in Beverages at Various Gas Volumes

Carbonation Level in Gas Volumes	Container Size (ml)				
	300	500	1000	1500	2000
1.60	0.9	1.6	3.2	4.7	6.3
1.80	1.1	1.8	3.6	5.3	7.1
2.00	1.2	2.0	4.0	5.9	7.9
2.20	1.3	2.2	4.3	6.5	8.7
2.40	1.4	2.4	4.7	7.1	9.5
2.60	1.5	2.6	5.1	7.7	10.3
2.80	1.7	2.8	5.5	8.3	11.1
3.00	1.8	3.0	5.9	8.9	11.9
3.20	1.9	3.2	6.3	9.5	12.7
3.40	2.0	3.4	6.7	10.1	13.4
3.60	2.1	3.6	7.1	10.7	14.2
3.80	2.3	3.8	7.5	11.3	15.0
4.00	2.4	4.0	7.9	11.9	15.8
4.20	2.5	4.2	8.3	12.5	16.6
4.40	2.6	4.3	8.7	13.0	17.4
4.60	2.7	4.5	9.1	13.6	18.2
4.80	2.8	4.7	9.5	14.2	19.0
5.00	3.0	4.9	9.9	14.8	19.8

OTHER ITEMS RELATED TO CARBONATION

A few more items of interest related to the subject of carbonation are described in the following sections.

PET Bottles

Despite the numerous advantages of PET bottles over their glass counterparts, they still fall short in one aspect — the PET material is not a 100% gas barrier. PET bottles under the internal CO_2 pressure will gradually, over time, lose the gas by diffusion through the bottle walls. This results in a drop in carbonation levels. For this reason, most soft drink companies allow a shelf life of about 3 months for their products in PET bottles.

It would also appear that the smaller the bottle size the more rapid is this carbonation loss. This probably has to do with the greater volume-to-bottle-wall-area ratio in a smaller bottle. To counter this gradual loss of CO_2 in PET bottles, many soft drink companies carbonate their products in PET at higher gas volume levels than those for the same product in glass or cans.

Gas Volume Specification

Most companies work with a ±0.25 gas volume tolerance range from the specific target carbonation level of a particular product. To address the CO_2 loss from PET bottles, the upper tolerance range is often increased by up to 0.5 gas volumes.

> Not many years ago, many soft drink companies lowered the gas volume specifications of products with high carbonation due to incidents of bursting glass bottles and the phenomenon of "missiles" with PET bottles. (The latter, when dropped or bumped hard enough, developed a small crack in the bottom. The bottle, under high carbonation, could literally take off in rocket fashion.) Flavors with normally high gas volumes, like soda water (5.0) and lemonade (4.0), had their specifications lowered to about 3.8 gas volumes. This often becomes the stipulated maximum level for any CSD.

Altitude Correction in Gas Volume Testing

At sea level, the column of air in the atmosphere above the land has weight, and it exerts an average pressure of 14.7 psi. This is the atmospheric pressure at sea level. At a higher altitude than sea level, this column of air decreases in weight and, therefore, exerts less pressure. In an aircraft, the pilot's altimeter, a kind of pressure gauge, is calibrated to sea level pressure so that he or she knows at what absolute height above sea level the plane is flying, no matter the actual location at the time.

Altitude correction for gas volume testing — another "hair-splitting" issue?

In a CSD plant at the coast, the pressure gauge used in a gas volume test is zeroed (e.g., by a dead-weight gauge tester) at 14.7 psi, the sea level atmospheric pressure. All pressure readings of CO_2 in the bottle for the gas volume tests indicated on this gauge include the local prevailing 14.7 psi of atmospheric pressure. Another way of putting this is to say that the pressure in the bottle includes the 14.7 psi atmospheric pressure.

Let us take a case where a bottle manufactured at the coast (at sea level) is, for some reason, brought inland to a higher altitude location *X* and then tested for gas volume. The pressure gauge used in the test at this location, unlike the aircraft's altimeter, would naturally have been zeroed locally and would, therefore, be at a lower atmospheric pressure than that of sea level (at which the beverage was manufactured). The bottle, being perfectly sealed, would still contain the additional sea level atmospheric pressure.

The pressure reading taken on this gauge during the gas volume test at location *X* would include this additional atmospheric pressure. The resultant gas volume determination of the beverage, using this inflated pressure reading, would be slightly higher than what it was when the bottled was

originally filled at the factory's coastal location. In order to obtain the true gas volume of this sample, we would need in this test to subtract from the pressure gauge reading the atmospheric pressure difference between sea level and that of location *X*. If the situation was reversed, i.e., filled at *X* and tested at the coast, the atmospheric difference would need to be added to the pressure gauge reading. The following general rule would therefore apply:

> When a sample of CSD is tested for gas volume at a geographical location at an altitude different than that at which it was manufactured, a pressure correction must be made to the pressure reading obtained in the gas volume test.

To calculate the correction *P*, the following formula can be used:

$$P \text{ (in psi)} = (A_m - A_t) \times 0.00164$$

where
A_t = the altitude at the location where the sample is tested;
A_m = the altitude at the location where the sample was manufactured; and 0.00164 = the atmospheric pressure change (in psi) in 1 m altitude difference.
If A_t is higher than A_m, *P* will have a negative value and must be subtracted from the pressure reading of the test.
If A_t is lower than A_m, *P* will have a positive value and must be added to the pressure reading of the test.

In order to quantify this correction impact on gas volumes testing at different altitude locations, let us take a numeric example, as follows:

- Beverage filled at location *M* at 250 m altitude
- Beverage tested at location *T* at 1470 m altitude
- Temperature of gas volume test at location *T* = 10°C
- Pressure reading in test = 30 psi

Consulting the gas volume chart in Table 12.1, we see that at 10°C and 30 psi, the carbonation of the beverage will be 3.60 gas volumes. No correction for altitude difference was applied. If we work out the correction *P* according to the given formula, this will be:

$$P \text{ (in psi)} = (250 - 1470) \times 0.00164 = -2.0$$

How significant is this altitude correction?

The negative value of *P*, –2.0, must be subtracted from the actual reading of 30 psi. This will result in a corrected pressure reading of 28 psi. From the gas volume chart, the carbonation will now be shown as 3.40 gas volumes, as opposed to the uncorrected value of 3.60. The question now is whether this difference in gas volume results using altitude corrections is of any significance — is it a train smash or merely a banana peel on a roller coaster rail?

Normally, it is not of much significance. First, regardless of what the true reading is, the beverage contains the amount of CO_2 with which it was prepared. There is no actual loss of gas when the bottle travels from one location to the other. Second, even if such a loss occurred, a 0.2 psi difference in pressure sensory-wise is not all that serious.

The testing of gas volume could be part of a quality monitoring program based on reporting test results on a pass or fail basis. For the particular beverage tested, if the gas volume specification

was 3.20 ± 0.20, the uncorrected result, 3.60, would be above the allowed upper tolerance limit of 3.40 by 0.20 psi. The sample would be deemed a "fail."

With the altitude-corrected system, the gas volume of the sample would be spot on at 3.40 gas volumes, the value at which it was originally bottled at location *M*. It would receive a "pass" disposition. To report the sample as a fail would not be doing justice to the production and QC staffs of the plant at location *M*. Moreover, many quality monitoring programs include a quality index rating for the plant or even for each filling line in the factory. This quality index is usually based, in one manner or another, on the number of passes as a percentage of total number of samples tested. Not to include an altitude correction for gas volumes, much like not using a temperature correction for Brix readings, is going to skew the quality index ratings considerably — both up and down. In such a case, the quality rating system would not only be meaningless but could get many QC and production personnel's backs up.

In conclusion, it is up to the technical management of soft drink companies to decide whether to include the altitude correction factor in gas volume testing. This, of course, applies only to cases in which carbonation testing of beverages produced in other locations at different altitude levels is practiced. It is advisable to be aware of the altitude correction issue in case the occasion arises where the issue of gas volumes of beverages produced at different altitudes somehow enters the picture. The correction for altitude in carbonation testing is a matter of scientific precision. For this reason, it was elaborated upon in this chapter.

CHAPTER REVIEW

The carbonation level of a CSD is a key intrinsic component of the beverage's taste profile. For this reason, continuous on-line gas volume testing and monitoring during the filling operation is of paramount importance.

CO_2 is an ingredient of CSDs, and as such, its utilization needs to be monitored and controlled for both quality assurance and costing purposes. This chapter attempted to provide the basic principles of carbonation in CSDs with respect to CO_2 properties, the process, and quality control.

13 Unitization — A Unique Ingredients System

CHAPTER OVERVIEW

Unitization is the system in which the prescribed quantities of all the ingredients for a soft drink formulation, other than the water, sugar, and CO_2, are preweighed and packed for a standard unit volume of final beverage. Thereafter, the combined pre-packed ingredients, which may be contained in one or more individual packs, are delivered to the soft drink operation in ready-to-use form for the manufacture of syrup or bulk ready-to-drink (RTD) product. This combined ingredient pack entity is called a unit, hence, the term "unitization."

Unitization is a system in which ingredients are packed in pre-weighed quantities for an established unit volume of final beverage.

Unitization systems are practiced in one form or another by most of the large international soft drink companies that demand that their beverages, made in bottling and canning plants all over the world, will be of the expected identically high standard quality. The unitized ingredients are prepared in special factories, sometimes referred to as beverage base plants.

These plants are specifically dedicated to sourcing ingredients from the most reliable suppliers that use thorough methodical testing of ingredient quality and rigorously controlled measuring of ingredient quantities for the unitized products. These beverage base plants operate under strict secrecy conditions, and justifiably so, as they deal with confidential proprietary formulations and processes of company products. This chapter does not intend to discuss the specifics of a beverage base plant operation. Rather, it aims to discuss the technical aspects and general operating principles of a unitization system, the advantages involved, and the purposes it could serve for an independent soft drink business operation.

Unitization could very roughly be compared to a do-it-yourself (DIY) kit. Regardless of whatever the kit is actually designed for, the DIY principle aims to take the guesswork out of the job for the nonspecialist person. DIY kits are also aimed at the individual who cannot be bothered with the details and wants to get the job done with minimum hassle, in the least time, and with the best results. Thus, for example, a beer-loving person may acquire a DIY home-brew kit to make his own brew, while the inexperienced tropical fish novice may go for a DIY fish-tank kit, complete with all accessories (and a few fish), for rapid hassle-free installation at home in one go.

To describe unitization as a DIY is somewhat farcical and does not do justice to the unitizing system. However, one of its main purposes is similar to that of the DIY principle: to free the user from any guesswork and to ensure that the end product will be a success — provided prescribed instructions are adhered to.

NONUNITIZED SYSTEMS

Before discussing the details of unitization systems in soft drink plants, it would be worthwhile to briefly review how batches of final syrup or bulk RTD beverage are prepared from ingredients for filling runs of final product in regular nonunitized systems. This review will serve as a comparison when discussing the details of unitization. For the purpose of this review, we will use an example

of a soft drink company that has a yearly production of 20 million liters of carbonated beverages and uses the water-to-syrup proportioning system for filling final beverage. We will assume that the company has a few brands covering a range of about 15 different product flavor variations.

The basics of a standard nonunitized system are presented to be used as a comparison with unitization.

For this review, the following could serve as a typical scenario for a plant that has a reasonably structured departmental organization with basic computerized logistics and accounting facilities:

1. Procurement of ingredients and quantities thereof is based on inventory and production forecasts. Consignments of ingredient deliveries are tested by quality control (QC) and released to stores for issue to production when required.

2. Production's syrup-making section receives hard-copy bills of materials (BOMs) for syrups required for the week from logistics' production schedules. These BOMs indicate the batch sizes of the syrups required that might not always be the same as previously prepared batches' sizes. The BOM for each flavor indicates the quantity, in kilograms or liters, for each ingredient. These quantities are computed from a database of master formulations of the products.

3. Copies of these BOMs are delivered to a section under QC control (or production supervision) called the dispensary. The dispensary maintains a small inventory of all formulation ingredients, which they periodically replenish from the main stores. Staff in the dispensary, under the supervision of a fairly qualified and experienced person, measure out the required quantities of ingredients (other than the sugar and water which are handled by the syrup-room staff), using scales or volumetrically graduated vessels.

4. The individual quantities of each ingredient can vary from a few grams (e.g., for colorant powders) to several kilograms or liters for acidulants and flavorants. These quantities are dispensed into suitable containers, such as paper or polyethylene bags, plastic tubs or containers, etc., each container being of suitable format and size for the nature and quantity of ingredient involved.

5. Each container is suitably labeled as to its identity, quantity, and syrup product batch in which it is to be used. The ingredient packs for each syrup batch are grouped and stored together in a suitable site in or near the dispensary site.

6. When the grouped ingredients are required for the preparation of the batch, they are collected by syrup-making staff and are transferred to the syrup room.

7. Syrup-room staff have, in addition to the hard-copy BOM, a master mixing instruction document for the preparation of the syrup batch, according to which the ingredients are added in a prescribed manner and sequence to the syrup tank designated for the particular batch.

8. The final syrup batch is completed and released, after QC testing, to the filling line.

This then, in a nutshell, is the basic typical scenario in which the ingredients, other than the sugar and the water, are handled from time of receipt of suppliers' consignments through the various supply chain stages up to the final step of syrup preparation. This type of system works very well, not only in the soft drinks industry but also in many other food-processing industries. However, there are some error-vulnerable junctures in the system that were not mentioned above, as these will be highlighted in the detailed description of the unitization system.

THE BEVERAGE BASE UNIT

The following are the key points of the beverage base unit — the physical entity around which the entire unitization system revolves.

Unit Design

The unitization system uses a standard volume of final beverage for all the company's products. In our example soft drink plant used in the previous section review, we will assume that the smallest practical filling run of final beverage for the slowest moving product in the plant is 5000 liters. Therefore, for the purpose of our discussion of unitization, we will establish 5000

A standard volume of final beverage serves as the base unit size on which the system operates.

liters final beverage as the unit size upon which the system is to be based. For the purpose of unitization, all final beverage formulations will need to be converted to this 5000 liters unit size basis. It naturally follows that final syrup formulations will also need to be converted to the 5000 liters basis.

All the ingredients for a final beverage or syrup formulation, excluding the water, sugar, and CO_2, can be referred to as the beverage base of the product. This term will be used throughout the chapter to designate these ingredients. The principle of unitization is the following. The beverage base ingredients are mea-

Formulation water, sugar, and CO_2 are not included in the unitization system.

sured out in quantities for the standard 5000 liters unit volume of final beverage and packed into suitable containers. Ingredients that are suitable for being mixed together are packed into the same container.

This principle is illustrated in Figure 13.1, which outlines how a beverage base unit for a particular final beverage is designed. A BOM is displayed, as an example, for 5000 liters of a relatively simple nominal formulation for final beverage XYZ. We will now go through the BOM and see how this formulation is unitized. As mentioned before, the 550 kg quantity of sugar is not involved in the unitization system. The water was excluded from this BOM example, as it also is not part of the unitization system.

The preservative sodium benzoate quantity of 1.000 kg is measured out and packed into a small poly-lined paper bag. It is packed on its own, as it must be added first and separately to the other ingredients during the syrup-making process (see Chapter 9). This pack of preservatives is called Part 1. The powder quantities of citric acid, sodium citrate, and colorant are weighed out. As they are compatible with each other, they are all added to a single poly-lined paper bag of a size that can accommodate the total powder weight of 10.750 kg. This bag is called Part 2. The 5.000 kg of flavor is weighed out into a standard-sized 5 l HDPE (high-density polyethylene) can (commonly referred to as a "polycan"). This is Part 3. Last, the 6.000 kg of cloud is weighed out into a suitably sized polycan, which becomes Part 4.

These four packs, which will be labeled by their respective Part numbers, are referred to as Part Units. When combined, they constitute what would now officially be referred to as one full unit of beverage base for 5000 liters final beverage XYZ.

The combined Part Units make up a full unit of beverage base.

In normal parlance, this full unit would be called one unit of XYZ — the term "full" would only be used to distinguish it from a Part Unit when such occasions arise. The descriptor, "5000 liter final beverage," is also omitted, because in this particular unitization system, all units would be designed on the unique 5000 liter final beverage basis.

With respect to this brief general explanation of how a beverage base unit is designed, the following points should be noted:

1. All Part Units are sealed with tamper-proofing devices applicable to the type of packaging used.
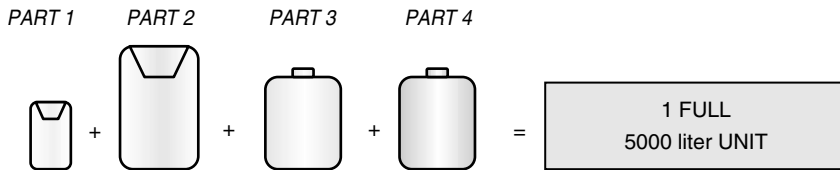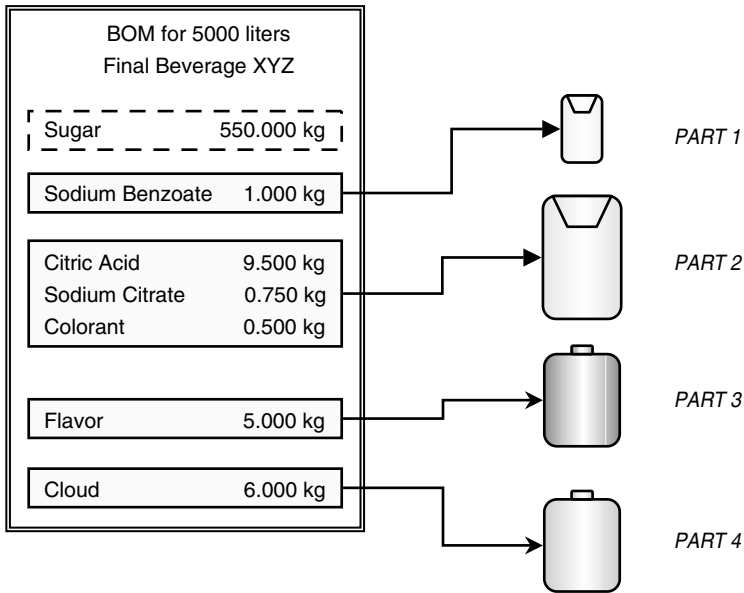
FIGURE 13.1 Beverage base unit design.

2. Different beverage formulations could have different numbers of Part Units. This would depend on the nature of the formulation. A naturally sweetened cola formulation would normally have two Part Units. On the other hand, a "diet" version of the example beverage XYZ, with several separate intense sweetener components, may have five or more Part Units.

3. A certain measure of rationale in the numbering of the Part Units should be maintained. When practically possible, Part 1 is reserved for the preservative ingredient; Part 2 for the acidulants and any other compatible powder ingredients that could be mixed into the paper bag; Part 3 for the flavorant, inclusive of a flavor emulsion that contains a cloud-ifying agent; and Part 4 for a separate cloud ingredient in the formulation, as in our example.

4. To further preserve this measure of rationale, which makes life easier for the factory personnel involved with unitized beverage base matters, if more than one flavor ingredient is present in the formulation and the ingredients cannot, for technical reasons, be mixed in one container, then they could be labeled as Part 3A, Part 3B, Part 3C, and so forth. A juice component could be labeled as a Part 3 flavorant.

5. The 5000 liters unit base chosen in the example should not be exceeded if another unit size base is preferred. This is noted for the simple reason that in very high-acidity beverage formulations, the acidu-lant powder ingredient, citric acid (or any other

Multiple units of the standard 5000 liters base can be designed and packed for larger plants.

organic acid such as malic acid) could well reach a weight above 40 kg in a unitization system based on unit volumes higher than 5000 liters. This could also apply to other ingredient pack weights, such as fruit juice concentrates and even dilute flavorants. This would make the Part Unit excessively heavy and would not lend itself to easy manual handling in the syrup room. Most plants using a 5000 liter unit size or lower, would not normally have a syrup room equipped with mechanized handling equipment for these heavy pack weights.

6. On the other hand, bigger plants may find the 5000 liter unit size to be too small for their large syrup batches, which are prepared for final beverage filling runs of over 100,000 liters. The answer to this is that the unitization system allows for multiple-unit parts specially designed for the "big boys" but still on the 5000 liter unit basis. For these bottling plants, larger-sized Part Units can be designed and prepared in 4×5000 liter unit quantities (for 20,000 liters of beverage). Thus, the standard 5000 liters unit is maintained as the base for the system.

   a. The multiunit principle can also be used for multifacility soft drink companies, which may have a mix of small and large plants in different parts of the country or outside of the country.

   b. A multiunit could also be used in a single plant that has, as it often happens, large-volume fast-moving brands as well as small-volume slow-moving brands. Multiunits would then be used for the former and single 5000 liter units for the latter.

   c. A further advantage for having a mix of single 5000 liter units and multiunit packs for 4×5000 liters is that by manipulating combinations of single- and multiunit packs, one could, for example, prepare a batch of syrup for 25,000 liters of beverage. For this, one single 5000 l unit and one multiunit 4×5000 pack (20,000 liter unit) could be used in combination.

7. I chose the 5000 liter size as a compromising value between smaller and larger soft drink organizations. A 1000 liter base unit size would work just as well as a 10,000 liter one — the size of the base unit should be decided upon by the company or organization concerned.

Whatever the case, with respect to the established base unit size, only one such base size should be used in a unitization system. The use of two or more base unit sizes to accommodate the different production volumes between brands or between company branches would defeat the entire standardization aim of the unitization system. This point will become clearer as we proceed to the other aspects of unitization.

Only one sole base unit size should be used throughout the company.

CODING

Every beverage base unit has an allocated code number that appears on the label of each Part Unit from which it is composed. This same code number will appear as an identifying number on the master formulation of the beverage and final syrup in which the beverage base is used. It will be recorded in syrup production batch reports.

Systematic identification coding of units is essential.

Depending on the company's information technology (IT) systems, the code number will identify the full units and Part Units in all relevant system modules, such as accounting, logistics, manufacturing, quality control, etc. This code number plays a pivotal role in inventory control, production scheduling, laboratory testing, costing, etc. Furthermore, it will serve as the key traceability factor for product complaints and for general production troubleshooting and investigations related to ingredients.

The format of the code number should be based on a rational system to allow for rapid identification of the final beverage flavor or brand and for easy distinguishing between similar beverages. As an example, OR-100 would identify an orange-flavored beverage and distinguish it from OR-200, the code number for an orange under a different brand name. A code number of OR-100-D could be for the diet version of OR-100.

This code number could be likened to a person's identification number (or Social Security number). It is the dominant identifier in the case of other "subordinate" coding systems that the company may use.

