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THE SCIENCE *of sugar confectionery*

W.P. EDWARDS

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THE SCIENCE OF SUGAR CONFECTIONERY

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Preface

While most people have eaten sugar confectionery at some time few people know the underlying science. Almost all sugar confectionery was developed not from an understanding of the science but by confectioners working by trial and error. In many cases this empirical knowledge was obtained before any scientific understanding was available.

There is one exception to this rule and that is where products have been made to resemble sugar confectionery but are free of sugars. This small area has absorbed more scientific effort than the rest of sugar confectionery put together.

This book is intended for everyone who has eaten sugar confectionery and wondered what the science behind it is. The work is not intended as a manual of methods for making confectionery but does give illustrative examples of manufacturing methods.

Some simple recipes have been included to allow readers to do some small scale confectionery making. Experiments can be based on these recipes to study a number of areas relating to confectionery making.

This book has to be dedicated to the largely anonymous confectioners who invented most sugar confectionery products. It is also dedicated to my old friend Brian Jackson.

Contents

Chapter 1

Introduction

The confectionery industry divides confectionery into three classes: chocolate confectionery, flour confectionery and sugar confectionery. Chocolate confectionery is obviously things made out of chocolate. Flour confectionery covers items made out of flour. Traditionally, and confusingly, this covers both long life products, such as biscuits, in addition to short-life bakery products. Sugar confectionery covers the rest of confectionery. In spite of the above definition, liquorice, which does contain flour, is considered to be sugar confectionery. The confectionery industry has created many confectionery products that are a mixture of categories, *e.g.* a flour or sugar confectionery centre that is covered with chocolate. There is another category that is sometimes referred to as 'sugar-free sugar confectionery'. This oxymoron refers to products that resemble sugar confectionery products but which are made without any sugars. The usual reason for making these products is to satisfy special dietary needs. A better name might be 'sugar confectionery analogues'.

The manufacture of confectionery is not a science-based industry. Confectionery products have traditionally been created by skilled craftsman confectioners working empirically, and scientific understanding of confectionery products has been acquired retroactively. Historically, sugar confectionery does have a link with one of the science-based industries – pharmaceuticals. In the eighteenth century, sugar confectionery products were made by pharmacists as pleasant products because the active pharmaceutical products were unpleasant. The two industries continue to share some technology, such as making sugar tablets and applying panned sugar coatings. There are products that although apparently confectionery are legally medicines. This usually applies to cough sweets and similar products. In the United Kingdom these products are regulated under the Medicines Act and require a product licence. This means that all the ingredients for the product are specified and cannot easily be altered. The dividing line between confectionery and medicines is not uniform in all countries.

One reason that confectionery making is not a science-based industry is the very long product life. The Rowntree's fruit pastille was invented in 1879 and was first marketed in 1881. This product is still one of the leading sugar confectionery lines in the UK today (1999), and it appears that it will continue to be sold into the 21st century. The man who invented it, Claud August Gaget, knew nothing of proteins or the peptide bond. In 1879 very little was known about proteins in scientific circles so there was no scientific basis from which to work.

FOOD LAW

Legislation affects all parts of the food industry. In Great Britain, modern food law developed from the Food and Drugs Acts. Such legislation came about after an outbreak of arsenic poisoning among beer drinkers, the cause of which turned out to be the glucose that had been used in making the beer – the glucose had been prepared by hydrolysing starch with sulfuric acid. The acid had been made by the lead chamber process from iron pyrites which contained arsenic as an impurity. The approach subsequently adopted was that all foods should be 'of the substance and quality demanded'. This was obviously intended to cover any future problems with other contamination, and not necessarily with arsenic. Other countries, particularly those whose legal systems follow Roman rather than Anglo-Saxon law, have tended to more prescriptive laws.

