2nd Edition

The Science of Chocolate

Stephen T Beckett

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Stephen T Beckett
Formerly Nestlé Product Technology Center, York, UK

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Preface

In 1988 I wrote a paper for *School Science Review*, in which I described some of the science involved in chocolate making and followed this by two experiments that could be tried in the classroom. As a result of this I received letters from both pupils and teachers requesting more information or new experiments to try. Subsequently I was contacted by Chris Butlin, who was then developing a food option for the Salters' Physics Advanced Level course. This resulted in some of the science of chocolate being included in this option. The numerous talks given by my colleagues and myself to junior schools, societies and universities also convinced me that there was a genuine interest in this topic and that people were not just coming for the free samples.

When, therefore, the Royal Society of Chemistry asked me if I would write a full book on this topic, aimed at schools and universities, I agreed to do so, without realising the amount of work involved. It was very gratifying, however, to learn in 2006 that the sales were such that a second edition of the book was required. Several people had commented that they wished to know more about the health and nutrition aspects of chocolate and, as a lot of research has recently been carried out in the area, this seemed the ideal subject for a new chapter. In addition, in 2005 New Scientist published a book entitled *Does Anything Eat Wasps*? in which the question was asked about how are bubbles put into Aero®. Possible solutions are given here as part of a second new chapter.

Having graduated in physics, the book is naturally biased in this direction, although I have tried to include a substantial amount of chemistry and even some mathematics in the project work. Several

of the chemical terms used in industry are different from those taught in schools. I have attempted to use the current terminology and have included a glossary in the hope that it will be useful, if someone is not familiar with the term in the text. This glossary also explains some of the industry's own technical names.

This book should be especially useful for someone studying food science at university or who is about to join the confectionery industry. Although a scientific background is required to understand the more difficult sections, such as fat chemistry or the Maillard reaction, most of the rest of the book should be readable by 16–18 year olds. Here I have attempted to show how concepts such as latent heat, relative humidity *etc.* play an important part in the making of something as apparently simple as chocolate. I hope that this in fact might prove to be a "painless" way of learning about them.

Several sections are relatively simple and can be adapted by teachers of GCSE science or even younger pupils. This is especially true of the projects described in Chapter 12. These are meant to be just basic ideas that can be adapted according to age. All use apparatus or ingredients that should be easy to make or obtain. The appropriate safety precautions must, of course, be taken especially for those involving glass, heat or chemicals.

Finally I would like to thank my wife Dorothy for her help with the book and our sons Christopher and Richard for their help with the diagrams, together with John Birkett, Patrick Couzens, Peter Geary, Duane Mellor and Lynda O'Neill for correcting the script, or testing the projects to ensure that they worked. I am also grateful to Awema, Blackwell Science, Loders Croklaan and Palsgaard Industri A/S for their permission to reproduce picture, diagrams and tables. In particular, Figures 1.2, 2.3, 3.5, 3.6, 3.10, 3.13, 3.14, 4.9, 4.11, 4.12, 5.2, 5.3, 5.8, 5.10, 5.13, 6.8, 7.1, 7.5 and 9.8 are all reproduced from *Industrial Chocolate Manufacture and Use* with the permission of Blackwell Science and Figures 1.3 and 1.4 with the permission of the Nestlé Archives, Vevey, Switzerland.

Stephen Beckett
York, UK

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CHAPTER 1

The History of Chocolate

Chocolate is almost unique as a food in that it is solid at normal room temperatures yet melts easily within the mouth. This is because the main fat in it, which is called cocoa butter, is essentially solid at temperatures below 25 °C when it holds all the solid sugar and cocoa particles together. This fat is, however, almost entirely liquid at body temperature, enabling the particles to flow past one another, so the chocolate becomes a smooth liquid when it is heated in the mouth. Chocolate also has a sweet taste that is attractive to most people.

Strangely chocolate began as a rather astringent, fatty and unpleasant tasting drink and the fact that it was developed at all, is one of the mysteries of history.

1.1 CHOCOLATE AS A DRINK

The first known cocoa plantations were established by the Maya in the lowlands of south Yucatan about 600 AD. Cocoa trees were being grown by the Aztecs of Mexico and the Incas of Peru when the Europeans discovered central America. The beans were highly prized and used as money as well as to produce a drink known as chocolatl. The beans were roasted in earthenware pots and crushed between stones, sometimes using decorated heated tables and mill stones, similar to those illustrated in Figure 1.1. They could then be kneaded into cakes, which could be added to cold water to make a drink. Vanilla, spices or honey were often added and the drink whipped to make it frothy.[1] The Aztec Emperor Montezeuma was said to have drunk 50 jars of this beverage per day.