Systematic and user-friendly coding of the beverage bases is one of the keys to an effective and problem-free unitization system. This coding system should be used and adhered to in all stages of handling in all the involved company departments, such as supply chain, production, QC, accounts, etc.

LABELING

A label will be affixed to every Part Unit at the time of preparation. An example of a recommended label format is given in Figure 13.2. The key data appearing in this example are as follows:

- ORANGE: the flavor of the beverage
- OR-100: the beverage base code number
- PART 2: the Part Unit number
- 1 UNIT: indicates that this is a single unit and distinguishes it from a multiunit pack, should that also exist in the unitization system
- PU09: a possible code number in the materials handling inventory database, i.e., the SKU (stock-keeping unit) number
- 1234: the manufacturing batch number of the Part Unit
- 31/06/2000: the manufacturing date of the Part Unit
- The other text on the label is optional and self-explanatory
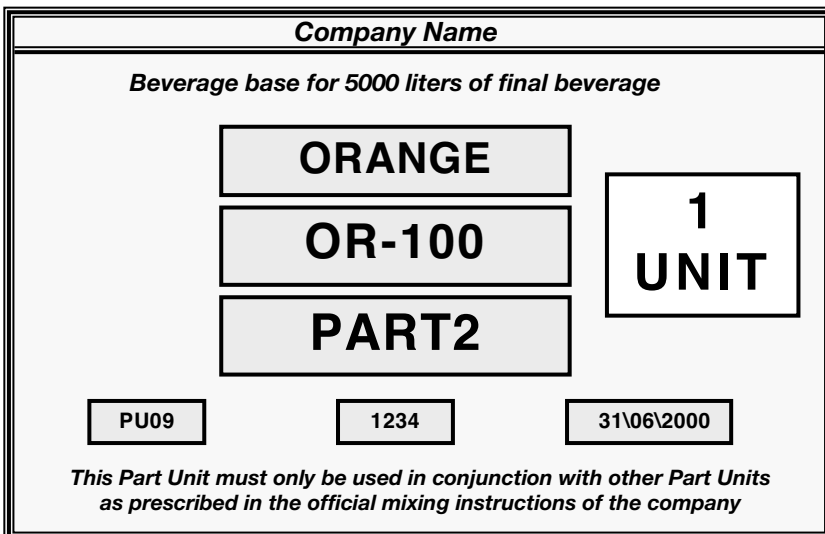
FIGURE 13.2 Label for a Part Unit.

The large-print data on the label should be typeset in size and prominence as to allow clear and quick visual identification from a reasonable distance, such as when searching for the item on racking in the storage site. Bold background coloration on the label specific to each flavor would help as well.

Effective labeling of Part Unit packs is another fundamental requirement.

Some Part Units will be small enough to be packed into outer cartons. A Part 3 flavor unit in a 5 liter polycan, as an example, could be packed four per carton. An outer carton should also bear a similar label indicating the number of Part Units contained therein. An expiry date should be stamped onto the label at the time of preparation of the Part Unit. This is of particular importance for Part Units of flavor emulsions and clouding agents, which usually have a shelf life of around 3 months. Part Units of powdered ingredients could have a 12-month expiry period.

PREPARATION OF UNITS

A soft drink company converting to a unitization system has the options of preparing the Part Units in-house or outsourcing the operation to an outside company. The latter option of outsourcing will be discussed briefly later in the chapter with respect to the advantages and disadvantages of this option. For an in-house operation, the following should apply:

1. Appropriately approved preparation instructions for beverage base units must be supplied to the staff involved, listing the Part Unit weights, tolerance ranges thereof, and manner of packing details.
2. Part Unit preparation should be conducted in a dedicated site in the plant that is divided into powder and liquid sections.
3. The section for powdered Part Units should be adequately ventilated and have a dust extraction facility.
4. The preparation site should be designed to afford optimal materials flow operation.
5. For manual filling of Part Unit packs, powder and liquid, accurate scales for the wide variety of Part Unit weight ranges must be available.

Automatic fillers with weight-control facilities would be preferred to manual filling, but this is not mandatory in view of the capital expenditure involved in such equipment.

6. Many of the liquid ingredients, such as flavors and emulsions, are purchased from flavor houses. These suppliers could be requested to supply the materials prepacked in the required quantities for some of the Part Units and, thus, exclude these from in-house preparation.
7. All ingredients used for Part Unit preparation must undergo the standard quality testing practiced in the company.
8. Upon completion of a Part Unit batch, a batch report must be made out detailing the quantity of units prepared and listing the lot numbers of ingredients used. The latter is required for tracing purposes.
9. Access to the Part Units' preparation site should be restricted to authorized personnel only. This access restriction must be rigidly adhered to.

Beverage base unit preparation is an operation in which quantity and quality parameters involved are of paramount importance. Any "mishaps" due to unauthorized access could have drastic snowballing consequences resulting in condemnation of an entire Part Unit batch, as well as of a syrup batch from which it was prepared.

10. Completed Part Units should be stored in a dedicated site with access limited to personnel from logistics, production, and QC.
11. All GMP principles applied in the plant in general should be rigidly enforced at the Part Unit preparation site.

THE FULL UNIT CONCEPT

In a unitization system, the mixing instruction for syrup manufacture will be modified to indicate the beverage base units required in place of individual ingredient quantities as in the standard system. The master mixing instruction should be designed for the preparation of syrup for one unit of beverage. It will, therefore, specify the quantity of beverage base required as one unit and list the sequence and manner of addition for the individual Part Units to the syrup tank. For syrup production orders for batches larger than one unit, the appropriate number of beverage base units will be requisitioned on the production order and issued to production. All syrup batches must be made in multiples of whole units.

The full unit concept is the entity on which the entire unitization system is based.

"Splitting of units" is a term used for the prohibited practice of removing a Part Unit from its full unit beverage base configuration. This sometimes can happen when one pack of a Part Unit is damaged (or otherwise lost) during the syrup-making process. In such a case, the full unit would not have been used. This would definitely affect the quality of the resultant syrup and the final beverage produced, should such syrup be released to production.

In order to rectify the situation in the above-described case, a Part Unit replacement must be requested from stores and issued with special approval granted from a designated authority. This approval is required, because the issuing of an "unmarried" Part Unit on its own is prohibited. An "unmarried" unit is a self-explanatory term used in unitization jargon to indicate that a full beverage base unit without its full Part Units complement is involved. An unmarried full unit is a useless item, as it would not contribute the required ingredient composition to the syrup or final beverage. Hence, an unmarried full unit is actually a potential hazard. Its use in production in incomplete form must be emphatically avoided.

Issuing a single Part Unit on its own to replace a damaged one or to complete an unmarried unit is also a kind of unit-splitting, inasmuch as stores will thereafter theoretically have one unmarried full unit in stock. This is, in theory, only because in the preparation of a Part Unit batch is it produced in large numbers of individual packs. These would not necessarily match the number of its other matching partner Part Units of the full unit configuration already in stock (or to be prepared later). Thus, it is virtually impossible to have an inventory of fully married full units at any given time. There will always be an excess of one or more Part Units in stock in stores.

Therefore, the prerequisite for an effective unitization system is to have a well-planned and balanced production schedule of matching Part Units that will result in a sufficient inventory of "fully married" beverage base units to meet syrup-making schedules.

Full units only must be used in syrup making.

The full unit concept also applies to the use of an incomplete Part Unit in syrup making. Occasionally, a bag of a powdered Part Unit breaks, and some of the powder is lost. The rule must be that the entire bag must be rejected and a full Part Unit replacement used. This is because many powdered Part Units contain more than one powdered ingredient, as was demonstrated in Figure 13.1. These powders are not homogeneously mixed, and the quantity missing from the damaged bag may contain the full content of the smaller quantity of powder ingredient in the Part Unit.

In any event, missing powder from a damaged Part Unit, regardless of which ingredient is involved, implies that the prescribed total required amount is not available. The only way to precisely replace the missing powder is to replace the damaged Part Unit with an intact one. The damaged Part Unit must be destroyed. This same principle would apply to a liquid Part Unit as well.

The full unit concept forms the fundamental principle upon which a unitization system is based. Splitting of units, use of damaged units from which ingredients have been lost, issuing of unmarried units to production, and breaking into a unit to use some of it as a replacement for lost material are all prohibited practices that are the antithesis to an effective unitization operation.

The management of a soft drink company considering a unitization system should be prepared to instill in its employees an inflexible discipline of adherence to the full unit concept.

BENEFITS AND ADVANTAGES OF UNITIZATION

Some readers, by now, may be overwhelmed or even confused by the seeming complexity of the unitization system when compared to the commonly used standard direct ingredient usage system (which, for convenience purposes, I will term the DI system in the discussion).

Unitization can appear to be somewhat complex and confusing. One can justifiably shy away from converting the DI system to unitization — after all, the devil you know is better than the one you do not know. The DI system works well — why change it?

Does the DI system really work all that well? I will attempt to answer this question by merely referring to one isolated example. This is the DI system of preparing ingredients in the dispensary for a syrup batch described in previous section of this chapter titled "Nonunitized Systems." I will address each relevant item individually and comment on it.

PROCUREMENT OF INGREDIENTS, INVENTORY, PRODUCTION FORECASTS, ETC.

It often occurs that a single required ingredient for syrup production is out of stock for one reason or another. Such reasons, to name but a few, could be the following: incorrect production forecasting, sales well above budget, defective quality discovered on testing, expiry date passed, or erroneous stock taking. An even simpler reason is that the regular supplier let the company down by not delivering the order in time or that the supplier is out of stock. The bottom line is that the syrup and the final beverage cannot be produced because a single ingredient is out of stock. This is a serious situation for any marketing business to be in.

By having buffer stocks of readily available full units, beverage production bottlenecks due to ingredients being out of stock can be avoided.

In a unitization system, as a rule, this would not occur. Beverage base units are produced well in advance of production scheduling. There would usually be a week or two of full unit buffer stocks, for all company products, for use in production until the out-of-stock ingredient situation is remedied.

Buffer stock of fully married beverage base units, immediately available to production for all company products, is a basic premise of the unitization system. Buffer stocks involve a larger weekly working capital, but this could possibly be justified by minimizing the potential loss of sales due to out-of-stock ingredients situations.

Inconsistencies in Batch Sizes of Syrups

Minimize errors in dispensing individual ingredients.

Though syrup batch sizes for a particular flavor are usually fairly consistent, occasions arise, for various reasons, when syrup production orders are placed for different-than-usual batch sizes. This is not the problem.

However, in the DI system, the dispensary supervisor and especially the staff are used to the regular quantities for the regular-sized batches. Even though they have a computer printout of the new BOM quantities on the production order, some confusion is often introduced. New different package sizes for the ingredient quantities will be required. New unfamiliar final weights have to be measured out. Scales may have to be changed to measure new larger or smaller ingredient weights. Established habit-formed routine actions in a production environment are hard to break, and errors are bound to occur.

An even worse scenario can be that a self-motivated dispensary operator may have taken the incentive of prepreparing ingredients for a few expected future batches of the regular size. To save time, the operator may decide to modify these to the new weights required. Again, error making is lurking around the corner. The dispensary worker is usually not fully engaged in ingredients preparation for syrup batches and will have other nondispensary duties elsewhere. The slight confusion that new ingredient weights may present can also lead to an element of panic. Errors can result. This general element of confusion and error-making potential to veer away from established routine production habits can also spin off to the syrup-room operators with drastic results.

In the unitization system, the dispensary staff members are not involved in the new and different syrup batch sizes problem. In fact, there is no problem at all. The syrup staff members place an order for a clearly defined quantity of units, and stores simply issue them. Syrup-room operators will not usually be concerned with the different batch sizes. The number of units of syrup required is clearly defined in the production order, which dictates everything that needs to be done.

A general situation exists in the dispensary, regardless of whether or not new batch sizes are involved. This is that during any given day, the staff deal with the preparation of ingredients for different syrups. They skip from one BOM to another, and this is usually done under deadline pressure, to supply the syrup-room requirements and meet filling run schedules. This alternating from one BOM to another, with a multitude of different bulk ingredients present in the room, can ultimately lead to errors, especially with staff under pressure and stress.

Part Units in the unitization system are mass produced in routine fashion, for one beverage flavor at a time. The bulk ingredient (or ingredients if more than one are involved) is the only one present in the filling room. There is no mistaking what is to be weighed out. Correct weights of packed units are individually checked and sometimes even double-checked. There is not much chance of error.

Labeling and Grouping of the Weighed Ingredients for the Syrup Room

Minimize errors in the syrup-making operation.

In the DI system described, the dispensary staff label the weighed ingredients, which is usually done with handwritten notes attached to or marked on the individual packs. These are then somehow grouped for respective syrup batches. The syrup-room operator, by means of the attached copy of the production BOM, identifies the grouping and transfers the packs to the syrup room.

I will not elaborate on the error-making potential involved in these activities. Suffice to say that incorrect labeling, incorrect grouping, and mixing of packs between groupings, are bound to happen, even with highly skilled and experienced operators. Furthermore, after transfer of the packs

to the syrup room, where sometimes two or more batches may be prepared simultaneously, still more errors can occur.

In the unitization system, the potential for such errors is minimized. The units are intact, clearly labeled, easily identifiable, and in the prescribed number for each syrup batch. Should a mix-up of Part Units from differently flavored products occur, e.g., by delivering them all on one pallet to the syrup room, these can be easily sorted in a matter of minutes.

In conclusion, this little comparison exercise conveys a single message: unitization considerably reduces the element of human error in the preparation of ingredients for syrup making as well as doing so in the syrup preparation process. It is not within the scope of this chapter to enumerate and describe in detail how unitization can reduce costly errors, most of which are operator related, that occur in pressure and stress manufacturing operations. I will, however, briefly list some of these as well as various other benefits of the system and the advantages over the DI system in general.

Orderly and Well-Controlled Measuring of Part Unit Ingredient Quantities

The operators in the Part Unit filling rooms are fully engaged in and dedicated only to ingredient dispensing for Part Units. They are well trained and, with time, will perform their duties with skill and efficiency. The material flow from bulk ingredient stock in the room to final packed and sealed Part Unit container does not allow much room for error, either in weight measuring or prescribed ingredient usage. Online checks for correct weights are part of the dispensing process flow. Weights are double-checked on outer carton contents when such are involved.

Mass Production of a Single Item

Mass production of a single Part Unit at a time results in greater production efficiency than for that same equivalent single item in the DI system. Mass production, though considered by labor activists as an evil form of the boredom factor, is a blessing in the unitization system, as routines and habits are established that minimize error making during a prolonged run of a single item.

Buffer Stocks between Ingredients and Syrup Making

Stockholding of sufficient readily available, fully married full beverage base units serves as a buffer between ingredient orders and syrup making. Out-of-stock ingredients do not affect, for a short period at least, the continuity of syrup production.

Simplified Issuing of Ingredients to Syrup Making

Nothing can be simpler than the issue of well-labeled, clearly identifiable Part Units, in the required numbers and at the correct preweighed double-checked formulation weights.

Easy Stock and Inventory Control for Production Planning

This can be explained by a short, simple scenario.

The CEO of the company, for some critical reason, requested that the logistics manager supply him with a quick estimate of how many liters of the 15 different final beverage flavors could be prepared with the shortest delay, from the current standing stock of raw materials.

In the DI system, the logistics manager would need to obtain an inventory printout of all the ingredients involved. With 15 differently flavored products, there could be about 20 or more such items.

With this list in his hand, he would, if he were wise, first establish the stockholding of flavorants specific to each of the 15 final beverage formulations. The stocks of flavorants would determine the maximum amount of each final beverage that could be produced. (Without the flavor, regardless of how much stock there is of other ingredients common to all beverages, i.e., preservative, acidulant, etc., no beverage can be produced.) To calculate this, he would have to consult the BOM of every one of the 15 final beverages to establish how much of it could be prepared from the flavorants stock figures in his list. This would take some time.

Now he is confronted with a quandary — how does he allocate the listed stockholdings of the ingredients common to all beverages to the different flavor stocks he established? I think that only a skilled statistician could work this one out. But even the statistician would need to consult the BOMs for each beverage to determine the standard ingredient requirement for each of the 15 beverages. This would take still more time — maybe a very long time indeed.

In the unitization system, this can be worked out in a jiffy. All that the logistics manager needs to do is, as for the DI system, obtain the inventory printout of the Part Units stockholdings. These would be clearly coded in the printout list, describing the beverage flavor involved. From the figures of each of the Part Units for a full beverage base unit, the lowest figure would be selected. This would indicate, for every beverage flavor, how many fully married beverage base units are in stock. The manager would then multiply this figure by 5000 and obtain the liters of final beverage for each flavor. This is the end of the story — and it would not take longer than half-an-hour.

I did not overlook the fact that there would be a stockholding of individual ingredients not yet incorporated into Part Units. I suggest that this stockholding would not be taken into consideration in view of the critical parameter of "how many liters of the 15 different final beverage flavors could be prepared with the shortest delay" in the CEO's request.

Whether this example event could really occur is immaterial. It shows how the unitization system can simplify many aspects of stock taking and inventory control. It shows how quickly and easily ingredients stocks in units can be converted to liters of final beverage, and vice versa.

STANDARDIZED AND GENERAL COSTING SIMPLIFIED

The standard costing of Part Units and full units is simplified as the costs of BOMs of these stock items are reflected in a single figure representing the ingredients involved. In a reasonable IT costing program, updated or changing costs of individual ingredients would be reflected in an overall cost change of the unit concerned. Such a program would also normally have an "exploding" facility to allow viewing of all the individual ingredients involved in a Part Unit or a full unit. In general costing exercises, the Part Units and full units can be used as single entities instead of as the numerous ingredients from which they are composed.

SIMPLIFIED FINAL PRODUCTION YIELD CALCULATIONS

Final beverage produced, when converted from liters to units, can be compared to syrup produced in units, and an immediate yield can be calculated. Unusually high variances not only indicate that syrup or beverage is being lost but also that there is a possibility that syrup making could be defective. Comparing actual units produced, in unit terms or in final beverage terms, against ingredient inventory changes during a defined period can also easily pick up variances in ingredient usage.

GENERAL ASPECTS

The instances in which the use of units as the standard quantity reference base are too numerous to list and elaborate upon in this handbook. Generally speaking, using the beverage base unit as a

reference quantitative base can simplify many calculations in administration, logistics, and accounting exercises.

In general, using the beverage base unit as a reference quantitative base can simplify many calculations in administration, logistics, and accounting exercises. The use of the unitization system ensures that apples are always compared to apples.

OUTSOURCING THE UNITIZATION OPERATION

In business terms, outsourcing any operation can involve additional operating costs to a company. The principle of outsourcing has significant advantages, even if additional costs are involved. This is evident in the fact that it is a growing global practice in the last decade or two.

Outsourcing the unitization operation is an option to be considered due to the potential benefits this could provide.

Outsourcing a unitization operation could have enormous benefits to a soft drink company, provided the outsourcing is to a reliable company that undertakes to perform the operation in conformance to the soft drink client's strict and high standards of quality and service requirements. Furthermore, the outsourced company should indicate confidence in quality of products and service levels by accepting full responsibility and liability for defective beverage base units supplied or shortfalls in scheduled supplies.

The benefits and advantages in outsourcing beverage base unit production and supply to an outside company that would meet such high-level quality and service requirements would be, among others, the following:

1. Dedicated to the production of beverage base alone, the outsourced company would very likely produce beverage base units of high-quality and of accurately measured ingredients. Defective items, if produced, would be rejected and not find their ways into the soft drink factory site.
2. The entire complex ingredients handling operation involving sourcing suppliers, price negotiations, placing of orders, deliveries scheduling, inventory control, etc., would be eliminated from the soft drink company administration workload.
3. The outsourced organization would undertake ingredients quality assurance, and the company's quality control department would be relieved of ingredient quality assurance responsibilities. The QC staff could then dedicate all their time and efforts to the regular activities of final beverage production — the core business of the company.
4. Out-of-stock situations of beverage base would be minimized.
5. Storage space usually allocated to ingredients would be freed for other purposes and functions.
6. Losses due to proven defective beverage base quality would be borne by the outsourced company.
7. An outsourcing fee structure based on payment per acceptable quality Part Unit delivered on time would serve as an incentive for the outsourced company to ensure quality and service.

GENERAL CONSIDERATIONS FOR CONVERTING TO A UNITIZATION SYSTEM

Some basic issues should be taken into account before considering a conversion to the unitization system on an in-house basis. First, there is the intangible aspect of the paradigm shift required from all the company's manufacturing personnel with respect

Some of the key considerations for outsourcing are presented.

to the full unit concept described previously. This paradigm shift would also be extended to all the company's nonmanufacturing administrative departments with respect to the use of the 5000 liter final beverage volume base unit (or any other chosen base unit) as the standard working unit. It would take some time to get used to this.

The Part Units dispensing operation should be staffed with competent, dedicated, and well-trained operators. It should be located in a suitably designed dedicated site with very restricted access. The cost involved in additional and possibly new equipment for the dispensary operation should be considered. Furthermore, company management would need to accept the necessary 1- to 2-week additional working capital involved in holding a buffer stock of fully married beverage base units.

A certain amount of master documentation reworking would be required to revise all QC, production, and logistics documentation to reflect the 5000 liter beverage base unit factor (product formulations, syrup mixing instructions, product BOMs, inventory databases and coding, etc.). Trivial as it may seem, not all IT accounting systems may be able to handle the full and Part Units concepts. This should be verified. For an outsourced unitization operation, the key factor lies in the confidence that the outsourced company can meet the quality and service levels expected.

CHAPTER REVIEW

Unitization can provide various benefits to a soft drink operation, the main one of which is the minimization of errors in ingredients dispensing for syrup or bulk RTD preparation. Converting to a unitization system may involve additional cost to a company in the form of capital equipment for effective dispensing of ingredients into Part Unit format as well as tying up working capital in holding additional ingredient stocks in beverage base unit format. These additional costs could be offset by savings in more efficient ingredients dispensing due to mass production, minimizing losses in defective syrup making, and avoiding final beverage out-of-stock situations.

In an outsourced unitization operation, the additional cost of outsourcing fees could be offset by reduced labor in the dispensary, less stockholding space due to the absence of individual ingredients, and elimination of administrative workload for purchasing and handling these absent ingredients. Certain pivotal considerations need to be addressed and accepted by the company's management before converting to a unitization system.

14 Flavors — The Magical Ingredients

WHAT ARE FLAVORS?

Flavors are the ingredients that give a soft drink its final overall distinctive sensory properties of taste and smell. Other ingredients also contribute to the taste of a beverage, such as the sweetener and the acidulant.

We need to distinguish between flavor-contributing ingredients and the flavor ingredients.