The British approach is to allow any ingredient that is not poisonous unless, of course, the ingredient is banned. Additives are regulated by a positive list approach: unless the substance is on the permitted list it cannot be used. There are anomalies where a substance can be legal in foods but which is not permitted to be described in a particular way. An example of this is the substance glycherrzin, which is naturally present in liquorice and has a sweet flavour. It would be illegal to describe it as a sweetener as it is not on the permitted sweetener list. Glycherrzin is permitted as a flavouring, however, and can be added to a food, which makes the overall product taste sweeter than it would without the addition. Conversely, the protein thaumatin is permitted as an intense sweetener yet, in practice, it has been found that thaumatin has more potential as a flavouring agent. It would have been much easier and cheaper to obtain approval for thaumatin as a flavouring rather than as a sweetener.

The British system does not automatically give approval to new ingredients merely because they are natural. This is in contrast with the position in some other countries – there will always be grey areas. One example is the position of the oligo-fructose polymers which are naturally present in chicory. Chicory is undoubtedly a traditional food ingredient; however, the oligo-fructoses extracted from it cannot necessarily be described as such. If the fructose polymers are hydrolysed to fructose then that is a permitted food ingredient. However, if they are partially hydrolysed then what is the status of the resulting product? The issue of fructose polymers is further complicated because one of the properties that is interesting is that they might not be completely metabolised. If that is the case then they would be considered as additives rather than ingredients. Additives need specific approval whereas ingredients do not.

Unlike chocolate confectionery, sugar confectionery is free of legal definitions. Terms such as 'pastille' or 'lozenge' although they have an understood meaning, at least to those in the trade, are sometimes applied to products that are not strictly within that understood meaning, *e.g.* there are products that are sold as pastilles but which are, in fact, boiled sweets. Butterscotch must contain butter, but gums do not have to contain any gum.

THE SCOPE OF SUGAR CONFECTIONERY

The confectionery industry is vast. It ranges from small shops, where the product is made on the premises, to branches of the largest companies in the food industry. Probably because sugar confectionery keeps well without refrigeration it has been a global market for many years. In spite of this there are distinct national and local tastes in sugar confectionery. A British jelly baby may resemble a German Gummi bear but the taste is quite different – curiously, the British jelly baby was invented by an Austrian confectioner. Similarly, the gum and gelatine pastilles made in France and Britain are very different, yet the leading British brand was invented by a French confectioner.

HEALTH AND SAFETY

Sugar confectionery is not an inherently dangerous product but several points should be made. Some sugar confectionery products are made at high temperatures, *e.g.* 150 °C, which is hotter than most forms of cookery even if it is not a high temperature by chemical standards. Precautions must also be taken to prevent contact between people and hot equipment or products. Sugar-containing syrups not only have a high boiling point but they are by nature sticky and a splash will tend to adhere. Precautions must be taken to prevent splashes and also to deal with any that occur. In the event of a splash, either plunging the afflicted area into cold water or holding it under cold running water is the best first aid. A sensible precaution is to make sure that either running water or a suitable container of water is always available.

Most sugar confectionery ingredients are not at high risk of bacterial contamination. However, some ingredients are prone to bacterial problems; examples are egg albumen and some of the gums and gelling agents. In handling these materials, precautions need to be taken so that they do not contaminate other ingredients or any finished product. Confectionery ingredients should be food grade and any confectionery being made to be eaten should be prepared using food grade equipment and not in a chemical laboratory. It must also be ensured that dusts from handling the ingredients do not cause eye or lung irritations. Some confectionery ingredients, although perfectly edible and of good food grade, can cause irritation if inhaled.

Chapter 2

Basic Science

There are several aspects of science which are fundamental to sugar confectionery. They are discussed here.

STABILITY

Sugar confectionery products keep well compared with most other food products. Their long life ensues because spoilage organisms cannot grow, and the reason that they cannot grow is because the moisture content is too low.

Water Activity

The relevant parameter is not only the water content but also the water activity. Water activity is a thermodynamic concept which accounts for the fact that materials containing different water contents do not behave in the same way, either chemically or biologically. It reflects the ability of the water to be used in chemical or biological reactions, and it is the concentration corrected for the differences in the ability of the water to undertake chemical reactions. If a non-volatile solute is dissolved in water then the vapour pressure decreases in a specific way for a perfect mixture. A thermodynamically ideal substance always has an activity of unity.