Christopher Columbus bought back some cocoa beans to Europe as a curiosity, but it was only after the Spaniards conquered

Figure 1.1 Ancient decorated mill stone with a hand grinder from the Yucatan.

Mexico that Don Cortez introduced the drink to Spain in the 1520s. Here sugar was added to overcome some of the bitter, astringent flavours, but the drink remained virtually unknown in the rest of Europe for almost a hundred years, coming to Italy in 1606 and France in 1657. It was very expensive and, being a drink for the aristocracy, its spread was often through connections between powerful families. For example, the Spanish princess Anna of Austria introduced it to her husband King Louis XIII of France and the French court in about 1615. Here Cardinal Richelieu enjoyed it both as a drink and to aid his digestion. Its flavour was not liked by everyone and one Pope in fact declared that it could be drunk during a fast, because its taste was so bad.

The first chocolate drinking was established in London in 1657 and it was mentioned in Pepys' *Diary* of 1664 where he wrote that "jocolatte" was "very good". In 1727 milk was being added to the drink. This invention is generally attributed to Nicholas Sanders.[2] During the eighteenth century, White's Chocolate House became the fashionable place for young Londoners, while politicians of the day went to the Cocoa Tree Chocolate House. These were much less rowdy than the taverns of the period. It remained however, very much a drink for the wealthy.

One problem with the chocolate drink was that it was very fatty. Over half of the cocoa bean is made up of cocoa butter. This will melt in hot water making the cocoa particles hard to disperse as well as looking unpleasant, because of fat coming to the surface. The Dutch, however, found a way of improving the drink by

removing part of this fat. In 1828 Van Houten developed the cocoa press. This was quite remarkable, as his entire factory was manually operated at the time. The cocoa bean cotyledons (known as cocoa nibs) were pressed to produce a hard "cake" with about half the fat removed. This was milled into a powder, which could be used to produce a much less fatty drink. In order to make this powder disperse better in the hot water or milk, the Dutch treated the cocoa beans during the roasting process with an alkali liquid. This has subsequently become known as the Dutching process. By changing the type of alkalising agent, it also became possible to adjust the colour of the cocoa powder.

1.2 EATING CHOCOLATE

Having used the presses to remove some of the cocoa butter, the cocoa powder producers were left trying to find a market for this fat. This was solved by confectioners finding that "eating" chocolate could be produced by adding it to a milled mixture of sugar and cocoa nibs. (The ingredients used to make dark chocolate are shown in Figure 1.2.) If only the sugar and cocoa nibs were milled and mixed together they would produce a hard crumbly material. Adding the extra fat enabled all the solid particles to be coated with

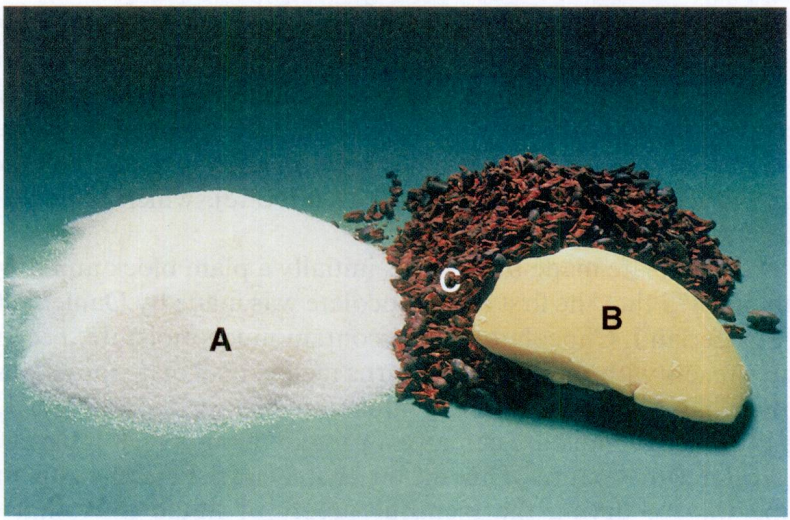

Figure 1.2 Unmilled ingredients used to make dark chocolate: A, sugar; B, cocoa butter; C, cocoa nibs.[3]

fat and thus form the hard uniform bar that we know today, which will melt smoothly in the mouth.

Almost twenty years after the invention of the press in 1847, the first British factory to produce a plain eating chocolate was established in Bristol in the UK by Joseph Fry.

Unlike Van Houten, Fry used the recently developed steam engines to power his factory. It is interesting to note that many of the early chocolate companies, including Cadbury, Rowntree and Hershey (in the USA) were founded by Quakers or people of similar religious beliefs. This may have been because their pacifist and teetotal beliefs prevented them from working in many industries. The chocolate industry was, however, regarded as being beneficial to people. Both Cadbury and Rowntree moved to the outside of their cities at the end of the 1990s, where they built "garden" villages for some of their workers. Fry remained mainly in the middle of Bristol and did not expand as quickly as the other two companies. It eventually became part of Cadbury.