A lemon-flavored drink would hardly taste like lemon if it did not have the sourness associated with the fruit that is contributed by its high citric acid ingredient content. Moreover, this same beverage would not be palatable if it did not contain enough sugar to render it sweet enough to drink. Indian tonic water beverages are usually nothing more than lemonades with a small amount of the added bitter-tasting ingredient quinine. In food technology terms, these ingredients, like the acids, sweeteners, and quinine, are considered substances that contribute to the sensory profile of a beverage and round off the distinctive flavor of the product to make it palatably acceptable and pleasant to the consumer.

If we drank, for example, an appropriately sweetened liquid with palatable acidity content, it could possibly taste like a pleasant sweet-and-sour concoction. If we added a reasonable amount of strawberry flavor to this beverage, it would very likely taste like a beverage reminiscent of that fruit. However, if instead of a strawberry flavor we added an orange flavorant to that same liquid, it would taste more like an orange than anything else.

This little bit of rhetoric was merely aimed at distinguishing between substances that contribute to the overall flavor of a beverage and actual flavors, the substances that impart the distinct characteristic sensory properties of the beverage. It is these latter ingredients, the flavors, with which this chapter deals. These are sometimes called flavorants to amplify this distinction from flavor-contributing ingredients.

FLAVORS AND SOFT DRINKS

How flavors are produced and their chemistries and sensory properties are subjects of great interest. However, the aim of this chapter is to focus on the general background of flavorants and how they are used in the soft drinks industry and to offer some brief guidelines to their applications, especially those involved in new product development.

The technology involved in flavors is complex. Flavorants are supplied by companies called flavor houses.

Flavorants are almost solely supplied commercially by companies with a core business of developing, producing, and marketing flavors and fragrances. These companies usually divide their business into two main categories: flavors for the food industry and fragrances for the cosmetics and allied products manufacturers. These companies are commonly called flavor houses.

A flavor house's food division is normally departmentally organized into savory, confectionery, dairy, and beverages sections. It is almost solely from these flavor houses, or their agents, that soft drink manufacturers obtain their flavorant ingredients.

Flavors for soft drinks can be divided into those that are water soluble and those that are not soluble in water.

Flavors used in soft drinks can be divided into two main types based on solubility in water. Water-soluble flavors present no major problems when used in beverages, as there is ample water in a beverage formulation to dissolve and disperse the relatively small amounts of flavor required.

A flavor containing oil components that are not soluble in water cannot be used directly in the formulation. These components would separate out in the beverage and form a neck-ring in the beverage or, sometimes, in clear beverages, be seen as tiny suspended particles, giving the drink an unsightly appearance. To overcome this problem, an insoluble flavor is prepared by a flavor house in the form of an emulsion that can then be used in a soft drink formulation. These are the flavor emulsions that are used for flavoring the beverage as well as giving the beverage its cloudy appearance (see Chapter 4).

It goes without saying that a flavor emulsion cannot be used in a clear beverage. Should a person want to use a particular water-insoluble flavor in a clear beverage, it is possible that the flavor house supplier may be able to modify the flavorant into a water-soluble form or supply a water-soluble variant of that particular flavor.

Flavors can contribute up to 50% of a soft drink's raw materials cost.

Most soft drink flavorants are used in liquid form, but powdered spray-dried flavors can also be used. Spray-dried flavors are mostly used in powdered instant beverage products. Again, the water-solubility factor must be taken into consideration.

The flavor component of a typical carbonated soft drink (CSD) formulation may amount to anything from 10 to 50% of the total raw materials cost, inclusive of the sugar sweetener. Thus, the cost contribution level can sometimes be of great significance in the beverage formulation design. Therefore, it will depend on the sophistication involved in the product design, which, in turn, may depend on the target market as well as on the company's profit margin policies. All in all, flavorants present a costing factor that should not be ignored in beverage formulations, both in current existing products as well as in new product development.

Flavorants are sometimes used in natural fruit juices as boosters of the natural fruit flavor. Fruit juice blends may contain such flavor boosters for the juices of the fruit species in the blend that are not in major proportions of that particular fruit mix. Local food laws govern the use of flavors in natural juice beverages, and these should be consulted before including them in formulations of these products.

Food laws may also govern the way flavors are described in the label's ingredient list, especially focusing on the "natural versus artificial" aspects that may be involved. Food legislation may also extend to the way the beverage may be described on the label.

HOW ARE FLAVORS MADE?

Most flavors are aromatic compounds.

It is widely accepted that aroma plays the most important role in human flavor perception. We can identify a good few thousand different odors, as opposed to the five perceptions of sweet, sour, salty, bitter, and the recently established "umami" savory-type taste category. Thus, most flavorants are composed of aromatic compounds, the odors of which, when combined with basic taste perception, result in the final perceived taste of the beverage.

The issue of "natural," "nature-identical," and "artificial" will be presented.

Most flavors for the soft drinks industry are derived from the plant kingdom and are termed "natural." In our modern days, many natural flavors can be "copied" by specialists in flavor chemistry who synthesize the natural aromatic compounds found in nature. These are called "nature-identical" in many parts of the world, but the food laws of the U.S. demand that these be termed "artificial." When a

flavor that has no existing counterpart in nature is synthesized, this has to be called "artificial" in all countries that have legislation focused on flavorants.

The technology of flavor development in the laboratory and subsequent mass production in factories is highly complex and beyond the scope of this handbook. In the soft drinks industry, as in the food industry as a whole, we tend to leave the details of this technology to the "flavorologists" — very much in the same way as we leave medicine prescriptions to the pharmacists.

Knowing a few basics of flavor production can do us no harm. Below is a brief description of how some of the different types of flavorants are prepared.

The most elemental types of flavors are those made of whole aromatic plants, such as mint, thyme, oregano, etc. These we commonly call spices, and they are not used much in the soft drinks industry — though with the way the new-age beverages are developing recently, they may soon play a considerable role in our industry. Vanilla, a spice by definition, is prepared by curing beans of the vanilla plant. When extracting some of the aromatic compounds of the vanilla bean, the flavorant vanillin results. Vanillin is extensively used in soft drinks, such as colas and cream soda formulations.

Aromatic compounds that are not too volatile and other nonvolatile flavor compounds are usually prepared from plant material by the process of extraction. In the extraction process, organic solvents are used to draw out and dissolve the flavor substances, after which most of the solvent, if not all of it, is removed, and the flavorant is retained in its pure concentrated form. In this way, vanillin flavor is produced as well as oleoresins of ginger and various fruit flavors used in soft drinks.

Volatile aromatic flavoring compounds can be prepared by using the process of distillation, in which water or steam is used to separate the compounds from their source plant materials. Thereafter, by virtue of the different temperatures at which they condense back into liquid form, they can be distilled in different fractions. These compounds are known as essential oils (or volatile oils). They comprise a large part of flavorants used in beverages.

Essential oils as well as other flavorant compounds can also be prepared by mechanical pressing of the plant source material, as is done in citrus fruit processing where peel oils are collected. These are known as the cold-pressed oils often used in beverages. Cold-pressed oils may be used as is or may be further processed by extraction or distillation processes. Cold-pressed oils usually contain flavor essential oil compounds (e.g., terpenes) that are insoluble in water. To use these pressed oils in soft drinks, the water-insoluble components have to be removed by extraction (for use in clear beverages) or be incorporated in the oil phase of the emulsion intended for use as a cloudifier in turbid cloudy drinks.

Therefore, an important point to be made at this juncture is that due to the various ways in which a flavor can be finally prepared, the resultant flavorant does not always have, or rather seldom has, the full complement of flavoring components that the fresh fruit has in nature. Thus, a lemon flavor offered by a flavor house agent, coded as Lemon-12345-67C as a nominal example, may be a cold-pressed lemon oil that was washed of its terpenes, which are essential oils that contribute to the total lemon flavor in the natural juice. A different lemon flavor offered, Lemon-19876-54T, may be a blend of only a few essential oils distilled from three different lemon species. Again, it is not the typical overall flavor of a lemon fruit.

In both of these cases, and in many other instances, the flavor does not necessarily guarantee that its use in a soft drink formulation will result in the overall fruit flavor expected in the final beverage formulated. One would need to first establish what the offered flavor really is and what it could be used for. Thereafter, the skills and creativity of the beverage formulator will come into play to achieve a satisfactory final formulation. This will be addressed in another section of the chapter devoted to the use of flavors in new product development.

These are the basic processes by which base-type flavors are produced. There is, however, a further step in preparing a final flavor to be offered by a flavor house to a prospective soft drink technologist involved in developing new product or in making modifications to an existing formulation. The flavor chemists of flavor houses may blend a few base aromatics of a certain fruit flavor to arrive at a final flavorant with a specific sensory profile. In another case, a "cooked" flavor compound may be added to a fresh fruit flavorant to lend it a "dessert-type" top note. In another case, a few different base fruit flavors may be blended to result in a "fruit punch" mixture. Or a "wine" note may be added for use in an alcoholic soft drink preparation. This is what is sometimes called the "art" in flavor creations.

FLAVOR HOUSES

There are many flavor houses in different parts of the world. More than a few are international business organizations with branches and agencies scattered all over the globe. Many other flavor houses are local concerns operating mainly in the country in which they developed. As mentioned previously, the sole core business of a flavor house is in flavors and fragrances. These two commodities usually go hand in hand, as fragrances, like flavors, are derived from aromatic compounds, with the difference that they are not intended for consumption in foods. Fragrances are used to add aroma to cosmetics and toiletries and are the substances responsible for the scents of perfumes and colognes. The technology involved in fragrances is similar, if not identical, to that of flavors.

For these reasons, flavor houses, especially the large international conglomerates, will usually be involved in both of these products but will have a clear-cut organizational and operational separation between the two. In this chapter, a reference to a flavor house will be taken to mean only the food-oriented side of the company. A typical well-organized and sophisticated flavor house would have its headquarters based in one of the world's continents that would include an advanced flavor research and development laboratory staffed by specialist flavor chemists and engineers. These people would be involved in production control of the company's flavor manufacturing facilities as well as in flavor technology research. Another function of the head office laboratories would be to provide technical backup to the many company representatives in the world engaged in the core business of selling flavors to the local food industries.

In most countries, the local branches or agencies would employ sales representatives with qualifications or experience in food technology to call on clients in the food industry. Such qualifications and experience are needed in order to discuss and suggest flavors suitable for the intended applications in the customers' food products and the processes in which they are manufactured. These representatives often undergo training in various flavor science and technology aspects of the business at the company's head office technical centers. They also receive training in the rudiments of flavor applications in the various food sectors, of which the beverage industry, soft drinks and beverages in general, is usually considered a sector on its own.

The flavor house representative would normally have a "library" of his company's flavorants that literally could number in the hundreds if not thousands. The library would be in the form of a master file, listing each item's identity code, characteristics, and potential applications for food products and processes. Many samples of these would be on the local branch's shelves, and those not there could be shipped from the head office to arrive in a matter of days for presentation to a local prospective customer. The flavor house representative for the soft drinks industry (and other selected industries) is much more than a salesperson — he or she provides a service to customers in the form of new product ideas and formulation suggestions that, if requested by the client, can be made up into actual samples for taste test and cost evaluation. The representatives can be very patient individuals who are capable of numerous repetitive trial-and-error submissions of such samples until the right one is sometimes obtained.

Confidentiality with regard to the customer's product formulations and processes, which could also be linked to the customer's company marketing plans and strategies, is of paramount importance in the flavor house representative dealings with a client. Also, a flavor especially developed for a particular customer, or a combination of flavorants used by the customer, is a matter of paramount confidentiality. Any representative who is found to have breached such confidences usually finds himself or herself and company written off by the client.

FLAVOR COSTS

Flavorants are highly concentrated ingredients. They function and impart their sensory properties of taste and odor in diluted forms in beverages. Like perfumes and colognes, they are used in very small quantities to attain their required effects. For optimum impact, one must have the right usage level in the drink.

Thus, we talk of the dosage level of a flavor in the final beverage product. For each flavorant offered by a flavor house, the customer will be informed of the recommended dosage for that particular flavor. This recommended dosage is merely a guideline at what level or thereabouts a new product developer should start his formulation trial samples. Usually, the recommended dosage serves this purpose well, but there can be cases in which double or half of this recommended dosage is actually found to be suitable in a new formulation of a drink. This is mainly due to the general sensory properties of the other flavor-contributing ingredients in the formulation, as well as to the sensory perceptions peculiar to the target market consumers.

Flavor houses normally produce their flavorants at three level ranges of concentrations, which, in turn, interpret into three levels of recommended dosages. These are roughly as follows:

- One in 10,000 or 0.01%: 0.1 kg flavorant per 1000 liters of final beverage
- One in 1000 or 0.1%: 1 kg flavorant in 1000 liters of final beverage
- One in 500 or 0.02%: 2 kg in 1000 liters of final beverage

The first listed recommended dosage is not too common, as these are very concentrated flavors indeed. They usually carry a cost benefit, as will soon be explained, but can cause some problems when used in some factories, especially low-volume ones, due to the relatively small amounts handled in very large syrup and bulk RTD batches. A few grams lost or overused could possibly have a significant sensory influence on the final product.

The other two recommended dosage levels are more common, as well as those below the 0.02% levels that are sometimes encountered. The relationship between flavor price and recommended dosage level should be obvious. A flavor price, for example, at $100/kg at a dosage of 0.01% in a beverage will have a cost contribution to 1000 liters of that beverage equivalent to $10 or 1¢/liter.

The same flavor offered at a concentration with a recommended dosage of 0.1% in a beverage may be priced somewhere around $20/kg. In 1000 liters of beverage, 1 kg would be required, and the cost contribution to these 1000 liters of beverage would therefore be $20 or 2¢/liter. This is double the cost of the more concentrated flavor at 0.01% recommended dosage. Thus, when assessing the cost implications of a flavorant, the following principle must be observed.

Identical flavorants at different concentrations and recommended dosage levels are not always available. When they are, the higher concentrated one will, in most cases, be less expensive and should be chosen if the handling of small quantities, both in the development laboratory and in the production facility, does not present a problem.

The actual cost of a flavorant cannot fully be determined from its nominal listed or quoted price until the actual dosage level of the flavor in an accepted and approved beverage sample is determined.

The corollary to the price and recommended dosage interrelationship is that when one is formulating a product requiring new flavors and the total cost of all beverage ingredients is

restricted to a maximum limit, a maximum price ceiling of "candidate" flavors offered must be allocated in terms of their cost contributions to a unit volume of final beverage at their eventual dosage levels in the drink.

HOW IS A SOFT DRINK FLAVOR SOURCED?

Like in most food manufacturing companies, the need for a new flavor arises in one or more of the following occasions:

- Launch of a new company product or extension of the range of current products
- Modification of a currently produced product for reasons of cost savings, poor quality of flavor, or service from current supplier
- Unavailability of currently used flavors
- Work on an ingredients and suppliers standardization project
- Adherence to a company's long-term new product development program

In a soft drink company, the technical department normally effects the sourcing of a new flavor and the eventual incorporation of it into the company's applicable beverage product. The following sections address the key guidelines of how to go about this somewhat involved exercise.

New Product Development Brief

Normally, the need to source a new flavor originates from a marketing official's request for a new product. Regardless of who the requesting authority is, the request should be formalized in a documented brief detailing the specifics of the new product. This is not just one of those official documents of red-tape nature, but rather a hard-copy guideline for the persons involved in the development of the new product (who shall, from this point on, be referred to as the developer).

The developer will be prone, in the rush and turmoil of daily routine work, to lose focus on critical factors of the project. The development brief will serve as a reminder for these as well as form the basis on which the developer will compile a development brief for the flavor houses from which the intended flavor is to be sourced. This in-house development brief should contain the following critical data and details:

- A clearly defined project description, its objectives, and the reasons for its request
- The maximum final beverage raw materials cost ceiling allowed (This permits the developer to define a reasonably feasible cost range for the flavor that will be stipulated to the flavor house representative. The total raw materials cost allowed figure is important, as the developer may "play around" with other ingredients in the formulation to arrive at a satisfactory final formulation.)
- The targeted deadline date for submission of new product samples for evaluation and approval by the requesting authority (This deadline date should be negotiated with the requesting authority that may not be aware of the numerous timing restrictions involved in new product development, including flavor sample submissions, trial-and-error evaluations with an array of various "candidate" flavor samples, taste testing of the prototype formulations with selected flavors, approval of the final candidate flavor formulation, and the possibility of a large-scale consumer taste test for final approval.)
- Agreed-upon applicable final beverage general quality specifications, such as Brix, acidity, carbonation, coloration, preservative level, etc.)

DEVELOPMENT BRIEF FOR FLAVOR HOUSE

The developer should compile a development brief for the flavor house representative for the similar reasons of serving as a reference document to ensure that all parameters are understood and acceptable to both the representative and developer. This brief should contain all the information, data, and prerequisites as in the in-house development brief, suitably modified for purposes of confidentiality, deadline dates, and financial negotiation, where applicable. In addition, this flavor house brief should contain the following:

- A clearly defined flavorant cost contribution
  - With reference to the flavorant price and dosage level issue discussed in the preceding section, it is of paramount importance, when restricted by a total beverage cost parameter (which is usually par for the course), to calculate an allowed maximum flavorant contribution cost to a unit volume of final beverage. This maximum contribution cost must be clearly stipulated in the brief to the flavor house. Otherwise they may very well offer flavors at recommended dosages that will far exceed the cost restrictions.
- Any nonconfidential technical information regarding the beverage concerned that would facilitate the flavor house selection process of suitable flavor samples for submission
  - For example, whether the flavor needs to be natural or artificial, is heat resistant to the pasteurizing process, has religion-related constraints, allows for single flavorants or a combined blend of flavorants, incorporates flavorant into a cloudifier emulsion if applicable, etc.
- A clearly defined sample submission format type — as flavorant sample for use in in-house trials, as final beverage sample submission by the flavor house, with or without carbonation, with or without beverage coloration, etc.
  - The format of this will depend on the developer's modus operandi of new product development projects.
- The total acceptable maximum volume or mass of flavorant in a unit volume of final beverage (e.g., 1000 liters)
- Any nonconfidential marketing strategy information that can be disclosed that may help with suitable flavor selection
  - For example, if the product is aimed at the kiddies' beverage market, the flavor house may already have tried and proven flavors in its "library" of samples. The same would apply to a product aimed at a competitor's brand.

If applicable, a reference sample of the benchmarked final beverage should accompany the brief with an attached formulation template if flavor samples are to be submitted by the flavor house in final beverage format. For ethical reasons, a sample of a competitor's flavor house flavorant or final beverage sample, if available, should not be given to the flavor house to which the brief is submitted. This would not apply in the case of a competitor's current product in the market being the reference product of the project. It would be ethically correct to use that product as a benchmark, even if it is known that a competitor flavor house supplies the flavoring system for that product.

THE NEW PRODUCT DEVELOPMENT PROCESS

The actual process of new product development is an integral part of sourcing new flavors. The enormous range and variety of flavors from several different flavor houses that could be potential candidates for the final new beverage would necessarily require a series of laboratory trials of some of these flavors in actual samples of new product.

Taste testing final beverage samples to eliminate the substandard or unsuitable flavors offered from the more favored ones and deciding on the final flavor to be purchased and supplied with make up a time-consuming step-by-step process that cannot really be avoided. Cost restrictions of flavor prices can only add to the duration of the process.

The scope of this chapter does not allow for a detailed discussion of the new product development process. I will, however, offer some brief fundamental guidelines on this subject inasmuch as it relates to the sourcing of candidate flavors for the project:

1. Always engage up to at least three different reliable and competently managed flavor houses for sourcing the candidate flavorants required. It can happen that one particular flavor house just has that one more ideally suitable candidate flavor, both in quality and in cost, for the particular application involved.
2. Always supply a hard-copy development brief to the flavor house representative.
3. Clearly define the costing parameters of the flavors required.
4. Use the recommended dosage levels supplied as a starting guide only. Experiment with levels above and below those recommended. This is not to say that the recommended dosage levels are incorrect. The flavor house simply cannot exactly define at what levels the flavors will function properly in your particular application conditions.
5. When settled on a potentially promising candidate flavor at a certain dosage level, try another one at about 10% level reduction. It may still work, and you can save your company a small fortune.
6. Be strict and unbiased in deciding on poor-performing candidate flavors. Playing around with flavors that do not have a first positive sensory impact at recommended dosage levels will only bog you down with numerous unnecessary sample preparations for taste-testing trials. This is especially true in the cases where you and not the flavor house are doing the actual flavor-in-beverage sample preparations.
7. After selecting a potential final candidate based on samples of beverage prepared by the flavor house, obtain a sample of the actual flavorant used for beverage samples preparation in your own company laboratory. This will verify that the flavor house prepared its samples correctly and adhered to all of your other final beverage specifications.
8. In new product development of CSDs, it may be wise to taste test the initial candidate samples in noncarbonated form. This is so the taste evaluation is not skewed by having different carbonation levels in the samples than what they would be at correct gas volume specification.
9. If, for some reason, a superior candidate flavor exceeded your cost restriction limits, do not immediately discard it. You may be able to negotiate a price reduction with the flavor house representative — they always want to secure new business. And, your marketing manager may be impressed with the candidate flavor and make an exception to the excessive cost.
10. Single out for future projects those flavor house representatives that afford you the best cooperation and professional service.
11. Last but not least, do not despair if at first your sourced samples do not match your expectations. Stubborn perseverance is the key to successful flavorant sourcing in new product development.

THE MAGIC AND MYSTERY IN FLAVORS

In the title of this chapter, I referred to flavors as "magical" ingredients. Perhaps "mysterious" would have been a better description, or maybe I should have used magical and mysterious together. Flavors are mysterious ingredients, at least for the food-processing technologist, if no one else.

They are not the run-of-the-mill-type of ingredients, like an organic acid, preservative, colorant, etc. For these, you merely call a suitable supplier, name the item you want, inquire about stock-holdings and delivery periods, negotiate a price, and place an order — end of story. Within a few days, the ingredient is delivered, and in another few more days, after passing muster with the QC department, it is being processed into your products.

With a flavor ingredient, this is not possible. You cannot simply name a required flavor to a supplier flavor house and expect to have it in a few days in your processed beverages. The mystery surrounding flavors also sometimes exists in your own company, when a marketing director, unacquainted with this mystery factory, asks you for a new flavored product to be launched and is perplexed when you say that the planned launch date in 1 month's time is utterly impossible. You may even say that it is ridiculous. As a new product designer, you also encounter this mystery issue — which one of the many candidate samples is going to be the right one? You are sometimes surprised that the least appealing one to yourself is the one chosen by the powers-that-be in your marketing department.

