engineers and food research

by Ken Morison, Department of Chemical and Process Engineering, University of Canterbury

The general public does not often associate chemical engineering with food processing, although process engineering has more obvious connections. Graduates in chemical and process engineering are often employed by the food industry to bring engineering expertise to the design, operation and optimisation of food processes. Below are some details of what chemical and process engineering researchers – both at the University of Canterbury and elsewhere – have been up to.

Drying fruit juice and stickiness

The NZ dairy industry is good at spray-drying milk to produce powder, but drying apple or orange juice is a sticky problem. Because drying is so fast the crystals cannot grow, making the spray-dried juice like fine moist toffee; in fact there is no product as it all sticks to the dryer walls and pipes. Graduate student Kloyjai Cheuyglintase from Thailand, thought that mixing it with carrot fibre (a by-product of carrot juicing) would help, and indeed it did when used to dry apple juice. The carrot fibre seems to impose a structure on the sugars in the juice so that they are less sticky. The product was a 'friable' powder without an obvious carrot flavour, and it was readily reconstituted.

A key tool in this work was the measurement of the glass transition temperature of the products. Toffee, for example, is a glass; it is so viscous that it cannot move. As it is heated up it starts to soften and become sticky. The temperature at which this happens is known as the glass transition temperature. If the toffee contains more water, it gets sticky at a lower temperature. That's one reason we cook up toffee so much – to drive off as much moisture as possible to form a glass at room temperature.

The same concepts are used within the dairy industry to ensure that the milk powder does not get too sticky. Some powders contain a lot of lactose and at certain moisture levels and temperatures they get sticky too.

Keeping milk evaporator wet

On a windy wet day rainwater might stream down your windows. With a little rain, little rivers (or rivulets) might form, but with a heavy downpour there might be enough water to maintain a complete film of water over the entire window. The same phenomenon occurs inside a milk evaporator as milk flows down the inside of steam heated tubes. The conditions required to achieve a complete film are the subject of research at the University of Canterbury. If a complete film is not formed, the milk can dry off and build up.

The minimum flow rate required for a complete film depends on the viscosity, density, surface tension and contact angle of the liquid. The contact angle is the angle of the intersection between the surface of a liquid droplet and a solid surface; it depends on the nature of the surface as well as the liquid. The minimum flow rate is also very dependent on how the liquid gets spread out at the top of the surface.

This project is an example of how the fundamental properties of a liquid and a surface impact on the successful design of industrial equipment. The results showed that the most difficult part is to get the milk to spread out at the top of evaporator tubes.

Fouling and cleaning

Just boil some milk in a pot and then wash it clean, and you will get an idea of the problems faced by the dairy industry every day. Milk proteins will happily stick to any surface with a temperature of more than 70°C. When milk is heated, high surface temperatures cannot always be avoided, so during pasteurisation and evaporation some of the milk always sticks to the stainless steel surfaces. After ten to twenty hours the plant must be shut down and cleaned with sodium hydroxide solution and acid to remove the milk deposit.

Both fouling reduction and faster cleaning are the subjects of research in many universities. At Canterbury, we have been trying to apply a single layer of poly ethylene glycol molecules to prevent the proteins sticking. Sometimes it works, but not for all conditions.

To enhance cleaning we have looked at the effect of temperature, concentration and type of cleaning solution of the cleaning rates. As others have found in the past, higher concentrations are not always better. Cleaning solutions with more than about 2% sodium hydroxide just turn milk protein into a sticky gel that is slow to remove. Lower concentrations are more effective, less costly and easier to treat for disposal.

Potatoes

Most of us just eat potatoes, but engineers like to write equations to model them. Consider the process of deep-frying potatoes. While you are waiting for the hot chips, inside the potatoes there are transfer of heat, flow of water, vaporisation of water, flow of water vapour, flow of oil, and reactions that are cooking the potato. All these processes are influenced by each other. Some chemical engineers from the USA have put together a mathematical model to describe it all (Food and Bioproducts Processing, v85, p209).

Why did they bother? Potato chips are well up on the list of foods that are high in fat, and people have also been concerned about reactions leading to the production of acrylamide that might be carcinogenic. Here's one of the many equations they used; it shows that there are mathematics challenges in engineering (but equations can be very effective sleeping pills too!).

$$\frac{\partial}{\partial t}\left(\phi S_g \rho_g\right) + \nabla \cdot \left(-\rho_g \frac{k^p_{r,g}\, k^p_{in.g}}{-\mu_g} \nabla P\right) = i$$

The process of mathematical modelling is one that forces engineers to question their understanding of the processes. Some would say that if we can't model it, we don't understand it.

One of the conclusions from this type of work is that potato chips do not get fatty until they are removed from the cooking oil. When the water vapour inside the chips cools down, it condenses and sucks in fat. Draining chips while they are hot is essential; draining chips in a vacuum would be even better.

For information about careers in food technology visit: **www.nzifst.org.nz**