

The Biochemistry of the Cupcake

Dr Jill Williams

A Biochemical Society Scientific Outreach Grant funded event.

Everyone loves cupcakes - the soft melting texture, the light, delicate sponge and the sweet, luscious icing. What may not be obvious however is that in making these pretty little morsels there is actually some very serious science going on. In fact, if you stop to think about it, it's really quite incredible that flour, sugar, butter and eggs combine then change in the heat of the oven to form something so deliciously different from any of the constituent ingredients. How can it be that a fine white powder, a white crystalline solid, a malleable, melting solid and a thick translucent fluid extracted from a calcified shell are able to form first a thick, viscous batter then a gas-interspersed solid matrix strong enough to support not only itself but the icing and various decorations on top?

Thanks to a workshop at Glasgow Science Centre funded by the Biochemical Society and in which we were assisted generously by the University of Strathclyde, the mysteries of the cupcake have now been revealed! Families and individuals from the city and beyond came along, and in a series of interactive workstations began to explore the chemical and biochemical processes taking place. We began by looking at the anatomy of the sponge and thinking about the yellow solid matrix and the gas bubbles interspersed within it. This led onto two workstations; the first describing carbon dioxide liberation by the baking powder contained in self-raising flour and the second, the formation of the solid which encompassed topics such as macromolecules, monomers and polymers, protein structure and activity and starch gelation.

The first of these workstations was all about making "cupcake bubbles". To do this we mixed sodium bicarbonate with vinegar and observed the resulting liberation of carbon dioxide. We explained that this reaction is very similar to the one which occurs when the baking powder in self-raising flour dissolves into aqueous solution (in this case, mostly fluid from the eggs). But as our demonstrators pointed out, you can't bite into bubbles, they would simply disappear! We need something to entrap them, and here the eggs and flour in the ingredients mix come into play. Proteins from these ingredients denature and form new chemical bonds in the heat of the oven. In other words, they set around the heat-expanded gas bubbles which come from baking powder and air incorporated during beating. In a visual and practical demonstration we explained that the uncooked proteins were a little like wool or string wound into tight bundles, then went on to say that as the temperature increased in the heat of the oven the bundles moved faster and faster and started to unwind, thus exposing new parts of the structure and enabling the formation of new chemical bonds. Eventually the proteins knit together to form an expanded network into which gas bubbles are entrapped. Some participants even got the knitting needles out and crafted their very own "protein" with wool bought along for the purpose.

We then went on to think about proteins in a little more detail and said that they were made up of single unit monomers termed amino acids. We said that these amino acids were analogous to individual letters of the alphabet - that just as we can form letters into words and from that literature of infinite variety and complexity we combine amino acids into polypeptides and from that a vast array of proteins. Participants were then given beads decorated with letters of the alphabet and allowed to make their very own "protein" necklace or bracelet.

After all that science we deserved a treat, so it was on to cupcake decorating. First of all though we had a think about how we really shouldn't eat too much food which is high in fat and sugar, and had a further discussion about energy balance and obesity, tooth decay and illnesses such as heart disease, type II diabetes and certain types of cancer. We also considered the health-giving properties of food components not found to any great extent in cupcakes such as vitamins, minerals and fibre. Finally we made sure our hands were nice and clean, which led on to a brief discussion of food hygiene and infection control.

In the event the participants decorated their cupcakes in every colour and style imaginable - chocolate and vanilla topped with icing, sprinkles and all manner of sweet, sugary things! We took a photograph of the finished cupcakes and uploaded them onto [Facebook](#) where they can now be viewed - 120 in total. Everyone had a fantastic time and we received excellent feedback. Fingers crossed we can repeat this event at least one more time, perhaps as part of British Science Week, 13-22 March. Keep logged on to our Facebook page for further updates.



Figure 1. A finished cupcake



Figure 2. Explaining proteins to visitors