Then there is the mystery of flavor pricing — why do two almost identical flavors, each from a different flavor house, differ so much in price, in recommended dosage levels, and in the eventually calculated cost contribution to the beverage formulation? You can possibly guess why there is a difference, but you will never really know exactly why. A flavor's properties cannot be measured in direct numeric terms. It is possible to measure its density, volatile oil content, and solvent concentration. You can also perform a gas liquid chromatography (GLC) test and obtain the well-known "fingerprinting" feedback with peaks for individual aromatics and other compounds. But you cannot put a figure to its "taste." Therein lies another mystery.

Then there is the magic about flavors. How a single or just a few drops of flavor can transform a bland beverage into a pleasure-giving potion is amazing. A flavor change to a flopping beverage brand can change it almost overnight into the flagship brand of the company, with a little help from the marketing department, of course. I worked with flavors almost all of my professional life. I never cease to be amazed at how sometimes, in new product development work, adding a few drops of flavor sample to one candidate formulation in the backrooms of the laboratory has snowballed into a success story for the company in terms of sales volumes and net profit. It is pure magic. The magicians are the flavor chemists and engineers. Without them, most of the food and beverage industries as we know them now would cease to exist.

15 Formulation — A Spreadsheet Template

CHAPTER PREVIEW

Many a time, a soft drink food technologist is called upon to draw up a master beverage formulation. This master formulation could be required for various reasons or purposes. There may be a need to check out a formulation that was acquired from an outside source, such as a flavor house, to confirm the claimed quality parameters of Brix, acidity, preservative levels, etc. Sometimes a currently used formulation, when prepared in the factory, does not result in the stipulated beverage Brix, and extra sugar is always needed to achieve the right specification.

Another instance in which a master formulation is required is when, after developing a new product in the laboratory, a mixing instruction for its preparation is required for production, and a bill of materials (BOM) is required for logistics or accounting. This also applies when a currently used formulation is modified, for some reason or another, such as cost reduction or ingredient changes. A master formulation is often required for prototype formulations in new product development projects to serve as a template for taste trials with different flavorant ingredients.

Whatever the case may be for compiling a new or master-type beverage formulation, the person involved may sometimes be stymied at first as to where to start. In most cases, the formulation is eventually designed successfully. However, this is sometimes achieved only after more than a little head scratching and running around in circles to arrive at the correct ingredient levels for a final beverage that meets the correct composition and established quality specifications.

This chapter is dedicated to demonstrating a type of methodology for quick and accurate formulation design that I used on many occasions. It involves using a spreadsheet application, such as Microsoft® Excel, and as such, this chapter is actually a practical exercise for the interested reader. Once the workings of the template are fairly understood, it can be used over and over again for future formulation designs.

EXERCISE SCENARIO DETAILS

It was requested that you formulate a cloudy orange beverage with the following specifications:

Brix: 13.0°B
% Acidity: 0.24% as citric acid anhydrous m/v
Preservative: 300 ppm sodium benzoate
Vitamin C content: 30 mg/100 ml

The formulation will be designed for 1000 liters of final beverage. For the purpose of the exercise, we will assume that after some initial laboratory trials, you satisfactorily established the required levels of flavorant, cloudifier, and colorant for the beverage. The spreadsheet application to be used is Microsoft Excel.

THE EXERCISE, STEP BY STEP

This formulation design exercise can be performed without an accompanying computer operation, as the different steps will be illustrated in spreadsheet form.

THE BLANK SPREADSHEET TEMPLATE

The blank formulation design template in Excel spreadsheet format is given in Figure 15.1. The smaller block on the left is used for the beverage specifications data, whereas the larger block on the right is where the actual beverage formulation will be compiled. Most of the columns of this block are self-explanatory, while D20 stands for density at 20°C and CAA stands for citric acid anhydrous.

STEP 1 — ENTERING SPECIFICATIONS AND INGREDIENTS LIST

As per Figure 15.2, enter the stipulated beverage specifications in the appropriate cells of the block. The specified volume of the final beverage, 1000 liters, is the key value on which all the calculations in this exercise will be based.

Note that the Brix and acidity values are entered in percentage format. This will facilitate formula calculations in the spreadsheet by not having to multiply or divide formulas by 100, where applicable. The D20 figure is obtained from the Brix/density tables for the 13.0 Brix value.

Enter the ingredient names in the formulation block in the descending order listed in Figure 15.2. This is done to accommodate certain spreadsheet formula calculations, as will be seen in the next steps of the exercise. Note that vitamin C is represented by its common chemical name, ascorbic acid.

STEP 2 — CALCULATING THE "TOTALS" VALUES

In cell E14, enter +B6. This will copy the beverage volume, 1000 liters.
In cell F14, enter +B8. This will copy the beverage D20 value.
In cell G14, enter +E14*F14. This calculates the mass of the 1000 liters of beverage.
In cell H14, enter +G14*B7. This calculates the total dissolved solids in 1000 liters of beverage.
In cell I14, enter +B9*B6. This calculates the kilograms of citric acid for the 0.24% acidity specification.

Figure 15.3 shows these totals. We are now ready to start the formulation calculations.

STEP 3 — ENTERING INGREDIENTS QUANTITIES

Study Figure 15.4. The formulation quantities of water, sugar, and CAA are not entered in this step. For the other ingredients, proceed as listed. Powdered ingredients, the quantities of which are measured by mass, are entered in column G "kg." For the sodium benzoate in cell G8, enter +B10/1000000*B6, which will result in the kilograms required for the 300 ppm preservative specification. In cell G9, enter 0.100 for the amount of Sunset Yellow established in previous laboratory trials as the required color level for the beverage. In cell G12, calculate how much ascorbic acid in kilograms is required for the 30 mg per 100 ml beverage by entering the somewhat long cell formula +B11*10*1000/1000000 (which could be simplified to +B11/100).

For the liquid ingredients, orange flavor, and neutral cloud, you already established in laboratory trials the required quantities. However, you measured these by volume in liters. These values are 1.0 liters of flavor and 1.2 liters of neutral cloud. Enter these volume values in the "liter" column in cells C10 and C11, respectively.

FIGURE 15.1 Blank template.

FIGURE 15.2 Step 1: Beverage specifications and ingredients list.

These volume values need to be converted to mass kilogram values, the reason for which will become clearer when we calculate the sugar and water quantities. At this stage, it can be explained that the neutral cloud liquid has dissolved solids and has a Brix value of its own. In previous chapters, it was explained that in the soft drinks industry, all dissolved solids are, for convenience sake, considered as sucrose or sugar (see Chapter 1). The solids of the neutral cloud must be taken into consideration as contributing to the final beverage Brix 13.0.

According to the suppliers' specification sheets, the orange flavor has a D20 of 0.85, while the neutral cloud's D20 is at 1.06. Enter these values in the D20 column in cells F10 and F11, respectively. To calculate the orange flavor mass, enter +E10*F10 in cell G10. For the mass of cloud, enter +E11*F11 in cell G11. At this stage, the spreadsheet formulation template should appear as displayed in Figure 15.4.

FIGURE 15.3 Step 2: Calculating totals.

FIGURE 15.4 Step 3: Entering ingredients quantities.

STEP 4 — CALCULATING CITRIC ACID ANHYDROUS

The total CAA mass of 2.400 kg in cell I14 is the quantity required for the 0.24% acidity specification. This is not necessarily the quantity of the CAA ingredient in the formulation, as other ingredients often contribute to the total acidity of the beverage. In our case, this applies to the ascorbic acid, which will contribute to the acidity titration of the beverage. In this acidity titration test, the results of all acids present are expressed in terms of CAA.

According to molecular weight equivalents, 1.00 kg of ascorbic acid is equivalent to 0.36 kg CAA. Therefore, the ascorbic value of 0.300 kg in cell G12 needs to be converted to CAA and recorded in cell I12 of the CAA column. Enter +0.36*G12 in cell I12. This value will be 0.108 kg, as displayed in Figure 15.5.

FIGURE 15.5 Step 4: Calculating the citric acid anhydrous quantity.

The required quantity of the CAA ingredient can now be calculated by subtracting the ascorbic acid CAA value from the total CAA figure. Calculate this value by entering +I14-I12 in cell I7. This will result in the CAA quantity of 2.292 kg. Copy cell I7 to cell G7 to enter this CAA ingredient quantity in the "kg" column.

STEP 5 — CALCULATING THE SUGAR QUANTITY

As mentioned previously, it is standard practice in the soft drinks industry to consider all soluble solids in a beverage as sucrose (or sugar in common terminology). Examples of such solids are the organic acid acidulants, preservatives, colorants, minerals and salts, gums and thickeners, to name just a few.

This is not only a matter of "convenience" but also is practical, as Brix refractometers are calibrated on refractive indices of sucrose solutions. It would immensely complicate matters if, for each of the myriad soluble solids that could be present in soft drink formulations, we would need specially calibrated instruments. Most of these nonsugar soluble solids are in such relatively minute quantities when compared to those of sugar that the error of considering them as sucrose is very small. However, these types of ingredients do contribute to the overall Brix reading of the beverage, and they must be taken into account when calculating the sugar quantity for a beverage formulation.

This is also true for liquid ingredients that contain soluble solids. Examples of such ingredients are fruit juice concentrates that contain relatively large quantities of natural sugars other than sucrose (e.g., glucose and fructose) as well as organic acids and minerals. Flavor emulsions and clouding agents also contain nonsucrose soluble solids in the forms of soluble gums and emulsifiers, such as in the case of the neutral cloud in our exercise formulation.

Therefore, all ingredients that contribute nonsucrose soluble solids to a beverage formulation form part of the total soluble solids. These ingredients and the sugar make up the total kilograms of solids in the formulation, which in turn, determines the final Brix of the beverage. It is for this reason that the column "Kg Solids" exists in our spreadsheet template.

To determine the amount of sugar required, we must subtract the total nonsugar soluble solids from the target total solids in the formulation. To do this, we need to transfer all the soluble solids quantities to their respective cells in the "Kg Solids" column. This applies first to all the powdered ingredients, which are 100% soluble, so that their already recorded masses in the template completed up to this stage are also their "Kg Solids" values.

	A	B	C	D	E	F	G	H	I
2	PRODUCT :			CLOUDY ORANGE					
3									
4	SPECIFICATIONS			FINAL BEVERAGE FORMULATION					
5	FINAL BEVERAGE			INGREDIENT	Liters	D20	Kg	Kg Solids	Kg CAA
6	Volume (Liters)	1000		Sugar				133.267	
7	Brix	13.00%		Citric Acid Anhydrous			2.292	2.292	2.292
8	D20	1.04961		Sodium Benzoate			0.300	0.300	
9	Acidity (%CAA m/v)	0.24%		Sunset Yellow			0.100	0.100	
10	Preservative (ppm m/v)	300		Orange Flavor	1.000	0.850	0.850		
11	Vitamin C (mg/100 ml)	30		Neutral Cloud	1.200	1.060	1.272	0.191	
12				Ascorbic Acid			0.300	0.300	0.108
13				Water					
14				TOTALS	1000.000	1.04961	1049.610	136.449	2.400
15									

FIGURE 15.6 Step 5: Calculating the sugar quantity.

Copy the CAA quantity to its corresponding "Kg Solids" column cell by entering +G7 in cell H7. Then, using the copy menu command, copy the contents of cell H7 to all the "Kg Solids" column cells of the applicable powdered ingredients, namely, to H8, H9, and H12. To view the copying effect, see Figure 15.6.

We must not forget the soluble solids in the neutral cloud, which, according to the supplier's product specification sheet in your possession, has a 15% soluble solids content. Therefore, to add these solids to the "Kg Solids" column, enter +0.15*G11 in cell H11. This will result in a value of 0.191 kg being displayed in cell H11 in Figure 15.6.

Note: The orange flavor ingredient is a liquid that is not considered as containing soluble solids, and therefore, no value was transferred to the "Kg Solids" column. As a rule, all liquid flavorants, essential oils, alcohols, and other organic solvents are considered as liquids not containing soluble solids.

We are now ready to calculate the sugar ingredient quantity. This is done by entering the formula +H14-SUM(H7:H12) in cell H6. This formula subtracted the sum of all the nonsugar soluble solids from the total kg solids, leaving a balance of 133.267 kg to be made up by sugar.

It may be of interest to note that the non-sugar solids amount to about 3 kg and are equivalent to about 2% of the total "Kg Solids" figure. As such, they contribute roughly about 0.3°B to the 13.0°B value of the final beverage. This is a significant contribution that cannot be ignored. Had we ignored the nonsugar solids' Brix-contributing effect and used only sugar as the soluble solid in our formulation, we would, in reality, land up with a beverage at somewhere around 13.3°B. And at the same time, would be overusing sugar by about 2%.

The last task in this step is to copy the sugar quantity into the "Kg" column by entering +H6 in cell G6. We are now ready for the final step of calculating the water ingredient quantities.

STEP 6 — CALCULATING THE WATER QUANTITY

The mass of water in the formulation is equal to the total mass of the beverage less the combined masses of all the other ingredients in the beverage. Therefore, to calculate the water quantity in cell G13, enter the following formula: +G14-SUM(G6:G12), which is 911.230 kg (see Figure 15.7).

	A	B	C	D	E	F	G	H	I
2	**PRODUCT :**			**CLOUDY ORANGE**					
3									
4	**SPECIFICATIONS**			**FINAL BEVERAGE FORMULATION**					
5	**FINAL BEVERAGE**			**INGREDIENT**	**Liters**	**D20**	**Kg**	**Kg Solids**	**Kg CAA**
6	Volume (Liters)	1000		Sugar			133.267	133.267	
7	Brix	13.00%		Citric Acid Anhydrous			2.292	2.292	2.292
8	D20	1.04961		Sodium Benzoate			0.300	0.300	
9	Acidity (%CAA m/v)	0.24%		Sunset Yellow			0.100	0.100	
10	Preservative (ppm m/v)	300		Orange Flavor	1.000	0.850	0.850		
11	Vitamin C (mg/100 ml)	30		Neutral Cloud	1.200	1.060	1.272	0.191	
12				Ascorbic Acid			0.300	0.300	0.108
13				Water	913.816	0.997	911.230		
14				**TOTALS**	1000.000	1.04961	1049.610	136.449	2.400
15									

FIGURE 15.7 Step 6: Calculating the water quantity.

As it is customary to measure water by volume in liters, this quantity must be converted to liters using the magical water D20 number 0.99717 often mentioned in this handbook. Enter this figure into cell F13. In cell E13 of the "liters" column, enter +G13/F13. The liters of ingredient water will work out to 913.816 liters.

> This figure of water liters is actually not required for a beverage formulation. Usually in such formulations, the water quantity is stated as "water to final volume," or in the equivalent beverage mixing instruction, as "top up to final volume with water." Still, it is good to have this figure on record if only to indicate how much water there is to "play" with to dissolve ingredients in preparing a laboratory sample of the beverage in a product development project or in the preparation bulk RTD beverage in the factory.

This is the final step in the formulation design exercise. The actual formulation for 1000 liters of beverage, composed of columns D and G as depicted in Figure 15.7, can now be transcribed to any format required and used as a master formulation document.

CHAPTER REVIEW

The template created in this exercise can now serve as a ready-to-use tool for other formulation designs. The principle to be observed is that all cells in the template that contain formulas must be preserved intact and undisturbed. The formula setup in the final beverage formulation block of the spreadsheet is given in Figure 15.8. (Note that the water D20 figure 0.99717 was also included in the cells that should not be disturbed.)

In this exercise, I allowed just enough rows for the ingredients of the somewhat simple formulation. Other more complex beverage formulations may require additional rows for more ingredients. To accommodate this, more rows must be inserted into the spreadsheet, but care must be taken to copy all applicable formulas into the respective cells that will be blank due to the insertion of additional rows.

This exercise of compiling a relatively simple beverage formulation was presented to guide the reader in the principles involved in such a task. It can be slightly more complicated when a formulation contains other types of ingredients, such as fruit juice concentrate. In such a formulation, the juice concentrate and its contributing factors to the formulation must be applied and built into the standard template. This concerns mainly the juice's solids content, its high acid

	D	E	F	G	H	I
2	**CLOUDY ORANGE**					
3						
4	**FINAL BEVERAGE FORMULATION**					
5	**INGREDIENT**	**Liters**	**D20**	**Kg**	**Kg Solids**	**Kg CAA**
6	Sugar			=+H6	=+H14-SUM(H7:H12)	
7	Citric Acid Anhydrous			=+I7	=+G7	=+I14-I12
8	Sodium Benzoate			=+B10/1000000*B6	=+G8	
9	Sunset Yellow			0.1	=+G9	
10	Orange Flavor	1	0.85	=+E10*F10		
11	Neutral Cloud	1.2	1.06	=+E11*F11	=0.15*G11	
12	Ascorbic Acid			=+B11*10*1000/1000000	=+G12	=0.36*G12
13	Water	=+G13/F13	0.99717	=+G14-SUM(G6:G12)		
14	**TOTALS**	=+B6	=+B8	=+E14*F14	=+G14*B7	=+B9*B6
15						

FIGURE 15.8 Template cells containing formulas.

levels, and the tricky subject of "single-strength juice basis" addressed in Chapter 7 of this handbook. The template has to be especially modified for syrup formulations, where the syrup Brix has to be determined to achieve the final beverage Brix after dilution, according to a specific water-to-syrup ratio.

> I leave all these and other necessary modifications to the interested reader wanting to use this formulation template who, I am confident, will be up to the task. I also leave it to such a reader's ingenuity to make improvements. Whatever the case, this exercise attempted to illustrate how a spreadsheet application can be used to methodically compile a beverage formulation. It can serve as a ready-to-use tool for future formulation design tasks.

16 Microbiology — The Biofilm Concept

WHAT IS A BIOFILM?

"Biofilm" is the term used to describe the microbiological structure attached to a solid surface in which microorganisms grow and surround themselves in a film-like mass of gelatinous material. The unique aspect of biofilms is that these microorganisms change their living mode as free-drifting individual separate cells in a liquid environment to that of a fixed-position colony-type agglomerate firmly attached to a solid surface. They then continue to multiply in a matrix of biological polymer that they create themselves.

Biofilms are unique in that free-drifting individual microorganisms change into a fixed-position interactive colony.

In microbiology terminology, this change in the living mode of microorganisms, such as bacteria, is referred to as a change from planktonic free-drifting form to that of fixed-position sessile form. The uniqueness of this change is further manifested by the fact that bacteria previously existing as entities functioning entirely on their own in the planktonic state can, in the biofilm, interact with each other. Different individuals may assume different appearances and functions in the colony-type structure they created. In fact, it is possible to find different bacteria species in the same biofilm.

The concept of biofilms is not at all new and has been known to the medical and dental professions for quite some time. Bacterial biofilms can grow, for instance, in catheter tubes of patients, and are the cause of dental plaque. The latter is the result of calcium salts deposited by the plaque bacteria in the biofilm on the surface of the teeth.

Biofilm is not a new concept.

In the food-processing industry, biofilms are, however, a relatively new concept of the last decade or two, having been found to be the cause of what appear as baffling and serious microbiological contamination and spoilage problems. This "baffling" factor of biofilms will be elaborated on in this chapter, which focuses on biofilms in the soft drinks industry.

HOW ARE BIOFILMS FORMED?

Biofilm formation is apparently triggered by a change in environmental conditions of the planktonic bacteria. A prerequisite for the development of a biofilm is that there must be a continuous flow of nutrient-bearing liquid in which the bacteria exist. This flow of liquid ensures the continuously replenished supply of nutrients favorable for the growth of the bacteria in the biofilm. Furthermore, a solid surface must be in close proximity onto which the biofilm can be attached and secured. Figure 16.1 schematically describes the way in which a biofilm can develop.

Biofilm forms due to changes in the bacteria environment.

In part (A), several individual planktonic bacteria are seen to exist as individuals near the wall of a piece of equipment, such as a pipeline, through which a nutrient-bearing liquid, e.g., a beverage product, is flowing in the direction indicated by the arrow.

Part (B) shows that, having the liquid flow passing by and supplying them continuously with enough required nutrients, the individual cells attach themselves to the inner surface of the pipe wall and start multiplying. They begin secreting a sticky, slimy, gelatinous mass that secures them
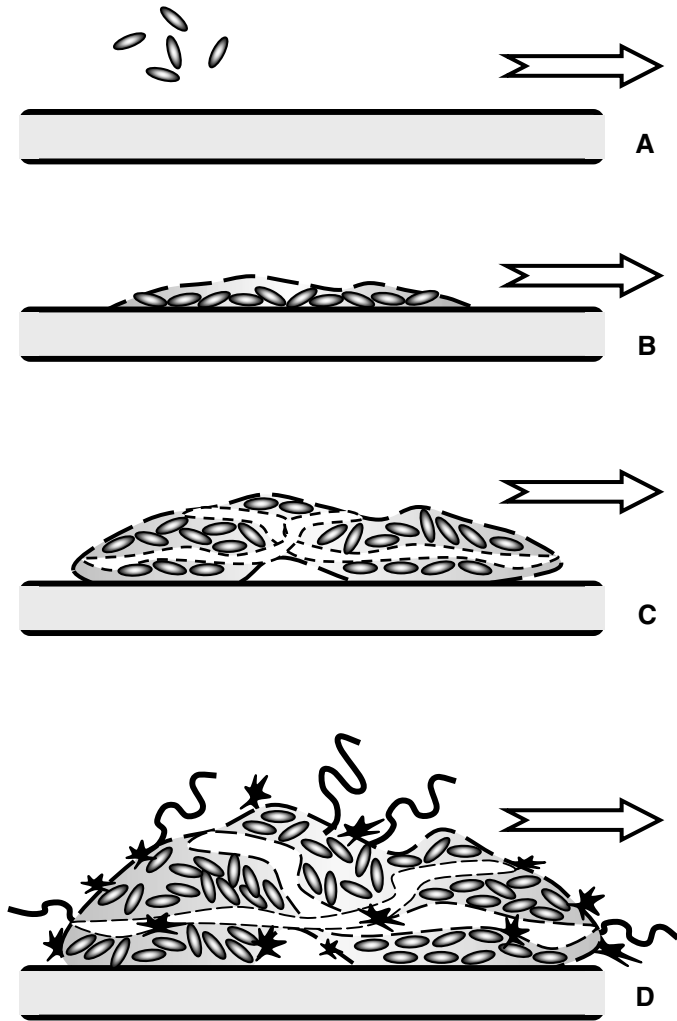
FIGURE 16.1 Development of a biofilm.

to the pipe wall as they grow in number. This mass is called the glycocalyx of the biofilm and is composed of long-chain polysaccharides produced by the bacteria.

In part (C), as the bacteria increase their numbers layer upon layer, minute channels are formed in the enlarging glycocalyx through which some of the beverage flow is directed. This channeling effect forms a network of ducts supplying all the individual cells in the biofilm with the water, nutrients, and substances essential for the cells' life processes.