Originally, water activity could not be measured directly. One method was to measure the weight loss of a product held at a range of controlled relative humidities, which also has the effect of holding the product over a range of water activities. If a product is held at its own water activity it neither gains nor loses weight, and this point is described as its equilibrium water activity.

Equilibrium Relative Humidity (ERH)

The is term is normally abbreviated to ERH. The ERH can be deduced by extrapolating the weight loss data over a range of water activities for values greater and less than those actually measured for the product. Where the two lines intersect lies the water activity of the product. This extremely tedious and time-consuming method has largely been superseded by instruments that measure the water activity directly. The ERH still has practical importance since it is an indication of the conditions under which the product can be stored without deterioration.

Dew Point

A related property is the dew point which is the point at which condensation occurs upon cooling. When products are being cooled the temperature must not fall to the dew point otherwise condensation will occur on the product and product spoilage is likely.

COLLIGATIVE PROPERTIES

Boiling Points

Colligative properties are defined as those properties that depend upon the number of particles present rather than the nature of the particles. In sugar confectionery the most important of these is the elevation of boiling point. Because sugars are very soluble, very large boiling point elevations are produced, *e.g.* as large as 50 °C. Remembering that elevation of the boiling point is proportional to the concentration of the solute it is not surprising that the boiling point is used as a measure of the concentration and hence as a process control.

The boiling point of a liquid is the temperature at which the vapour pressure is equal to the atmospheric pressure. If the pressure is increased the boiling point will also increase whereas reducing the pressure will reduce the boiling point. Most sugar confectionery is made by boiling up a mixture of sugars in order to concentrate them. The use of vacuum here has several advantages. Energy consumption is reduced, browning is reduced and the whole process is speeded up. A common practice is to boil a mixture of sugars under atmospheric pressure to a given boiling point. A vacuum is then applied, which causes the mixture to boil under reduced pressure. This not only concentrates the mixture, but the latent heat of evaporation also cools the mixture rapidly, thus speeding up the production process since the product must ultimately be cooled to ambient temperature for further handling.

Another area where boiling points are important is with regard to steam. Most heating in a confectionery plant is done by saturated steam, *i.e.* steam at its boiling point. The temperature of steam can be regulated by controlling the pressure. One advantageous side effect of using vacuum boiling rather than boiling at atmospheric pressure is that lower steam pressures can be used because the boiling point has been reduced. These lower steam pressures produce a considerable saving in terms of the capital cost of steam boilers and pipework since they do not have to be built to withstand the higher pressures.

Measuring Vacuums

In controlling a process the level of the vacuum obtained controls the amount of water in the product. From a product stability consideration this is obviously important, and the level of vacuum applied can be measured in a number of ways. Although they may have been used in the past, mercury manometers, for obvious reasons, are no longer used. Nowadays, the commonest measuring instrument is probably the Bourdon gauge although various designs of pressure sensor are also available. Calibration of the gauge can be in a number of different units. It is common to find calibrations in units of length, *e.g.* inches or millimetres of mercury – this is a legacy of using a mercury manometer. Alternatively, units of pressure such as pounds per square inch (psi) or Newtons per square metre ($N\ m^{-2}$) are found. Another system is to use bars or millibars, where one bar is equal to one atmosphere.

pH

The pH scale is a convenient way of measuring acidity or alkalinity. The definition is

$$pH = -\log^{10}[H^+] \qquad (2.1)$$

where $[H^+]$ is the concentration of hydrogen ions present in solution. This has the considerable advantage that it almost always gives a positive number. On the pH scale 14 is strongly alkaline whereas 1 is strongly acidic. The pH system does, however, imply that the solution is aqueous. When, as not infrequently happens in sugar confectionery, there is a higher concentration of sugar than water it does imply interesting questions regarding the result produced by a pH probe.

In sugar confectionery the pH of the product is important for a number of reasons. Fruit-flavoured products normally have some acid component added to complement the fruit flavour. Where a hydrocolloid is present the pH of the product can be critical otherwise the product will not be stable or it may not gel at all. If a hydrocolloid is held at its