With the development of eating chocolate the demand for cocoa greatly increased. Initially much of the cocoa came from the Americas, with the first cocoa plantation in Bahia in Brazil being established in 1746. Even earlier, however, the Spaniards took cocoa trees to Fernando Po (Biyogo), off the coast of Africa, and this soon became an important growing area. In 1879 a West African blacksmith took some plants home to the Gold Coast (now Ghana). The British governor realised its potential and encouraged the planting of trees, with the result that Ghana has become a major source of quality cocoa. Other European powers also encouraged the growing of cocoa in their tropical colonies, *e.g.* France in the Ivory Coast (Côte d'Ivoire), which is now the world's largest producer of cocoa.

The chocolate made by Fry was initially a plain block and it was only in 1875 that the first milk chocolate was made by Daniel Peter in Switzerland. Chocolate cannot contain much moisture, because water reacts with the sugar and turns melted chocolate into a paste rather than a smoothly flowing liquid (see Project 5 in Chapter 12). As little as 2% moisture can give a product a poor shelf life as well as an inferior texture. This meant that Daniel Peter had to find some way of drying the plentiful supply of liquid milk that he found in his own country. He was helped in this by the recent development of a condensed milk formula by Henri Nestlé. This

meant that he had much less water to evaporate, and he was able to remove the remaining amount using relatively cheap water-powered machines. In most countries milk chocolate products are now much more popular than plain chocolate ones. In the early 1900s Daniel Peter was challenged to prove that he did in fact invent milk chocolate, so he took his original notebook to the lawyer to get it stamped. The original page together with the lawyer's mark is reproduced in Figure 1.3.

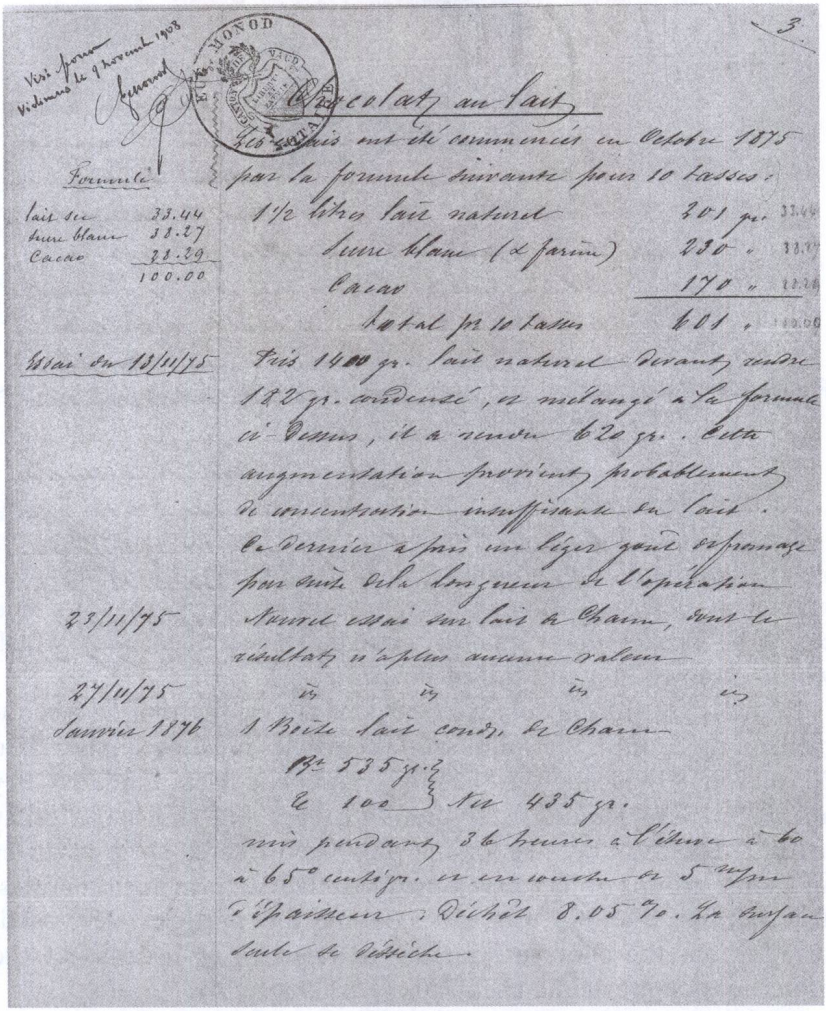

Figure 1.3 Page from Daniel Peter's notebook (permission of Nestlé Archives, Vevey, Switzerland).