As the extremely sticky glycocalyx matrix grows in size (part D), it starts trapping bits and pieces of microscopic debris contained in the liquid passing by. This association of trapped debris on the sticky gelatinous glycocalyx material is a characteristic feature of biofilms and is quite visible when viewed even under low-power magnification of a microscope. (If large enough, this could also be seen with the naked eye in a beverage containing biofilm fragments.)

This entire development process can be completed in a matter of a few days, and sometimes even more quickly. Though the biofilm is securely attached to the surface on which it develops, occasionally portions of the glycocalyx break off the main body and are shed into the flowing liquid. The sloughed portions are then carried off by the liquid to other locations. In a soft drink process, they can find their ways into bottled product.

SPECIAL CHARACTERISTICS OF BIOFILMS

In soft drink processing equipment, biofilms can develop on sites that are continuously in contact with product, such as gaskets, O-rings in pipe connections, valves, and even on heat exchanger plates. It would seem that biofilms favor sites that offer some protection from the vigorous physical scrubbing action of detergents.

BIOFILM BACTERIA VS. PLANKTONIC FORM

The bacteria in biofilms display characteristics that distinguish them from their counterparts in the free-swimming planktonic state. Some of these characteristics make biofilms a potential microbiological hazard and contribute to what was previously mentioned as "baffling" spoilage problems.

Biofilm bacteria have very different characteristics from their planktonic counterparts.

The gelatinous glycocalyx matrix surrounding the bacteria offers added protection from the chemical activities of cleaning and sanitizing agents, making them particularly resistant to standard clean-in-place (CIP) operations. Biofilm bacteria also display much higher resistance to the elevated temperatures that are effective against the planktonic forms. The normal staining methods used in preparing slides for microscope observation do not seem to work for the bacteria in biofilms — highly specific staining techniques are required.

Though quite evident in microbiologically spoiled beverages, both by visual observation and by discernable off-taste and spoilage odor, when such beverages are microbiologically tested by the regular methodology used in soft drink plants, colonies do not grow from the plated samples. The regular growth media used in these tests do not support colony growth for biofilm bacteria as they do for the equivalent in planktonic form. This has given rise to the VBNC concept — viable but not culturable. It would seem that in the biofilm form, though the bacteria are "alive and well" in the product, they refuse to grow on the plates used in the tests.

This is, by far, the most unique characteristic of biofilm bacteria that can make an investigation into a beverage spoilage problem somewhat baffling. You can see the biofilm film growth in the beverage, you can detect the fermentation spoilage odor, and if you dare, you can taste the spoilage in the beverage — but you cannot prove that the bacteria are there.

BIOFILM ON HEAT EXCHANGER PLATES

Biofilms can also be responsible for other damaging effects in the soft drink manufacturing process. These can become fairly evident in a specific processing equipment site — the plate heat exchanger.

Plate heat exchangers are particularly vulnerable to biofilm formation.

The fouling of heat exchanger plates can occur due to a leak between plates, as minute as it may be, that results in a sudden influx of product with nutritional ingredients into the previously nutrient-starved coolant water side of the heat exchanger plates. If present in the water, bacteria will quickly form biofilms attached to the plate surface. As mentioned, it only takes a day or two to develop these biofilm sites on the surface of the plate. If allowed to develop unrestrictedly, the eventual formation of numerous biofilm sites on the plates can have one or more of the following detrimental effects:

- Excessive biofilm coating on the plates can significantly reduce thermal conductivity of the plate material and reduce the heat transfer performance expected from the equipment.
- Like all living organisms, biofilm bacteria metabolism involves fixing and storing minerals in their cells and in the glycocalyx matrix in which they live. Very much like in the case of dental plaque, calcium salts are deposited in the biofilm sites on the plates.

Excessive deposits can cause mineral scale to develop, which, in turn, will impede liquid flow and contribute to reduction of thermal conductivity.

- The depositing of excessive minerals in different site locations of the metal heat exchanger plates can result in the formation of anodic and cathodic areas on the plate surface that will act as microscopically sized electrolytic cells. This will lead to a metal corrosion process and the formation of pitted areas in the plate. This process, termed microbiologically influenced corrosion (MIC), can have drastic effects on heat exchanger function and cause leakage of contaminants from heating and cooling water into the beverage product being pasteurized.
- The property of sticky biofilms trapping debris from the liquid passing around the glycocalyx and through its channeling system, if not controlled, will eventually result in blocking the liquid flow through the narrow spaces between plates.

All in all, any one or more of the above can occur in other types of processing equipment. But, it would seem that by virtue of their structural and operational nature, plate heat exchangers seem to be especially vulnerable to biofilm contamination.

BIOFILMS IN THE SOFT DRINKS INDUSTRY

It is not easy to identify the presence of biofilms in a soft drink manufacturing operation and is even less so to immediately and unequivocally pinpoint a microbiological contamination in a beverage as being the result of biofilm formation in processing equipment. One can, however, deduce from data and information obtained during an investigation that the possibility of biofilm as the cause is to be considered.

Some baffling microbiological spoilage problems can be attributed to biofilms.

I became fully acquainted with the biofilm concept during a beverage spoilage investigation I was called upon for assistance on some years ago. I will briefly list some factors that should be addressed during a microbiological spoilage investigation that may point to biofilms as the cause of contamination. It should be noted that not every item on its own is a conclusive indication of a biofilm problem, but when taken in conjunction with other factors, a pattern of "evidence" may be obtained that agrees with characteristics and behaviors peculiar to biofilm.

1. The contamination is the presence of small slimy gelatinous bodies clearly visible as suspended masses in the beverage when the bottle is gently swirled. (These are referred to as the "floaters," for convenience sake.)
2. Floaters appear in beverage bottles a few days or weeks after being filled. There are no floaters in the beverage samples taken off the line while filling.
3. Floaters are not observed in all bottles filled during a given period. Some bottles have the floaters, and others do not. This indicates a sporadic occurrence of the problem. It is not found throughout the entire batch.
4. Floaters appear in some production batches and not consistently in all of them. Again, floater appearance is sporadic.
5. The presence of floaters is not flavor specific.
6. The floater problem is specific to the one dedicated line. It does not appear in products produced on other production lines.

Up to this stage of the list, there is no specific evidence pointing to biofilms as a possible cause. However, if coupled to the factors listed below, this "pattern of evidence" takes on a more meaningful indication of biofilm presence in production equipment solely dedicated to the contaminated products' flavor range.

7. Observation of floaters under stereomicroscope magnification shows them as gelatinous stringy masses with a multitude of microscopic debris particles (black specks, fibers, etc.) embedded in or attached to these masses. This is the typical characteristic of biofilms entrapping small particles of debris on the sticky glycocalyx.

8. In-plant microbiological testing of samples with visible floaters by membrane filtration fails to produce counts in all samples tested, only in some of them. This could possibly be due to the VBNC principle of biofilms. The sessile forms of the bacteria in the biofilm do not develop into colonies on the standard growth media used in regular factory microbiological testing. The counts in samples that did show them could possibly be due to bacteria that reverted to the planktonic state.

9. Samples of floaters should be submitted for testing by an outside specialist microbiology laboratory, which may report them as viable bacterial cells contained in an organic substrate identified as "complex polymeric material" or something similar. If this were the case, it would perfectly fit the morphological description of a typical biofilm.

10. If the problematical product is produced with a plate heat exchanger pasteurizing process, before filling, the unit should be dismantled and individual plates examined for corrosion and pitting markings. If these are present, this could be due to MIC and points in the direction of biofilms.

11. If production operators report that the target pasteurizing temperatures have recently become unattainable without intermittent manual adjustment, this could indicate a loss of thermal conductivity due to biofilm formation in the plates.

At this stage of an investigation, my own conclusion, based upon the above evidence and data, would be that microscopic fragments of sheared-off biofilm in processing equipment of the specific production line were finding their ways into beverage-filled bottles. After some time, these either grow or agglomerate into the visible floaters or revert to the nonvisible planktonic form.

I would also conclude that the plate heat exchanger might well be a source, if not the only one, of biofilm formation. An obvious addendum to this final conclusion is that in order to form biofilms, there must first be a source of planktonic bacterial contamination. Therefore, an in-depth extensive cleaning and sanitizing action would be required for the processing equipment as well as for any raw material supplies that were microbiologically suspect.

PREVENTING BIOFILMS IN THE SOFT DRINK OPERATION

In the ever-growing soft drinks industry, the trend has been to supply greater volumes of final beverage product in any given period. For this purpose, beverage preparation and filling equipment has been improving in both sophistication and production volume capacities.

Long continuous production runs can give the biofilms the time needed to develop.

A spin-off of this trend is that production runs of beverage filling of a single product flavor have been extended to longer periods. A full 24-h filling run is not uncommon. It is in these long period runs where insignificant numbers of harmless bacteria present in the water used for beverage preparation have the perfect opportunity and time to convert to the "biofilm mode" and multiply at logarithmic pace under the favorable growth conditions.

Even with regular cleaning and sanitizing that should be performed between the these long period runs, the biofilm bacteria will have obtained an upper hand, because they have become more resistant to the cleaning processes than their planktonic counterparts. My suggestions for preventing biofilm formation in our industry are as follows:

1. Maintain the regular microbiological contamination prevention systems at the highest levels possible. After all, a biofilm requires a precursor in order to develop.

2. Familiarize operational staff with biofilm concept basics.
3. Reduce production runs to lowest practical duration (maximum of about 10 h).
4. Conduct a periodic visible inspection of favored biofilm formation sites in equipment — gaskets and O-rings in valve and pipe connection fittings, heat exchanger plates, filling valves, etc. This may mean an added workload in dismantling piping lines, heat exchangers, etc. Heat exchangers, if used in beverage production, should be given special attention. If found, first remove the biofilm by physically scrubbing before administering subsequent cleaning and sanitizing procedures. Contaminated gaskets and O-rings should be replaced with new ones.
5. Cleaning and sanitizing materials types should be changed every 6 months or so to prevent resistance buildup in potential bacterial contaminants.

Biofilms can be prevented by eliminating the initial bacterial contamination from which they develop.

In general, there is not much more to be done than as outlined above. As biofilms form from bacteria in their planktonic form, the corollary is that to prevent their formation, initial bacterial contamination must be present in the equipment. Therefore, this initial contamination must be eliminated or prevented by having effective water treatment, ensuring the high quality of raw materials (mainly sugar), and implementing an effective cleaning and sanitizing program. Each soft drink operation may require additional measures to prevent biofilm formation in its particular processes and products. I will conclude this chapter with a single remark about biofilms.

Biofilms can be a "disaster waiting around the corner" for any soft drink operation, small or large. Therefore, operational management and staff should be acquainted with the biofilm concept and should treat it with the respect it deserves.

17 Quality — The Key to Performance

WHAT IS QUALITY?

Quality can be simply defined as a level of excellence. Excellence can be described as having great merit. Merit, in turn, can mean having a feature of quality deserving of praise. So, in trying to define quality, we go around in circles of semantics.

Quality determines the performance of a beverage in the marketplace.

To cut through this morass of semantics, I will offer a definition of quality as it applies to the subject of this handbook — the soft drink product. A quality beverage is one that meets the standards of performance expected by both the manufacturer and the consumer. To perform well, the beverage must meet the following basic quality standards:

- The beverage must have the sensory properties that satisfy the consumer's expectations.
- It must present no health hazard to the public, in general, and to the consumer, in particular.
- The beverage must retain its initially produced quality for the prescribed shelf life in the marketplace.
- The product must meet the description offered on its label and in media advertising.
- The full range of a company's beverage products must reflect a positive image of the company.
- The cost of the beverage to the purchaser must be reasonable.

A marketing perception of performance is often of how well the product is selling. Is it exceeding budgeted sales, are sales growing exponentially, is it making the expected profits for the company? I do not often agree with marketing personnel's perceptions of technical issues, but here I do agree. A high-quality beverage meeting all the above-mentioned performance quality standards stands a very good chance of being a sales success. And it is precisely for this reason that I linked performance to quality in the title of this chapter.

Does this mean that a beverage that is not enjoying a successful sales life is of inferior quality? A marketing person could explain that the flop of the beverage was due to misjudging consumer acceptance, overpricing, special vigorous marketing measures by the competition, poor promotion by the company, or an array of other similar excuses. According to my definition of quality and performance, one or more of the standards would not have been met. The most likely one being that the beverage simply did not appeal to consumer taste. Was it then of inferior quality? My answer is that performance-wise, it was. But then this is a matter of opinion that will be touched upon later in this chapter.

QUALITY MANAGEMENT

Whether the performance level of a soft drink product is determined by its overall success in sales in the market or by individual quality parameters of taste, stability on the shelf, freedom from spoilage defects, etc., is not the real issue here in this chapter. What is of importance is how do we go about ensuring that the quality of a company's beverages will be of a satisfactory "level of

excellence" to give the product all the chances for success in sales. This is achieved by effective quality management. Before discussing the nuts and bolts of this subject, a few items related to quality concepts in general should be clarified.

QUALITY ASSURANCE AND QUALITY CONTROL

These two concepts are often confusing and taken to mean the same thing. I believe a clear distinction in the meaning of these two terms will help the reader in the subsequent sections of this chapter. Therefore, I will attempt to distinguish these concepts as follows. In simpler terms, in order for a soft drink production facility to manufacture a quality beverage meeting all the performance parameters listed previously, quality assurance personnel must provide this manufacturing facility with the means, inclusive of information, procedures, controls, and equipment descriptions, to prepare such a product.

> Quality assurance, in terms of a company's operational organizational structure, is the authority responsible for a planned and systematic design of all the actions necessary to provide adequate confidence that a product will conform to established requirements.

To use some exaggerated examples for emphasis, it would be meaningless for quality assurance to prescribe a preparation procedure for the beverage if suitable processing equipment is not available to the factory, to stipulate quality specifications tolerances that are realistically unachievable, and to formulate the beverage with an ingredient cost composition that would preclude any probability of meeting established company profit margins.

In short, quality assurance must establish all the activities to be implemented in the overall quality management system that clearly demonstrate a high degree of confidence that the product will be able to meet the quality parameters it set up as standards for the company.

Again, in simpler terms, quality control is the on-line and in-plant authority that implements, monitors, and controls the activities of the overall management plan to ensure company conformance to quality standards.

> Quality control, in terms of a company's operational organizational structure, is the authority that implements the operational techniques and activities required to achieve the established standards for quality.

From the above descriptions, it would appear that quality control is subservient to quality assurance in the sense of the company's organizational structure. Indeed, in large multinational soft drink conglomerates, the quality assurance department usually resides in a head office site and functions on a staff basis, while the quality control department functions separately in the bottling plants in a line fashion.

However, even in such a case, the lines between the two authorities sometimes overlap and become blurred. In a smaller independent private company, quality assurance and quality control often reside in the same department and even in the same individual. Whatever the case, the seemingly subservient position of quality control to quality assurance is merely a matter of distinguishing between two functions — one of design and the other of implementation. In this way, the accountability and responsibilities of each authority are clearly defined.

If the distinction between quality assurance and quality control as described is acceptable, then the definition of quality management becomes somewhat easier. Though a quality management system is, in essence, a technical function, it requires the continued support and involvement of all of a company's management staff.

> Quality management is the ongoing process of confirming that all components of the quality assurance program are being implemented in compliance with the overall quality assurance plan.

BUILDING QUALITY INTO THE SOFT DRINK

Having discussed the somewhat broader aspects of quality systems and how they function, let us turn to the realities of how quality is built into soft drinks produced in a typical beverage manufacturing operation. The final quality of a bottle of beverage standing on the shelf of a supermarket store is the result of a building process in which the components of quality are laid down, block by block, in an orderly manner.

Quality is the result of a block-by-block building process.

THE QUALITY CONTROL DEPARTMENT

One fact must be clarified from the start of this short study of quality building — quality is not built into the product by that department called quality control (QC). It is built into the product by production and the other support departments of the company. The function of the QC department is to monitor the quality status at the various stages of the process.

Quality is not built into the product by quality control.

QC is the policeman of the factory and has often been called the "necessary evil." QC stops a filling line because the Brix is out of specification; it puts "on hold" urgently required finished stock, preventing it from being dispatched; it is responsible for out-of-stock product, having condemned substandard quality raw materials; it points to microbiologically contaminated lines in the equipment; and the list can go on and on.

That is the job of QC, to check and report back, and sometimes to take action that upsets more than a few people in the factory. On the other hand, many a time, QC enters the act as a helping hand. In the long run, the QC department always achieves the respect and trust of all those who appear to suffer at its hands.

SOME OF THE QUALITY-BUILDING BLOCKS

Quality management operates within the design of a quality assurance program and in the framework of continuous monitoring by QC to build quality into the product. I will select a few of the many quality requirements for the ultimate successful performance of a soft drink product as examples and attempt to describe how the different departments in a company contribute to achieving the established quality standards.

All company departments contribute to the quality-building process.

TASTE

By far, one of the most critical quality parameters of a beverage is the sensory profile, which I will, for convenience purposes, refer to simply as taste. It all starts from sourcing the correct ingredients of standard quality. The purchasing department only acquires ingredients from an established list of approved suppliers. This example of the taste quality parameter demonstrates how various departments of a soft drink company, in their different ways, participate in building quality into a beverage.

- *Stores* hold these in designated suitable storage locations under conditions applicable to each type of ingredient. They are issued to production in strict prescribed first-in, first-out (FIFO) stock rotation manner to avoid quality deterioration due to aging and expiry of recommended shelf life, with particular emphasis on flavors, emulsions, and fruit juices.
- The *syrup room* prepares the syrups in strict adherence to master formulations and mixing instructions.

- *Bottling/canning* then converts the syrups into final beverage using the prescribed water-to-syrup ratio for each product flavor. Continuous on-line checking is conducted for adherence to key quality parameters such as taste, Brix, and carbonation as well as for capping, seaming, and batch and expiry date coding.
- Packed final beverage is stored in the *warehouse* and only delivered to the trade when released by quality control after satisfactory quality testing. Dispatches to the trade are conducted in strict FIFO stock-rotation manner. The elimination of off-tastes in a beverage is an ongoing process that takes place in parallel to the above-described final beverage production processes.
- Prescribed effective *water treatment* is continuously conducted on incoming municipality raw water to eliminate potential off-tastes and foreign odors in the water used for production.
- *Cleaning and sanitizing* programs are enforced to ensure sanitary conditions in equipment and lines in which microbiological contamination could result in fermentation off-notes and off-odors. These programs also ensure proper lines and equipment rinsing between flavor changeovers that could result in residual flavor cross-contamination.
- *Bottle and can rinsing* also play their roles in off-taste elimination, as well as maintenance's role in identifying oil leaks in pumps, agitators, and other lubricated equipment.
- *CO_2 gas purity* is also a factor in beverage off-tastes due to the presence of minute quantities of oil in gas of substandard quality. This potential taste hazard must also be addressed by the installation of in-line filters in CO_2 piping to the filling machine.

APPEARANCE

The appearance of a beverage in a bottle is, like taste, also a prime quality parameter. The beverage may taste fine, and it may possess all its unique selling point characteristics, but if it does not look right, it will not sell.

Many of the "building blocks" of appearance quality are the same as mentioned before for taste. To be added is the preservation of color by avoiding exposure of the bottled products to direct sunlight. Product cases are required to be covered during daylight delivery operations, and drivers are instructed to ensure that off-loaded products at large supermarket sites are not allowed to be kept in the sun.

Electronic and sometimes even visual bottle inspection stations are mandatory on filling lines, for both empties and fulls. These are checked for foreign objects, particulate matter (black specks from carbon purifiers), net content (fill heights), etc.

A particularly troublesome appearance defect is a neck-ring in a bottle of cloudy beverage that is usually due to the breakdown of the emulsion stability. Careful monitoring of not exceeding the usually short expiry period of cloudifiers and flavor emulsions as well as storage of the emulsions in cold-rooms and away from excessive heat is a mandatory function of stores.

HEALTH HAZARDS

Soft drinks are food products and, as such, elimination of contamination of products with pathogenic microorganisms is high on the list of quality requirements. Pathogens, if at all present in a soft drink, are most likely to be introduced through contaminated raw water supplies. This issue of pathogen contamination, unlikely as it may be, is addressed by the various disinfection stages of the multiple barrier principles of water treatment, the key process in soft drink quality systems.

Added steps to control pathogen contamination are rigorously enforced plant hygiene practices and pest and vermin control practices. Staff health monitoring supervised by administration or human resources is also a prerequisite in the soft drink factory. Pathogen contamination as well as general microbiological control is globally addressed by an effective cleaning and sanitizing program, the responsibility for which lies in production.

QUALITY BUILDING SUPPORT

The simple three examples presented above were to demonstrate that quality building is a diversely distributed function in the soft drink operation. Quality is the result of a coordinated system in which quality assurance establishes the achievable quality standards and supplies the wherewithal to do so, QC monitors adherence to these standards, and general effective quality management, so to speak, puts "the cherry on top of the cake." There are many other factors that support the objective of achieving high levels of quality in soft drink manufacturing operations.

First, and above all, is the matter of training and skills development for floor operators. This is not necessarily an item unique to quality building, as it is a fundamental principle in any and all types of processing operations. Operators need training, and development of their skills will always result in increased efficiency.

Floor operator training is essential to quality building.

The issue with quality is that it is more or less an intangible concept. It is not too difficult to train an operator to handle a machine, to make adjustments when needed, and even to take the initiative when emergencies arise. Learning how the machine works, where the bottlenecks lie, and how to fix them is part of the skills development process.

Quality is an "intangible" and requires education in order to be fully understood.

But how does one train an operator in quality issues, such as microbiological contamination, aging of raw materials, the density/Brix relationship, the temperature/pressure relationship for gas volumes, etc.? The line operator usually views these as part of the mystery of science and technology, which he or she assumes to be above his or her level of understanding.

The answer to this is education, which can be easily accomplished if time and opportunity are afforded to the operator in periodic seminar-type presentations. Even a basic understanding of the workings of science and technology will help the operator to better appreciate the fundamentals of good quality building and thus improve the operator's contribution to the process.

A prerequisite to effective quality management is the existence, and indeed the availability, of master documentation in hard copy or computerized format for all quality and production manuals, specifications, and standard procedures. These are usually supplied, in principle, by the quality assurance authority of the company, but they require constant updating and modification to suit the everchanging conditions in the working environment.

Incentives to staff are a general means of increasing efficiency in any workplace environment, and a quality incentive could have the same analogous effect. The question is how to design an incentive scheme for quality and what should it be based upon? Normal incentives are based on numerically evaluated achievements, such as production yields, machine downtime, or sales volumes. How does one quantify quality? One way of quantifying quality is to conduct a quality rating system by means of which a quality index can be calculated for a given period. The practice of rating quality is described in the following section, not necessarily only in connection with quality incentives, but more as a system for monitoring the quality status of the company's products.

QUALITY RATING SYSTEMS

Conducting a quality rating program in a soft drink operation can considerably enhance the overall process of quality management, as it provides a means with which to monitor the general quality status and individual aspects of products, processes, and equipment. It can also serve as a quality history archive and indicate trends.

A quality rating system can serve as a powerful tool in quality management.

Basic System Operation Principles

Whether the quality rating system is simple or sophisticated, the basic elements and operation are very much the same and use the following guidelines:

1. A few key quality parameters characteristic for the type of beverage involved are selected as the elements on which the quality rating is to be based. For a carbonated soft drink, one of these parameters would obviously be gas volume, while a low-alcohol soft drink would have percent alcohol content included.

2. Monthly samples of company products, of all flavors, package types, and sizes, are collected and tested for the established quality parameters. The prerequisite for a meaningful quality rating system is that these samples be randomly collected and chosen without any bias as to their appearance, location, age, etc. The total number of samples to be collected depends on the additional laboratory workload allowed for the program, but this total should include at least two samples of each flavor in different package types and sizes. The most suitable location for drawing samples would be from the trade — the place where quality of products is most critical.

3. Test results are recorded and designated as "pass" or "fail" based on the quality parameter's individual specification and applicable tolerance range. The actual test results and the pass or fail designation are recorded in tabular format relating to the sample tested and other sample data, such as date sampled, flavor, package, date coding, etc., included in the system design and objectives. As it is best to record all the systems data and results in a database program, the pass or fail can be designated "1" or "0" (zero), respectively. This will allow for numeric data sorting and subsequent rating calculations. The pass or fail recording must be practiced uncompromisingly. Even a 0.01 Brix result out of specification must be recorded as a fail. A taste test result, as an example, is either a pass or a fail — there is no in between designation.

4. The total number of pass results for each quality parameter is expressed as a percentage of the total number of samples tested for that parameter. This percentage pass figure is entered in the database table under the appropriate quality parameter column and can be termed the quality rating for that parameter.

5. The overall quality rating can now be calculated, and it is up to the system designer to select a meaningful mathematical formula to be used for this calculation. The simplest yet still meaningful calculation would be the arithmetic average of the sum of the different parameters' quality ratings, expressed as a percentage. (This will be the calculation used in a demonstration given later in this section.) This averaged figure would then represent the quality index of the product population sampled for the month. It can, therefore, be used as a quality rating for the company's products for the period involved.

6. Two database reports can be generated as follows:
   a. A detailed report listing each sample tested and its corresponding test results, indicating a pass or fail disposition. The report is designed to count all the pass results for each quality parameter and record this value as a percentage of the total samples tested, i.e., the quality rating for the parameter. The quality ratings for each parameter are summed, and an average is calculated. This is the overall quality index for all the samples tested.
   b. The second report is the summary report in which each product flavor's individual quality ratings per quality parameter are calculated and expressed as a quality index for that particular product. Depending on the system designer's choice, these summaries can be sorted and presented in different categories, such as by flavor, package size, filling line number, or in the case of a multifacility company, by factory location.

7. A further report can be generated in chart format to display previous overall quality index values on a monthly, 3-month average or year-to-date basis. The options are varied and numerous.
8. Printouts of the reports are sent to company officials concerned, and a meeting for scrutiny and discussion of results is convened.

WORKING EXAMPLE OF A QUALITY INDEX REPORT

Before entering into a discussion of the merits and possible weaknesses of a quality rating system such as that described above, let us briefly study a simulated mock example of a typical quality index report. For the purpose of simplifying this study, we will assume the following:

1. The soft drink operation only runs three carbonated soft drink products:
   a. Cola in 2000 ml and 500 ml PET bottles
   b. Lemonade in 2000 ml and 500 ml PET bottles
   c. Orange in 2000 ml and 300 ml PET bottles
2. The 2000 ml products are filled on filling line number 1, and the smaller sizes, 500 and 300 ml are filled on filling line number 2.
3. Five quality parameters are used in the rating system, as follows:
   a. Brix: Pass or fail based on numeric specification tolerance range
   b. Gas volume: Pass or fail based on numeric specification tolerance range
   c. Yeasts and molds: Pass or fail based on numeric specification tolerance range
   d. Taste and appearance: Pass or fail based on "OK" or "Not OK"
   e. Date coding on bottle: Pass if present, correct, and legible, otherwise fail
4. For the month concerned, five samples of each product flavor and size were taken from the shelf of a supermarket store, amounting to a total of 30 samples.
5. The quality index rating system considers an index of 90 and higher as satisfactory. An index below 90 is considered as unsatisfactory.

Table 17.1 represents the monthly quality index summary report compiled from a previously generated details report that contained the individual samples' test results and quality parameter pass or fail disposition for each of the thirty samples tested. This summary report, as explained previously, only contains the quality ratings (i.e., the percentage pass results) and does not show the individual test results.

Proceeding with the study of the quality index report, we will see at first glance that the plant quality index is at 90, a satisfactory level. But, being borderline, it could still be improved. The parameters of Brix, yeast and molds, and taste and appearance are satisfactory. Those of gas volume and date coding are somewhat wanting. These are the parameters that are lowering the plant quality index to the 90 level.

Looking at the second index item, all products, a pattern is evident that all the flavors filled on line number 1 have very high quality index levels, whereas those made on line number 2 are unsatisfactorily low in index level. Lemonade and orange made on this line show ratings of 60 for gas volume (which means that only three out of the five samples tested for each flavor passed the gas volume specification).

By consulting the detail quality index report, we find that the gas volumes for these flavors were either above or below the carbonation specifications. In other words, carbonation can be assumed to be erratic on this filling line.

Further scrutiny will reveal that the date coding rating on line number 2 is also low (60) for all three flavors.

TABLE 17.1
Monthly Quality Index Summary Report

Quality Index Item	Size (ml)	Line Number	Quality Index	Brix	Gas Volume	Yeast and Mold	Taste and Appearance	Date Coding
Plant Quality Index			90	97	80	100	93	80
All products								
Cola	2000	1	100	100	100	100	100	100
Cola	500	2	88	100	80	100	100	60
Lemonade	2000	1	100	100	100	100	100	100
Lemonade	500	2	80	80	60	100	100	60
Orange	2000	1	96	100	80	100	100	100
Orange	300	2	76	100	60	100	60	60
Flavors								
Cola			94	100	90	100	100	80
Lemonade			90	90	80	100	100	80
Orange			86	100	70	100	80	80
Filling lines								
Line number 1			99	100	93	100	100	100
Line number 2			81	93	67	100	87	60
Bottle size								
2000 ml			99	100	93	100	100	100
500 ml			84	90	70	100	100	60
300 ml			76	100	60	100	60	60

Again, by consulting the test results in the detailed report, we find that the fail disposition is explained by the comment "illegible" — the ink-sprayed dating digits are not readable. It would appear, therefore, that something is wrong with the date coding equipment. As the coding dates are not legible, we cannot determine if this is a one-off incident during one filling run or if it is a prevalent situation occurring at different dates.

One more item of concern in the all products quality index category is the 60 quality rating for the Orange 300 ml taste and appearance parameter.

Consulting the detailed report, we find that the two fails for taste and appearance were due to skewed plastic labels on the bottles. The two 300 ml bottles had readable coding dates indicating that these bottles were from two separate filling runs. We could, therefore, be led to believe that the skewed label application was a recurring problem that was not fully resolved.

All in all, it seems that line number 2 is generally problematical — in gas volumes, date coding, and labeling of the 300 ml bottles. The data in the filling lines category confirms this, with respective ratings of 67, 60, and 87 for the above-mentioned problematical quality ratings.

The bottle size quality index category again confirms this issue, as both the 500 and 300 ml bottles are filled on line number 2. The 300 ml bottle quality index is the lowest due to the labeling defect.

I purposely skipped the flavors quality index category in this discussion, as the indices are more or less in order. This is because the very high ratings for all flavors, filled on line number 1, "masked" the low values for line number 2, by virtue of the arithmetic averaging calculation for the quality index. Had, for instance, a taste defect been picked up in one of the flavors tested, due to a globally intrinsic flavor problem, it could very well have been reflected in this category, as it is not at all filling machine related.

In conclusion, this simplistic presentation of a quality rating system gives one an idea of how it can be used to evaluate quality numerically as well as to identify root causes of quality defects. With a soft drink operation involving many product flavor and package types and sizes, filled on numerous lines and possibly in different manufacturing facilities, these quality "diagnostic" features necessarily require a well-operating sophisticated database program. Such a database could handle enormous amounts of numerical data related to the pass and fail classification system. The data could be collected and stored over lengthy periods; it could be sorted and tabulated per relevant applicable criteria; and trends could be charted and detected.

How Meaningful Is the Data?

One of the main arguments often directed against a quality rating system such as that described in the example is the question of how a few samples can be representative of a filling run involving thousands of bottles filled in a regular bottling run. Can the quality status of an entire run be based on these few samples? Is it justified to "condemn" a plant by allocating it with a low quality index rating based on one or two defective samples? The answer to these questions is that, to a certain extent, data from a few samples cannot truly reflect the quality status of an entire bottling run involving tens if not hundreds of thousands of bottles filled in a single bottling run.

The "weakness" factor of the small sample number is discussed.

But then, let us look at it from another angle. In a bottling run after the initial startup adjustments are completed, it is not common that a only a few bottles of product with quality defects are filled and allowed to slip through on-line quality control routine checks. If something goes wrong, e.g., a drop in carbonation, it will continue for some time until picked up by on-line testing. This would involve quite a few bottles or cases of product, especially if filled on the modern high-speed fillers we now have in most plants. These cases of product should then normally be traced, isolated, and destroyed. They should not find their ways into the regular stock of regular-quality product that would eventually land up in the trade.

The small sample number could, in fact, be the "strongest" factor of the system.

Thus, if substandard quality product somehow evaded attention in the plant and found its way into the trade, it would be in small but significant quantities. The probability of some of these bottles being sampled for quality rating testing will be in direct proportion to the quantity in the trade. If a substandard quality bottle of product is picked out in the few samples collected, it would be an indication that this substandard product exists in significant quantities in the trade.

If due to freak circumstances, and the single sampling location used (e.g., a supermarket store) contains substandard quality product in large quantities out of proportion to the number of defective bottles actually produced, this will unfavorably skew the monthly quality index of the plant. But then, it would be better to have identified the quality problem than to have missed it altogether.

So, to sum up the argument of misrepresentation of quality status by the very small number of samples used in the quality rating system, theoretically, the small number of samples is not representative of an individual filling run and the entire quality status of the plant. However, if

substandard samples are picked up in the sampling process, regardless of whether this is due to coincidence or to a large quantity present in the trade, quality problems are being detected. This is the aim of the system. The substandard samples should not be there at all. They are there either because they slipped through the quality control system or, if the defect was picked up during production, the defective product was not isolated and destroyed. In either case, there is a flaw in quality management, and it must be identified and corrected.

> Of course, there is the other side to the story. The small sample number factor may result in substandard product, if such exists, not being picked out at all, and a resultant high quality index allocated to the plant will also be misleading, and dangerously so.

> My answer is that this is applicable in a oneoff sense. However, a quality rating system runs continuously for long periods. In the long term, such "hidden" quality issues usually eventually come to the fore. I say this out of experience of both having participated in quality rating systems and having managed them as well.

Quality Rating as an Incentive

A quality rating system is an ideal tool for quality incentive schemes. The quality index can serve as a numerical criterion on which to base the scheme.

Incentive bonuses can be determined on the level of a quality index for the plant. Who receives the bonus payment and the cash sums (or other "kinds of payment") involved are matters for plant management to decide upon. Constructive positive rivalry can be introduced in a single-facility operation with several filling lines by using the line number quality index as the criterion. The monthly bonus could go to the operating staff of the line with the highest index rating. In multi-facility organizations, this rivalry can be extended to the different factories of the company.

In all cases, the incentive is not only the cash sum involved, it is also the accompanying pride often generated in the staff as a result of achieving and maintaining high levels of the quality index. This pride can only enhance quality management in the workplace.

Outsourcing the Quality Rating System

It is common to outsource the running of a quality rating system to an outside operation, as this both eliminates the element of in-house bias and avoids the extra workload that it would impose on the plant's quality control department were it to undertake the task.

If outsourced to an outside agency, the quality rating system should be designed by the soft drink company, or at least the company should participate in such a design if created by the outsourced company. This is important, because each beverage company knows its own operation and the prevailing quality issues peculiar to its own operation. These can be especially built in as criteria and parameters for the operation of the system. In the larger soft drink companies, the role of quality rating is usually allocated to a head office technical authority that designs and runs the system.

CHAPTER REVIEW

This chapter attempted to view the quality of a soft drink from a specific angle — as a measure of its overall performance as a successful beverage in the marketplace. This raises the question of whether an unsuccessful beverage in the market is of low quality. My answer is a categorical affirmative one, as simply put, what is it doing in the market in the first place?

It is true that the lack of success does not imply that its intrinsic quality properties, such as taste, appearance, microbiological and health soundness, etc., are defective. The failure of the product is due to "something wrong with it" — consumer appeal, pricing structure, or even lack

of marketing promotion. I will be bold enough to state that these could all be included in the concept of quality — a high level of excellence.

The chapter also attempted to define and explain some of the confusing terminology used in quality matters, such as quality assurance, quality control, and quality management. Quality in this chapter was portrayed as a block-by-block building process involving all company operational departments and is not the sole monopoly of QC. A major part of the chapter was dedicated to the concept of quality rating systems. These were described as a potentially powerful tool in quality management and can serve as the basis for quality incentive schemes.

What was not mentioned in this chapter and will be stated here, is that by far the best tool for quality enhancement in a soft drink operation is to have an effective and alert QC department. The rest will follow suit.

Appendix 1

Brix/Density Conversion Tables

Source: From National Bureau of Standards, Table 114, Circular of the National Bureau of Standards C440, *Polarimetry, Saccharimetry and the Sugars*, U.S. Government Printing Office, Washington D.C., 1942.

°Brix at 20°C	Density at 20°C	Kg Solids per Liter	°Brix at 20°C	Density at 20°C	Kg Solids per Liter
0.0	0.99717	0.0000	5.0	1.01680	0.0508
0.1	0.99756	0.0010	5.1	1.01719	0.0519
0.2	0.99795	0.0020	5.2	1.01759	0.0529
0.3	0.99834	0.0030	5.3	1.01799	0.0540
0.4	0.99872	0.0040	5.4	1.01839	0.0550
0.5	0.99911	0.0050	5.5	1.01879	0.0560
0.6	0.99950	0.0060	5.6	1.01919	0.0571
0.7	0.99989	0.0070	5.7	1.01959	0.0581
0.8	1.00028	0.0080	5.8	1.01999	0.0592
0.9	1.00067	0.0090	5.9	1.02040	0.0602
1.0	1.00106	0.0100	6.0	1.02080	0.0612
1.1	1.00145	0.0110	6.1	1.02120	0.0623
1.2	1.00184	0.0120	6.2	1.02160	0.0633
1.3	1.00223	0.0130	6.3	1.02200	0.0644
1.4	1.00261	0.0140	6.4	1.02241	0.0654
1.5	1.00300	0.0150	6.5	1.02281	0.0665
1.6	1.00339	0.0161	6.6	1.02321	0.0675
1.7	1.00378	0.0171	6.7	1.02362	0.0686
1.8	1.00417	0.0181	6.8	1.02402	0.0696
1.9	1.00456	0.0191	6.9	1.02442	0.0707
2.0	1.00495	0.0201	7.0	1.02483	0.0717
2.1	1.00534	0.0211	7.1	1.02523	0.0728
2.2	1.00574	0.0221	7.2	1.02564	0.0738
2.3	1.00613	0.0231	7.3	1.02604	0.0749
2.4	1.00652	0.0242	7.4	1.02645	0.0760
2.5	1.00691	0.0252	7.5	1.02685	0.0770
2.6	1.00730	0.0262	7.6	1.02726	0.0781
2.7	1.00769	0.0272	7.7	1.02766	0.0791
2.8	1.00809	0.0282	7.8	1.02807	0.0802
2.9	1.00848	0.0292	7.9	1.02848	0.0812
3.0	1.00887	0.0303	8.0	1.02888	0.0823
3.1	1.00927	0.0313	8.1	1.02929	0.0834
3.2	1.00966	0.0323	8.2	1.02970	0.0844
3.3	1.01006	0.0333	8.3	1.03011	0.0855
3.4	1.01045	0.0344	8.4	1.03052	0.0866
3.5	1.01084	0.0354	8.5	1.03093	0.0876
3.6	1.01124	0.0364	8.6	1.03133	0.0887
3.7	1.01163	0.0374	8.7	1.03174	0.0898
3.8	1.01203	0.0385	8.8	1.03215	0.0908
3.9	1.01243	0.0395	8.9	1.03256	0.0919
4.0	1.01282	0.0405	9.0	1.03297	0.0930
4.1	1.01322	0.0415	9.1	1.03338	0.0940
4.2	1.01361	0.0426	9.2	1.03379	0.0951
4.3	1.01401	0.0436	9.3	1.03420	0.0962
4.4	1.01441	0.0446	9.4	1.03461	0.0973
4.5	1.01480	0.0457	9.5	1.03503	0.0983
4.6	1.01520	0.0467	9.6	1.03544	0.0994
4.7	1.01560	0.0477	9.7	1.03585	0.1005
4.8	1.01600	0.0488	9.8	1.03626	0.1016
4.9	1.01640	0.0498	9.9	1.03667	0.1026

°Brix at 20°C	Density at 20°C	Kg Solids per Liter	°Brix at 20°C	Density at 20°C	Kg Solids per Liter
10.0	1.03709	0.1037	15.0	1.05811	0.1587
10.1	1.03750	0.1048	15.1	1.05854	0.1598
10.2	1.03791	0.1059	15.2	1.05897	0.1610
10.3	1.03833	0.1069	15.3	1.05940	0.1621
10.4	1.03874	0.1080	15.4	1.05983	0.1632
10.5	1.03916	0.1091	15.5	1.06026	0.1643
10.6	1.03957	0.1102	15.6	1.06069	0.1655
10.7	1.03999	0.1113	15.7	1.06112	0.1666
10.8	1.04040	0.1124	15.8	1.06155	0.1677
10.9	1.04082	0.1134	15.9	1.06198	0.1689
11.0	1.04123	0.1145	16.0	1.06241	0.1700
11.1	1.04165	0.1156	16.1	1.06284	0.1711
11.2	1.04207	0.1167	16.2	1.06327	0.1722
11.3	1.04248	0.1178	16.3	1.06370	0.1734
11.4	1.04290	0.1189	16.4	1.06414	0.1745
11.5	1.04332	0.1200	16.5	1.06457	0.1757
11.6	1.04373	0.1211	16.6	1.06500	0.1768
11.7	1.04415	0.1222	16.7	1.06544	0.1779
11.8	1.04457	0.1233	16.8	1.06587	0.1791
11.9	1.04499	0.1244	16.9	1.06630	0.1802
12.0	1.04541	0.1254	17.0	1.06674	0.1813
12.1	1.04583	0.1265	17.1	1.06717	0.1825
12.2	1.04625	0.1276	17.2	1.06761	0.1836
12.3	1.04667	0.1287	17.3	1.06804	0.1848
12.4	1.04709	0.1298	17.4	1.06848	0.1859
12.5	1.04750	0.1309	17.5	1.06891	0.1871
12.6	1.04793	0.1320	17.6	1.06935	0.1882
12.7	1.04835	0.1331	17.7	1.06978	0.1894
12.8	1.04877	0.1342	17.8	1.07022	0.1905
12.9	1.04919	0.1353	17.9	1.07066	0.1916
13.0	1.04961	0.1364	18.0	1.07110	0.1928
13.1	1.05003	0.1376	18.1	1.07153	0.1939
13.2	1.05046	0.1387	18.2	1.07197	0.1951
13.3	1.05088	0.1398	18.3	1.07241	0.1963
13.4	1.05130	0.1409	18.4	1.07285	0.1974
13.5	1.05172	0.1420	18.5	1.07329	0.1986
13.6	1.05215	0.1431	18.6	1.07373	0.1997
13.7	1.05257	0.1442	18.7	1.07417	0.2009
13.8	1.05300	0.1453	18.8	1.07461	0.2020
13.9	1.05342	0.1464	18.9	1.07505	0.2032
14.0	1.05385	0.1475	19.0	1.07546	0.2043
14.1	1.05427	0.1487	19.1	1.07593	0.2055
14.2	1.05470	0.1498	19.2	1.07637	0.2067
14.3	1.05512	0.1509	19.3	1.07681	0.2078
14.4	1.05555	0.1520	19.4	1.07725	0.2090
14.5	1.05598	0.1531	19.5	1.07769	0.2101
14.6	1.05640	0.1542	19.6	1.07814	0.2113
14.7	1.05683	0.1554	19.7	1.07858	0.2125
14.8	1.05726	0.1565	19.8	1.07902	0.2136
14.9	1.05768	0.1576	19.9	1.07947	0.2148

°Brix at 20°C	Density at 20°C	Kg Solids per Liter	°Brix at 20°C	Density at 20°C	Kg Solids per Liter
20.0	1.07991	0.2160	25.0	1.10251	0.2756
20.1	1.08035	0.2172	25.1	1.10297	0.2768
20.2	1.08080	0.2183	25.2	1.10343	0.2781
20.3	1.08124	0.2195	25.3	1.10389	0.2793
20.4	1.08169	0.2207	25.4	1.10435	0.2805
20.5	1.08213	0.2218	25.5	1.10482	0.2817
20.6	1.08258	0.2230	25.6	1.10528	0.2830
20.7	1.08302	0.2242	25.7	1.10574	0.2842
20.8	1.08347	0.2254	25.8	1.10620	0.2854
20.9	1.08392	0.2265	25.9	1.10667	0.2866
21.0	1.08436	0.2277	26.0	1.10713	0.2879
21.1	1.08481	0.2289	26.1	1.10759	0.2891
21.2	1.08526	0.2301	26.2	1.10806	0.2903
21.3	1.08571	0.2313	26.3	1.10852	0.2915
21.4	1.08616	0.2324	26.4	1.10899	0.2928
21.5	1.08660	0.2336	26.5	1.10945	0.2940
21.6	1.08705	0.2348	26.6	1.10992	0.2952
21.7	1.08750	0.2360	26.7	1.11038	0.2965
21.8	1.08795	0.2372	26.8	1.11085	0.2977
21.9	1.08840	0.2384	26.9	1.11131	0.2989
22.0	1.08885	0.2396	27.0	1.11178	0.3002
22.1	1.08930	0.2408	27.1	1.11225	0.3014
22.2	1.08975	0.2420	27.2	1.11272	0.3027
22.3	1.09020	0.2432	27.3	1.11318	0.3039
22.4	1.09066	0.2444	27.4	1.11365	0.3051
22.5	1.09111	0.2456	27.5	1.11412	0.3064
22.6	1.09156	0.2468	27.6	1.11459	0.3076
22.7	1.09201	0.2480	27.7	1.11506	0.3089
22.8	1.09247	0.2492	27.8	1.11553	0.3101
22.9	1.09292	0.2503	27.9	1.11600	0.3114
23.0	1.09337	0.2515	28.0	1.11647	0.3126
23.1	1.09383	0.2527	28.1	1.11694	0.3139
23.2	1.09428	0.2539	28.2	1.11741	0.3151
23.3	1.09473	0.2551	28.3	1.11788	0.3164
23.4	1.09519	0.2563	28.4	1.11835	0.3176
23.5	1.09564	0.2575	28.5	1.11882	0.3189
23.6	1.09610	0.2587	28.6	1.11929	0.3201
23.7	1.09656	0.2599	28.7	1.11977	0.3214
23.8	1.09701	0.2611	28.8	1.12024	0.3226
23.9	1.09747	0.2623	28.9	1.12071	0.3239
24.0	1.09792	0.2635	29.0	1.12119	0.3251
24.1	1.09838	0.2647	29.1	1.12166	0.3264
24.2	1.09884	0.2659	29.2	1.12214	0.3277
24.3	1.09930	0.2671	29.3	1.12261	0.3289
24.4	1.09976	0.2683	29.4	1.12308	0.3302
24.5	1.10021	0.2696	29.5	1.12356	0.3315
24.6	1.10067	0.2708	29.6	1.12404	0.3327
24.7	1.10113	0.2720	29.7	1.12451	0.3340
24.8	1.10159	0.2732	29.8	1.12499	0.3352
24.9	1.10205	0.2744	29.9	1.12546	0.3365

°Brix at 20°C	Density at 20°C	Kg Solids per Liter	°Brix at 20°C	Density at 20°C	Kg Solids per Liter
30.0	1.12594	0.3378	35.0	1.15024	0.4026
30.1	1.12642	0.3391	35.1	1.15073	0.4039
30.2	1.12690	0.3403	35.2	1.15123	0.4052
30.3	1.12737	0.3416	35.3	1.15172	0.4066
30.4	1.12785	0.3429	35.4	1.15222	0.4079
30.5	1.12833	0.3441	35.5	1.15271	0.4092
30.6	1.12881	0.3454	35.6	1.15321	0.4105
30.7	1.12929	0.3467	35.7	1.15371	0.4119
30.8	1.12977	0.3480	35.8	1.15420	0.4132
30.9	1.13025	0.3492	35.9	1.15470	0.4145
31.0	1.13073	0.3505	36.0	1.15520	0.4159
31.1	1.13121	0.3518	36.1	1.15570	0.4172
31.2	1.13169	0.3531	36.2	1.15620	0.4185
31.3	1.13217	0.3544	36.3	1.15669	0.4199
31.4	1.13266	0.3557	36.4	1.15719	0.4212
31.5	1.13314	0.3569	36.5	1.15769	0.4226
31.6	1.13362	0.3582	36.6	1.15819	0.4239
31.7	1.13410	0.3595	36.7	1.15869	0.4252
31.8	1.13459	0.3608	36.8	1.15919	0.4266
31.9	1.13507	0.3621	36.9	1.15970	0.4279
32.0	1.13555	0.3634	37.0	1.16020	0.4293
32.1	1.13604	0.3647	37.1	1.16070	0.4306
32.2	1.13652	0.3660	37.2	1.16120	0.4320
32.3	1.13701	0.3673	37.3	1.16170	0.4333
32.4	1.13749	0.3685	37.4	1.16221	0.4347
32.5	1.13798	0.3698	37.5	1.16271	0.4360
32.6	1.13846	0.3711	37.6	1.16321	0.4374
32.7	1.13895	0.3724	37.7	1.16372	0.4387
32.8	1.13944	0.3737	37.8	1.16422	0.4401
32.9	1.13992	0.3750	37.9	1.16473	0.4414
33.0	1.14041	0.3763	38.0	1.16523	0.4428
33.1	1.14090	0.3776	38.1	1.16574	0.4441
33.2	1.14139	0.3789	38.2	1.16624	0.4455
33.3	1.14188	0.3802	38.3	1.16675	0.4469
33.4	1.14236	0.3815	38.4	1.16726	0.4482
33.5	1.14285	0.3829	38.5	1.16776	0.4496
33.6	1.14334	0.3842	38.6	1.16827	0.4510
33.7	1.14383	0.3855	38.7	1.16878	0.4523
33.8	1.14432	0.3868	38.8	1.16929	0.4537
33.9	1.14481	0.3881	38.9	1.16979	0.4550
34.0	1.14530	0.3894	39.0	1.17030	0.4564
34.1	1.14580	0.3907	39.1	1.17081	0.4578
34.2	1.14629	0.3920	39.2	1.17132	0.4592
34.3	1.14678	0.3933	39.3	1.17183	0.4605
34.4	1.14727	0.3947	39.4	1.17234	0.4619
34.5	1.14776	0.3960	39.5	1.17285	0.4633
34.6	1.14826	0.3973	39.6	1.17336	0.4647
34.7	1.14875	0.3986	39.7	1.17387	0.4660
34.8	1.14925	0.3999	39.8	1.17439	0.4674
34.9	1.14974	0.4013	39.9	1.17490	0.4688

°Brix at 20°C	Density at 20°C	Kg Solids per Liter	°Brix at 20°C	Density at 20°C	Kg Solids per Liter
40.0	1.17541	0.4702	45.0	1.20151	0.5407
40.1	1.17593	0.4715	45.1	1.20204	0.5421
40.2	1.17644	0.4729	45.2	1.20257	0.5436
40.3	1.17695	0.4743	45.3	1.20311	0.5450
40.4	1.17747	0.4757	45.4	1.20364	0.5465
40.5	1.17798	0.4771	45.5	1.20417	0.5479
40.6	1.17849	0.4785	45.6	1.20470	0.5493
40.7	1.17901	0.4799	45.7	1.20524	0.5508
40.8	1.17953	0.4812	45.8	1.20577	0.5522
40.9	1.18004	0.4826	45.9	1.20630	0.5537
41.0	1.18056	0.4840	46.0	1.20684	0.5551
41.1	1.18107	0.4854	46.1	1.20737	0.5566
41.2	1.18159	0.4868	46.2	1.20791	0.5581
41.3	1.18211	0.4882	46.3	1.20845	0.5595
41.4	1.18263	0.4896	46.4	1.20898	0.5610
41.5	1.18314	0.4910	46.5	1.20952	0.5624
41.6	1.18356	0.4924	46.6	1.21006	0.5639
41.7	1.18418	0.4938	46.7	1.21059	0.5653
41.8	1.18470	0.4952	46.8	1.21113	0.5668
41.9	1.18522	0.4966	46.9	1.21167	0.5683
42.0	1.18574	0.4980	47.0	1.21221	0.5697
42.1	1.18626	0.4994	47.1	1.21275	0.5712
42.2	1.18678	0.5008	47.2	1.21329	0.5727
42.3	1.18730	0.5022	47.3	1.21383	0.5741
42.4	1.18782	0.5036	47.4	1.21437	0.5756
42.5	1.18835	0.5050	47.5	1.21491	0.5771
42.6	1.18887	0.5065	47.6	1.21545	0.5786
42.7	1.18939	0.5079	47.7	1.21599	0.5800
42.8	1.18991	0.5093	47.8	1.21653	0.5815
42.9	1.19044	0.5107	47.9	1.21707	0.5830
43.0	1.19069	0.5120	48.0	1.21761	0.5845
43.1	1.19148	0.5135	48.1	1.21816	0.5859
43.2	1.19201	0.5149	48.2	1.21870	0.5874
43.3	1.19253	0.5164	48.3	1.21924	0.5889
43.4	1.19306	0.5178	48.4	1.21979	0.5904
43.5	1.19358	0.5192	48.5	1.22030	0.5918
43.6	1.19411	0.5206	48.6	1.22088	0.5933
43.7	1.19483	0.5221	48.7	1.22142	0.5948
43.8	1.19516	0.5235	48.8	1.22197	0.5963
43.9	1.19569	0.5249	48.9	1.22251	0.5978
44.0	1.19622	0.5263	49.0	1.22306	0.5993
44.1	1.19674	0.5278	49.1	1.22360	0.6008
44.2	1.19727	0.5292	49.2	1.22415	0.6023
44.3	1.19780	0.5306	49.3	1.22470	0.6038
44.4	1.19833	0.5321	49.4	1.22525	0.6053
44.5	1.19886	0.5335	49.5	1.22580	0.6068
44.6	1.19939	0.5349	49.6	1.22634	0.6083
44.7	1.19992	0.5364	49.7	1.22689	0.6098
44.8	1.20045	0.5378	49.8	1.22744	0.6113
44.9	1.20098	0.5392	49.9	1.22799	0.6128

°Brix at 20°C	Density at 20°C	Kg Solids per Liter	°Brix at 20°C	Density at 20°C	Kg Solids per Liter
50.0	1.22854	0.6143	55.0	1.25651	0.6911
50.1	1.22909	0.6158	55.1	1.25708	0.6927
50.2	1.22964	0.6173	55.2	1.25765	0.6942
50.3	1.23019	0.6188	55.3	1.25822	0.6958
50.4	1.23074	0.6203	55.4	1.25879	0.6974
50.5	1.23130	0.6218	55.5	1.25930	0.6989
50.6	1.23185	0.6233	55.6	1.25993	0.7005
50.7	1.23240	0.6248	55.7	1.26050	0.7021
50.8	1.23295	0.6263	55.8	1.26108	0.7037
50.9	1.23351	0.6279	55.9	1.26165	0.7053
51.0	1.23406	0.6294	56.0	1.26222	0.7068
51.1	1.23461	0.6309	56.1	1.26279	0.7084
51.2	1.23517	0.6324	56.2	1.26337	0.7100
51.3	1.23572	0.6339	56.3	1.26394	0.7116
51.4	1.23628	0.6354	56.4	1.26452	0.7132
51.5	1.23683	0.6370	56.5	1.26509	0.7148
51.6	1.23739	0.6385	56.6	1.26566	0.7164
51.7	1.23794	0.6400	56.7	1.26624	0.7180
51.8	1.23850	0.6415	56.8	1.26682	0.7196
51.9	1.23906	0.6431	56.9	1.26739	0.7211
52.0	1.23962	0.6446	57.0	1.26797	0.7227
52.1	1.24017	0.6461	57.1	1.26854	0.7243
52.2	1.24073	0.6477	57.2	1.26912	0.7259
52.3	1.24129	0.6492	57.3	1.26970	0.7275
52.4	1.24185	0.6507	57.4	1.27028	0.7291
52.5	1.24241	0.6523	57.5	1.27086	0.7307
52.6	1.24297	0.6538	57.6	1.27143	0.7323
52.7	1.24353	0.6553	57.7	1.27201	0.7339
52.8	1.24409	0.6569	57.8	1.27259	0.7356
52.9	1.24465	0.6584	57.9	1.27317	0.7372
53.0	1.24521	0.6600	58.0	1.27375	0.7388
53.1	1.24577	0.6615	58.1	1.27433	0.7404
53.2	1.24633	0.6630	58.2	1.27492	0.7420
53.3	1.24690	0.6646	58.3	1.27550	0.7436
53.4	1.24746	0.6661	58.4	1.27608	0.7452
53.5	1.24802	0.6677	58.5	1.27664	0.7468
53.6	1.24858	0.6692	58.6	1.27724	0.7485
53.7	1.24915	0.6708	58.7	1.27782	0.7501
53.8	1.24971	0.6723	58.8	1.27841	0.7517
53.9	1.25028	0.6739	58.9	1.27899	0.7533
54.0	1.25084	0.6755	59.0	1.27958	0.7550
54.1	1.25141	0.6770	59.1	1.28017	0.7566
54.2	1.25199	0.6786	59.2	1.28075	0.7582
54.3	1.25254	0.6801	59.3	1.28134	0.7598
54.4	1.25311	0.6817	59.4	1.28193	0.7615
54.5	1.25367	0.6833	59.5	1.28251	0.7631
54.6	1.25424	0.6848	59.6	1.28309	0.7647
54.7	1.25481	0.6864	59.7	1.28367	0.7664
54.8	1.25538	0.6879	59.8	1.28426	0.7680
54.9	1.25594	0.6895	59.9	1.28485	0.7696

°Brix at 20°C	Density at 20°C	Kg Solids per Liter	°Brix at 20°C	Density at 20°C	Kg Solids per Liter
60.0	1.28544	0.7713	65.0	1.31533	0.8550
60.1	1.28602	0.7729	65.1	1.31595	0.8567
60.2	1.28661	0.7745	65.2	1.31655	0.8584
60.3	1.28720	0.7762	65.3	1.31716	0.8601
60.4	1.28779	0.7778	65.4	1.31777	0.8618
60.5	1.28838	0.7795	65.5	1.31837	0.8635
60.6	1.28897	0.7811	65.6	1.31898	0.8653
60.7	1.28956	0.7828	65.7	1.31959	0.8670
60.8	1.29015	0.7844	65.8	1.32019	0.8687
60.9	1.29074	0.7861	65.9	1.32081	0.8704
61.0	1.29133	0.7877	66.0	1.32142	0.8721
61.1	1.29193	0.7894	66.1	1.32203	0.8739
61.2	1.29252	0.7910	66.2	1.32264	0.8756
61.3	1.29311	0.7927	66.3	1.32325	0.8773
61.4	1.29370	0.7943	66.4	1.32385	0.8790
61.5	1.29430	0.7960	66.5	1.32446	0.8808
61.6	1.29489	0.7977	66.6	1.32509	0.8825
61.7	1.29548	0.7993	66.7	1.32570	0.8842
61.8	1.29608	0.8010	66.8	1.32632	0.8860
61.9	1.29667	0.8026	66.9	1.32693	0.8877
62.0	1.29726	0.8043	67.0	1.32754	0.8895
62.1	1.29786	0.8060	67.1	1.32816	0.8912
62.2	1.29845	0.8076	67.2	1.32878	0.8929
62.3	1.29905	0.8093	67.3	1.32939	0.8947
62.4	1.29966	0.8110	67.4	1.33001	0.8964
62.5	1.30025	0.8127	67.5	1.33062	0.8982
62.6	1.30085	0.8143	67.6	1.33124	0.8999
62.7	1.30145	0.8160	67.7	1.33186	0.9017
62.8	1.30205	0.8177	67.8	1.33248	0.9034
62.9	1.30265	0.8194	67.9	1.33309	0.9052
63.0	1.30325	0.8210	68.0	1.33371	0.9069
63.1	1.30385	0.8227	68.1	1.33433	0.9087
63.2	1.30446	0.8244	68.2	1.33495	0.9104
63.3	1.30506	0.8261	68.3	1.33557	0.9122
63.4	1.30566	0.8278	68.4	1.33619	0.9140
63.5	1.30626	0.8295	68.5	1.33681	0.9157
63.6	1.30686	0.8312	68.6	1.33743	0.9175
63.7	1.30747	0.8329	68.7	1.33805	0.9192
63.8	1.30807	0.8345	68.8	1.33867	0.9210
63.9	1.30867	0.8362	68.9	1.33930	0.9228
64.0	1.30927	0.8379	69.0	1.33992	0.9245
64.1	1.30988	0.8396	69.1	1.34054	0.9263
64.2	1.31048	0.8413	69.2	1.34116	0.9281
64.3	1.31108	0.8430	69.3	1.34179	0.9299
64.4	1.31169	0.8447	69.4	1.34241	0.9316
64.5	1.31229	0.8464	69.5	1.34304	0.9334
64.6	1.31290	0.8481	69.6	1.34366	0.9352
64.7	1.31350	0.8498	69.7	1.34429	0.9370
64.8	1.31412	0.8515	69.8	1.34491	0.9387
64.9	1.31473	0.8533	69.9	1.34554	0.9405

°Brix at 20°C	Density at 20°C	Kg Solids per Liter	°Brix at 20°C	Density at 20°C	Kg Solids per Liter
70.0	1.34616	0.9423	75.0	1.37797	1.0335
70.1	1.34679	0.9441	75.1	1.37862	1.0353
70.2	1.34742	0.9459	75.2	1.37926	1.0372
70.3	1.34805	0.9477	75.3	1.37991	1.0391
70.4	1.34867	0.9495	75.4	1.38055	1.0409
70.5	1.34930	0.9513	75.5	1.38119	1.0428
70.6	1.34993	0.9531	75.6	1.38184	1.0447
70.7	1.35056	0.9548	75.7	1.38249	1.0465
70.8	1.35119	0.9566	75.8	1.38314	1.0484
70.9	1.35182	0.9584	75.9	1.38379	1.0503
71.0	1.35245	0.9602	76.0	1.38444	1.0522
71.1	1.35308	0.9620	76.1	1.38510	1.0541
71.2	1.35371	0.9638	76.2	1.38575	1.0559
71.3	1.35434	0.9656	76.3	1.38640	1.0578
71.4	1.35498	0.9675	76.4	1.38705	1.0597
71.5	1.35561	0.9693	76.5	1.38770	1.0616
71.6	1.35625	0.9711	76.6	1.38835	1.0635
71.7	1.35688	0.9729	76.7	1.38900	1.0654
71.8	1.35751	0.9747	76.8	1.38965	1.0673
71.9	1.35814	0.9765	76.9	1.39030	1.0691
72.0	1.35877	0.9783	77.0	1.39096	1.0710
72.1	1.35940	0.9801	77.1	1.39161	1.0729
72.2	1.36004	0.9819	77.2	1.39225	1.0748
72.3	1.36067	0.9838	77.3	1.39291	1.0767
72.4	1.36131	0.9856	77.4	1.39356	1.0786
72.5	1.36194	0.9874	77.5	1.39422	1.0805
72.6	1.36258	0.9892	77.6	1.39488	1.0824
72.7	1.36322	0.9911	77.7	1.39554	1.0843
72.8	1.36385	0.9929	77.8	1.39619	1.0862
72.9	1.36450	0.9947	77.9	1.39685	1.0881
73.0	1.36514	0.9966	78.0	1.39751	1.0901
73.1	1.36578	0.9984	78.1	1.39816	1.0920
73.2	1.36642	1.0002	78.2	1.39882	1.0939
73.3	1.36708	1.0021	78.3	1.39948	1.0958
73.4	1.36769	1.0039	78.4	1.40013	1.0977
73.5	1.36833	1.0057	78.5	1.40079	1.0996
73.6	1.36896	1.0076	78.6	1.40145	1.1015
73.7	1.36960	1.0094	78.7	1.40211	1.1035
73.8	1.37024	1.0112	78.8	1.40277	1.1054
73.9	1.37088	1.0131	78.9	1.40343	1.1073
74.0	1.37153	1.0149	79.0	1.40409	1.1092
74.1	1.37217	1.0168	79.1	1.40475	1.1112
74.2	1.37281	1.0186	79.2	1.40541	1.1131
74.3	1.37345	1.0205	79.3	1.40607	1.1150
74.4	1.37410	1.0223	79.4	1.40674	1.1170
74.5	1.37475	1.0242	79.5	1.40740	1.1189
74.6	1.37539	1.0260	79.6	1.40806	1.1208
74.7	1.37604	1.0279	79.7	1.40872	1.1227
74.8	1.37668	1.0298	79.8	1.40939	1.1247
74.9	1.37733	1.0316	79.9	1.41005	1.1266

Appendix 2

Temperature Correction Tables for Refractometric Brix Readings

Temperature °C	Brix Range of Sample										
	0	5	10	15	20	25	30	40	50	60	70
Subtract from Reading											
10	0.50	0.54	0.58	0.61	0.64	0.66	0.68	0.72	0.74	0.76	0.79
11	0.46	0.49	0.53	0.55	0.58	0.60	0.62	0.65	0.67	0.69	0.71
12	0.42	0.45	0.48	0.50	0.52	0.54	0.56	0.58	0.60	0.61	0.63
13	0.37	0.40	0.42	0.44	0.46	0.48	0.49	0.51	0.53	0.54	0.55
14	0.33	0.35	0.37	0.39	0.40	0.41	0.42	0.44	0.45	0.46	0.48
15	0.27	0.29	0.31	0.33	0.34	0.34	0.35	0.37	0.38	0.39	0.40
16	0.22	0.24	0.25	0.26	0.27	0.28	0.28	0.30	0.30	0.31	0.32
17	0.17	0.18	0.19	0.20	0.21	0.21	0.21	0.22	0.23	0.23	0.24
18	0.12	0.13	0.13	0.14	0.14	0.14	0.14	0.15	0.15	0.16	0.16
19	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08
Add to Reading											
21	0.06	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08
22	0.13	0.13	0.14	0.14	0.15	0.15	0.15	0.15	0.16	0.16	0.16
23	0.19	0.20	0.21	0.22	0.22	0.23	0.23	0.23	0.24	0.24	0.24
24	0.26	0.27	0.28	0.29	0.30	0.30	0.31	0.31	0.31	0.32	0.32
25	0.33	0.35	0.36	0.37	0.38	0.38	0.39	0.40	0.40	0.40	0.40
26	0.40	0.42	0.43	0.44	0.45	0.46	0.47	0.48	0.48	0.48	0.48
27	0.48	0.50	0.52	0.53	0.54	0.55	0.55	0.56	0.56	0.56	0.56
28	0.56	0.57	0.60	0.61	0.62	0.63	0.63	0.64	0.64	0.64	0.64
29	0.64	0.66	0.68	0.69	0.71	0.72	0.72	0.73	0.73	0.73	0.73
30	0.72	0.74	0.77	0.78	0.79	0.80	0.80	0.81	0.81	0.81	0.81

Appendix 3

Significance Tables for Two-Sample Preference Taste Test

Number of Judges	Number of Preferences for One Sample Required to Determine Significance at Confidence Level			Number of Judges	Number of Preferences for One Sample Required to Determine Significance at Confidence Level		
	5%	1%	0.1%		5%	1%	0.1%
6	6	—	—	36	25	27	29
7	7	—	—	37	25	27	29
8	8	8	—	38	26	28	30
9	8	9	—	39	27	28	31
10	9	10	—	40	27	29	31
11	10	11	11	41	27	29	32
12	10	11	12	42	28	30	32
13	11	12	13	43	28	30	33
14	12	13	14	44	29	31	33
15	12	13	14	45	30	32	34
16	13	14	15	46	30	32	35
17	13	15	16	47	31	33	35
18	14	15	17	48	31	33	36
19	15	16	17	49	32	34	37
20	15	17	18	50	32	35	37
21	16	17	19	51	33	35	38
22	17	18	19	52	34	36	38
23	17	19	20	53	34	36	39
24	18	19	21	54	35	37	40
25	18	20	21	55	35	38	40
26	19	20	22	56	36	38	41
27	20	21	23	57	36	39	41
28	20	22	23	58	37	39	42
29	21	22	24	59	38	40	43
30	21	23	25	60	38	40	43
31	22	24	25	61	39	41	44
32	23	24	26	62	39	42	44
33	23	25	27	63	40	42	45
34	24	25	27	64	40	43	46
35	24	26	28	65	41	43	46

Number of Judges	Number of Preferences for One Sample Required to Determine Significance at Confidence Level			Number of Judges	Number of Preferences for One Sample Required to Determine Significance at Confidence Level		
	5%	1%	0.1%		5%	1%	0.1%
66	41	44	47	130	77	80	84
67	42	45	47	135	79	83	87
68	43	45	48	140	82	86	90
69	43	46	49	145	85	89	93
70	44	46	49	150	88	91	96
71	44	47	50	160	93	97	101
72	45	47	50	170	98	102	107
73	45	48	51	180	104	108	113
74	46	49	52	190	109	113	118
75	46	49	52	200	114	119	124
76	47	50	53	225	128	132	138
77	47	50	53	250	141	145	152
78	48	51	54	275	154	159	165
79	49	51	55	300	167	173	179
80	49	52	55	350	194	200	206
82	50	53	56	400	220	226	233
84	51	54	58	450	246	253	260
86	53	55	59	500	272	279	287
88	54	57	60	550	298	306	314
90	56	58	61	600	325	332	341
92	56	59	62	650	350	358	367
94	57	60	63	700	376	385	394
96	58	61	65	800	428	437	447
98	59	62	66	900	480	489	500
100	60	63	67	1,000	531	541	553
105	63	66	70	2,000	1,044	1,058	1,074
110	66	69	73	3,000	1,554	1,571	1,591
115	69	72	76	4,000	2,062	2,082	2,105
120	71	75	79	5,000	2,570	2,592	2,617
125	74	77	81	10,000	5,098	5,129	5,165

Appendix 4

Significance Tables for Triangular Taste Test

Number of Judges	Number of Correct Choices to Determine Significance at Confidence Level		
	5%	1%	0.1%
6	5	6	—
7	5	6	7
8	6	7	8
9	6	7	8
10	7	8	9
11	7	8	9
12	8	9	10
13	8	9	10
14	9	10	11
15	9	10	12
16	10	11	12
17	10	11	13
18	10	12	13
19	11	12	14
20	11	13	14
21	12	13	15
22	12	14	15
23	13	14	16
24	13	14	16
25	13	15	17
26	14	15	17
27	14	16	18
28	15	16	18

Number of Judges	Number of Correct Choices to Determine Significance at Confidence Level		
	5%	1%	0.1%
29	15	17	19
30	16	17	19
31	16	18	19
32	16	18	20
33	17	19	20
34	17	19	21
35	18	19	21
36	18	20	22
37	18	20	22
38	19	21	23
39	19	21	23
40	20	22	24
41	20	22	24
42	21	22	25
43	21	23	25
44	21	23	25
45	22	24	26
46	22	24	26
47	23	25	27
48	23	25	27
49	23	25	28
50	24	26	28

Appendix 5

Acidity Correction Tables for Refractometric Brix Readings

Percent Acidity	Add to Reading	Percent Acidity	Add to Reading	Percent Acidity	Add to Reading	Percent Acidity	Add to Reading
0.0	0.00	11.0	2.10	22.0	4.05	33.0	5.98
1.0	0.20	12.0	2.27	23.0	4.24	34.0	6.16
2.0	0.39	13.0	2.46	24.0	4.41	35.0	6.33
3.0	0.58	14.0	2.64	25.0	4.58	36.0	6.51
4.0	0.75	15.0	2.81	26.0	4.75	37.0	6.68
5.0	0.97	16.0	3.00	27.0	4.94	38.0	6.86
6.0	1.15	17.0	3.17	28.0	5.10	39.0	7.03
7.0	1.34	18.0	3.35	29.0	5.28	40.0	7.21
8.0	1.54	19.0	3.53	30.0	5.46	41.0	7.40
9.0	1.72	20.0	3.70	31.0	5.63	42.0	7.58
10.0	1.91	21.0	3.88	32.0	5.81	43.0	7.76

Note: Acidity is represented as percent citric acid anhydrous mass/mass.

Appendix 6

Microsoft® Excel Template for Final Beverage Brix Calculation

TEMPLATE A
Cells in Value Format

2	B	C	D	E	F	G	H
	Syrup Brix	Syrup D20	Water Part	D20 Water	Total kg Weight	Total kg Solids	Target Brix
3	52.4	1.24185	5	0.99717	6.22770	0.65073	10.45
4	52.5	1.24241	5	0.99717	6.22826	0.65227	10.47
5	52.6	1.24297	5	0.99717	6.22882	0.65380	10.50
6	52.7	1.24353	5	0.99717	6.22938	0.65534	10.52
7	52.8	1.24409	5	0.99717	6.22994	0.65688	10.54
8	52.9	1.24465	5	0.99717	6.23050	0.65842	10.57
9	53.0	1.24521	5	0.99717	6.23106	0.65996	10.59

TEMPLATE B
Cells in Formula Format

	B	C	D	E	F	G	H
2	Syrup Brix	Syrup D20	Water Part	D20 Water	Total kg Weight	Total kg Solids	Target Brix
3	52.4	1.24185	5	0.99717	=+C3+D3*E3	=+B3/100*C3	=+G3/F3*100
4	52.5	1.24241	5	0.99717	=+C4+D4*E4	=+B4/100*C4	=+G4/F4*100
5	52.6	1.24297	5	0.99717	=+C5+D5*E5	=+B5/100*C5	=+G5/F5*100
6	52.7	1.24353	5	0.99717	=+C6+D6*E6	=+B6/100*C6	=+G6/F6*100
7	52.8	1.24409	5	0.99717	=+C7+D7*E7	=+B7/100*C7	=+G7/F7*100
8	52.9	1.24465	5	0.99717	=+C8+D8*E8	=+B8/100*C8	=+G8/F8*100
9	53.0	1.24521	5	0.99717	=+C9+D9*E9	=+B9/100*C9	=+G9/F9*100

Appendix 7

Glossary of Technical and General Terms Used in this Handbook

Acidity The level of sourness of a beverage usually expressed as percent citric acid anhydrous mass per volume determined by an acid/base titration.

ACL (Applied ceramic label) This is the label of a glass bottle that is embossed on the glass during the bottle manufacturing process.

Activated carbon An amorphous form of carbon that was pretreated to increase its adsorption properties; used for the removal of off-tastes, foreign odors, chlorine, trihalomethanes, and other undesirable substances from water, syrups, etc.

Aerobic Indicates that a microorganism requires atmospheric oxygen for growth.

Altitude correction The required correction for a gas volume reading when the beverage sample is tested at an altitude different than that at which the beverage was filled.

Anaerobic Indicates that a microorganism is able to live in the absence of atmospheric oxygen.

Aromatic compounds Substances that contribute to the odor of a flavor; sometimes referred to as "aromatics," for short.

Aseptic Indicates that microbial contamination from external sources is avoided.

ATP bioluminescence assay The method used for detecting microbial contamination on processing equipment using measurable bioluminescence formed by light-generating chemicals in microorganism cells.

Backwashing Directing the flow of water through filtration equipment in the reverse direction to its normal operation.

Bactericidal Indicating that microorganisms are killed.

Bacteristatic Indicating that growth of microorganisms is inhibited.

Ballot sheet The questionnaire or check-sheet used in taste tests.

Beverage base The total complement of ingredients of a beverage formulation, excluding natural sweetener, water, and carbon dioxide.

Beverage base unit The combined part units for a beverage product in a unitization system.

Biofilm The microbiological structural entity composed of bacteria and the gelatinous polymeric material matrix in which they are enclosed.

BOM (Bill of materials) The formulation of a beverage for a standard size volume of beverage entered into an applicable logistics or accounting system.

Brix The scale of measurement used for expressing the percentage of dissolved sucrose in an aqueous solution on a mass for mass basis; measurement is expressed as degrees Brix (°B).

Brix/acid ratio The value for the ratio of the Brix of a fruit juice to the percent acidity of the juice.

Brix acidity correction The correction to a refractometric Brix reading of a fruit juice with respect to the acidity level of the juice.

Brix temperature correction The correction to a refractometric Brix reading at temperatures other than 20°C.

Bulk RTD The ready-to-drink (RTD) beverage prepared in bulk used for filling individual beverage containers, e.g., bottles or cans, at the filling machine.

Bulk syrup Simple syrup prepared as a source of dissolved sugar for syrup or bulk RTD preparation.

Carbonated soft drink A nonalcoholic beverage to which carbon dioxide was added (often referred to as a CSD).

CFU (Colony-forming unit) The visible colony that develops from a single microorganism cell.

Chlorine break point The point in chlorine addition to water where completely free chlorine is available after the chlorine demand is satisfied.

Chlorine demand The amount of chlorine consumed in oxidizing the nitrogenous (and other soluble inorganic) matter in the water until free chlorine is available.

CIP (Clean-in-place) The system of cleaning and sanitizing equipment by circulating detergents, sanitizing agents, and water without dismantling the equipment.

Clean-in-place See CIP.

Cloudifier An emulsion ingredient used to impart turbidity to a beverage; also called a "clouding agent."

Cloudifying power The intensity of turbidity formed by a unit quantity of clouding agent.

Cloudy drink A beverage with an additive that imparts turbidity to the drink; the additive may be a fruit juice, an emulsion, or both.

COA (Certificate of analysis) Document of a supplier listing test results that confirm that the product supplied meets the relevant specifications.

Coagulation/flocculation The process of removing suspended particulate matter in water.

Coliforms Group of bacteria that live in the intestinal tract of humans and other animals.

Combined chlorine All chlorine compounds other than free chlorine.

Comminuted fruit juice A juice concentrate in which the normally inedible portions of the fruit, such as the peel, are included in the processed juice.

Concentrate A concentrated liquid that contains all the ingredients of a beverage base.

Confidence level The level of confidence at which the probability that the significance of a taste test result is considered as not due to chance alone.

Counterpressure The CO_2 gas pressure in the filler bowl equal to that in a bottle of the carbonated soft drink beverage being filled that allows for a gravity-based filling process.

Creaming The process of oil droplets separating out of an emulsion and rising to the surface of the liquid.

Crown cap The beverage bottle cap with a pry-off design.

D20 Density measured at 20°C.

D20 of water The value 0.99717 used as water density in all mass/volume/density calculations involving water.

Date coding Affixing numerical coding script to the beverage container that reflects the date or time of manufacture, expiry date, and other selected information, such as filling line number.

Density The mass of a volume of liquid.

Dilutables The category of soft drinks in which the product is in a concentrated form that requires dilution with water by the consumer to obtain the ready-to-drink beverage; typical dilutables are squashes and cordials.

Dipstick A flat metal rod, calibrated with volume graduation markings, that is suspended into the syrup in a tank to measure its volume.

Disaccharide Chemical term for a compound composed of two molecules of sugar.

Disinfection The total elimination of any pathogenic microorganisms present in the raw water and the reduction of nonpathogenic microorganisms to acceptable levels; this is accomplished by using chemicals or by physical means or by a combination of both.

Dispensary The site at which ingredients are measured out and packed for individual final syrup and bulk ready-to-drink batches.

Dosage level The level at which an ingredient, such as a flavorant or a cloudifier, is added to a beverage formulation to obtain the target performance effect in the beverage.

Effervescence The formation of gas bubbles in a liquid.

Emulsion A suspension of microscopic oil droplets in water used to cloudify beverages or to disperse in the beverage oil-based flavors that are not water soluble.

Enhanced filtration A filtration process that is capable of removing minute matter at the molecular level, as opposed to simple filtration in which only relatively larger particulate matter is filtered out of the water.

Escherichia coli A species of bacteria, the presence of which is used as a standard reference in microbiological testing to indicate the possibility of water being contaminated with human or animal feces.

Essential oil Volatile oils that contribute to the overall flavor of the fruit; individual essential oils may be prepared by distillation or solvent extraction from the source material.

FIFO (First-in, first-out) Stock rotation system in which items are used or dispatched according to the chronological sequence in which they were received or produced.

Final syrup A syrup containing all the beverage base ingredients used for beverage preparation by dilution with treated water at a prescribed water-to-syrup ratio.

Final volume The volume of a final syrup or bulk ready-to-drink batch that needs to be achieved before being used for filling beverage containers.

First-in, first-out See FIFO.

Flaming technique The procedures in microbiological sampling and testing of destroying external microbial contamination of test equipment, glassware, and sampling points by using a naked flame.

Flavor emulsion A flavor preparation containing oils that are not soluble in water; these flavor oils are dispersed in the beverage as a suspension of microscopic oil droplets.

Flavor house A company that supplies flavorants.

Flavorant An ingredient that supplies the key sensory property to a beverage, namely, the specific flavor, or part thereof, characteristic to the beverage; also referred to as "flavoring" or "flavor" in common parlance.

Food laws The generic term used to denote the entire complement of food-related legislation of a country.

Forced decision The principle of instructing the judge in a taste test to make one of the choices required in spite of the fact that the judge detected no differences in the samples presented.

Formulation The list of ingredients and their respective quantities for a specified volume of final beverage; sometimes commonly referred to as the "recipe."

Free chlorine The portion of the total chlorine existing as hypochlorous acid.

Fresh Brix The Brix value of a sugar solution at the time of its preparation.

Fruit juice The liquid obtained from the edible portion of a ripe fresh fruit or from a fruit kept in fresh condition by suitable means.

Fruit juice concentrate Juice that was concentrated by the evaporation of a large portion of its natural water content.

Fruit pulp The insoluble suspended solids of a juice concentrate derived from fleshy or fibrous parts of the fruit.

Full unit The combined part units for a beverage product in a unitization system.

Gas volume The unit of measurement for carbonation levels in soft drinks.

Gas volume chart A chart relating pressure to temperature from which the carbonation can be determined in gas volume units.

Glycocalyx The gelatinous matrix produced by bacteria in a biofilm.

GMP (Good manufacturing practice) The concept of maintaining the highest quality standards in a food manufacturing operation; this relates to, among others, products, processes, factory structure and equipment, hygiene, staff training, safety, etc.

HACCP (Hazard analysis of critical control points) A system of ensuring that established quality standards in food processing are maintained by identifying key points to be monitored for compliance to such standards.

HFCS (High-fructose corn syrup) A natural sweetener produced from the hydrolysis of starch in which part of the glucose was converted to fructose; used as an alternative for sucrose as a sweetener.

Homogenization The process of reducing the oil droplets in an emulsion to required diameter size, usually at micron-size level.

Incubation In microbiology, the storage of test plates at prescribed temperatures and periods.

Inverted Brix The Brix value of a sucrose solution in which the sucrose was fully inverted into its glucose and fructose components.

Ion exchange A water treatment system based on removal of unwanted ions from the water by exchanging them with other ions supplied from a resin column of the ion exchange unit.

Judge Term used to describe a taster in a taste test.

Membrane filtration In microbiology, the method used to isolate and grow microorganisms present in a test sample using a thin cellulose-type membrane filter of micron-size porosity.

Membrane filtration In water treatment, the process that uses a pressure differential to force materials through a membrane on a selective basis.

MIC (Microbiologically influenced corrosion) The corrosion of metal equipment due to mineral and other chemical deposits formed by microorganisms attached to the metal surface.

Microbiology The science that studies living organisms of microscopic size.

Microorganisms Any of a large variety of living organisms, plant and animal, most of which are of microscopic size and are not visible to the naked eye.

Monosaccharide Chemical term for a compound composed of one molecule of sugar.

Multibarrier water treatment An orderly series of reliable processes that in a complementary and incremental manner completely removes or reduces targeted raw water adverse quality factors to acceptable levels.

Multiunit A beverage base unit prepared in a quantity equivalent to a multiple of single units in a unitization system.

Nanofiltration A type of reverse osmosis process in which the smallest sizes of particles that can be filtered are larger than those that can be removed in regular reverse osmosis.

Neck-ring A ring that appears in a beverage at the neck of a bottle due to the separation of oil droplets out of an unstable emulsion in the beverage.

Nutrient medium The material on which microorganisms grow in microbiological testing methods; sometimes also referred to as growth medium.

Nutrition information The legally required list of ingredients and their nutritional contributions to the beverage that is placed on the product label and adequately justifies the claim declared on the label.

Oil phase The combined ingredients of the oil component of an emulsion.

Osmosis The process in which water molecules diffuse from a low concentration solution through a permeable membrane to a higher concentration solution.

Outsourcing The practice of engaging an external agency to perform a specific operation for a soft drinks company.

Ozone (O_3) The naturally occurring three-atom form of oxygen.

Part Unit One of several beverage base units that, together with the other Part Units, make up one full beverage base unit in a unitization system.

Pathogen Microorganism that causes disease.

Permeate The filtered liquid in a membrane filtration system.

PET (Polyethylene terephthalate) The chemical compound of which PET bottles are made.

Planktonic The term used to describe bacterial cells that are free-drifting individuals in a liquid environment.

Plate count The number of microorganisms counted in a microbiological test.

Plating The procedure of preparing a petri dish with sampled material for microbiological testing.

Polishing filter Filtration equipment to remove particulate matter that was not removed in previous filtration steps, and especially to remove activated carbon particles carried over from an in-line carbon purifier.

Potable water Water that, based on local health authorities' standards, is considered safe to drink; in the absence of local standards, the standards of the World Health Organization (WHO) would be applicable to this definition.

Pour plate method In microbiology, the method used to grow microorganisms present in a test sample by mixing some of the sample in the agar of the plate in which the test is conducted.

Preservative Chemical substance that inhibits the growth of microorganisms.

Quality The sum total of properties of a product that reflect its ability to satisfy established quality standards.

Quality assurance The authority responsible for a planned and systematic design of all the actions necessary to provide adequate confidence that a product will conform to established requirements.

Quality control The authority that implements the operational techniques and activities required for achieving the established standards for quality.

Quality index The value that indicates the number of samples that meet selected quality parameters standards established in a quality rating system as a percentage of the total number of samples tested.

Quality management The ongoing process of confirming that all components of the quality assurance program are being implemented in compliance with this program.

Quality rating system A system for numerically quantifying the quality status of products.

Raw water Source water supplied to a soft drinks manufacturing facility.

RDA Recommended dietary allowance.

Regulation An individual item of legislation dedicated to a specific aspect of food legislation.

Retentate The liquid that retains the unfiltered particles in a membrane filtration system, also referred to as concentrate.

Reverse osmosis The process in which water molecules, upon which a pressure force is applied, are transferred from a high-concentration solution through a permeable membrane to a solution of lower concentration — the opposite of normal osmosis.

RTD (Ready-to-drink) Denotes that a beverage is to be consumed without further dilution with water.

Sanitizing Eliminating pathogens and reducing other microorganism counts on processing equipment to an established acceptable level.

Seltzers The historically derived name given to naturally carbonated mineral water.

Sensory The term used to describe the overall sensation a beverage imparts in terms of taste, smell, mouthfeel, and visual impacts.

Sensory evaluation Evaluation of the sensory properties of a beverage; commonly called taste testing.

Sessile The term used to describe bacterial cells that attached themselves to a fixed location on a solid surface.

Sight glass A vertical tube made of transparent material alongside a tank, connected to the bottom of the tank and calibrated with graduations indicating the corresponding volumes of liquid in the tank.

Significance level The level at which differences in judgments in a taste test are considered as being significant or not in terms of the taste test objectives.

Significance tables Tabulated statistical data used for the determination of the significance levels in taste test results.

Simple syrup The solution of sweetener and water prior to the addition of beverage base in final syrup or bulk ready-to-drink preparation.

Single-strength juice Juice as extracted from the fruit without any concentration process.

Snifting The release of gas under pressure in the head of a carbonated soft drink bottle or can.

Specific gravity Ratio of the mass of a volume of the liquid to the mass of an equal volume of water at 4°C or other specified temperature.

Stabilizer An ingredient that assists in maintaining the oil droplets of an emulsion in suspension.

Stokes' law A mathematical equation demonstrating the correlation between factors governing the creaming rate of an emulsion.

Sucrose The disaccharide sugar composed of glucose and fructose; also known as cane sugar or beet sugar, depending on the plant source from which it is derived; the commonly used term sugar is often used to denote sucrose.

Sugar When used without specific qualification, "sugar" usually refers to "sucrose"; also see sugars.

Sugar inversion The hydrolysis of sucrose into its two monosaccharide components: glucose and fructose.

Sugars The name given to a large group of carbohydrate compounds that share common structural and chemical properties (e.g., sucrose, glucose, and fructose).

Syrup proportioning The process in which the final beverage is prepared by mixing concentrated syrup with treated water in a prescribed ratio.

Syrup shrinkage The seemingly paradoxical phenomenon that occurs when water and syrup are mixed, in that the resultant volume of the mixture of the two materials does not exactly add up to the sum of the volumes of the water and the syrup.

THM (Trihalomethane) By-product that can be formed from chlorine used in the disinfection of water treatment process.

Total chlorine The total of free chlorine and combined chlorine.

Treated water Raw water that was treated to achieve established quality standards for water used in soft drink products.

Ultrafiltration A filtration process in which the smallest sizes of particles that can be filtered are larger than those that can be removed in regular reverse osmosis and nanofiltration processes.

Ultraviolet irradiation Commonly called UV light; a nonvisible component of sunlight that can also be produced by specially designed lamps.

Unitization The system of packing premeasured quantities of beverage base ingredients for a standard unit volume of final beverage.

Unmarried unit A beverage base unit that lacks one or more of the part units it is composed of in a unitization system.

VBNC (Viable but not culturable) The term that describes the phenomenon of living bacteria that do not grow on the regular nutrient media used in microbiological testing.

Water phase The combined ingredients of the water-soluble component of an emulsion.

Water treatment The process of rendering source water as satisfying established quality specifications for use in soft drinks manufacture.

Water-to-syrup ratio The volumetric ratio at which water is mixed with syrup to attain the ready-to-drink beverage.

Weighting agent An high-density ingredient added to the oil phase of an emulsion to raise its overall density.

Zeta potential The measure of the electrolytic composition of an emulsion.