Science at home

Harnessing biology

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One of the current broad trends in technology is the use of biological systems rather than chemical or industrial processes. There are some big potential benefits to this, like lower energy use, but it's important to understand that biology works a little differently to chemistry. For one, it has a more complicated relationship with temperature. We can explore that in a quick practical.

Practical 1: temperature in biological systems

My three glasses of yeast and sugar water

- You'll need 3 glasses or mugs, a couple of sachets of yeast, and some sugar.
- Fill one glass with cold water, one with warm water (not too hot – you should be able to comfortably hold your hand under the tap), and one with freshly-boiled water from the kettle.
- Stir a teaspoon of sugar into each glass, until it's dissolved.
- Add a teaspoon of yeast to each glass. You should have some left – keep that for the second practical!
- Check back in 10-20 minutes and compare how much the yeast has bubbled up in each glass.
- You should find a few bubbles in the cold glass, lots in the warm glass, and none in the hot glass

This practical shows that biological systems are sensitive to temperature, but in a more complicated way than simple chemical reactions. You would perhaps have noticed that the sugar dissolved more quickly in the warm water than in the cold, and faster still in the hot water. That's how chemistry generally works – the hotter the temperature, the faster things go. The yeast behaved differently – warm was better than hot. Biological systems do go faster as they get warmer, but only up to a certain point – if it gets too hot, they stop working.

That might sound a bit surprising, because biological systems are based on chemical reactions. But while simple chemistry involves different substances reacting with each other directly, biological processes use protein molecules as middle-men in reactions.

Proteins stop working if they get too hot, and it's this that puts a temperature limit on biological processes.

Yeast is a bit more complicated than just a protein – it's a living organism. Not only does the boiling water stop the yeast working, it kills it and breaks open the yeast cells. You can actually use your nose to smell this – the cold and warm glasses will smell 'yeasty' or beery, while the hot glass will smell bready. It turns out that a lot of the smell of a loaf of bread is actually the smell of dead yeast!

Temperature isn't the only thing that can stop biological systems working. Too much of any of a range of things can cause problems: acids, bases, salt, alcohol… So if biological processes are so fussy, why would we want to use them? Well, using those protein molecules to help reactions along means that they can work efficiently without applying really the really high temperatures or pressures a lot of chemical processes need. That means they need less energy, which often makes them cheaper and easier, even if they take a little longer.

Take the yeast practical we just did. The yeast was turning sugar into alcohol and carbon dioxide gas (which formed the bubbles we saw). This is how every alcoholic drink is made, as well as a lot of alcohol used for other things. There's another way of making alcohol – by reacting a gas called ethene, which you can get by processing crude oil, with water. It's quite widely used, but as well as relying on fossil fuels, it needs a high temperature and a pressure about 60 times atmospheric pressure (to put that in perspective, the pressure in your bicycle tyres is about 3-4 times atmospheric pressure), and you need to use toxic chemicals to make the reaction possible. Those toxic chemicals mean alcohol produced this way isn't fit to drink, but because this process is quicker, and can be run continuously, a lot of the alcohol used for other things is made this way.

Bone is another example of the ability of biological processes to do things efficiently. The hard bit of bones is made of a substance called hydroxyapatite. Your body is, clearly, able to build bones at body temperature – about 37°C – although it takes a while (think how long it takes to heal a broken bone, or to grow them in the first place). We can produce something similar in an industrial process, but it's complicated and needs a temperature of around 1000°C (about as hot as a glowing bit of charcoal on your barbecue).

A duck feather showing the blue patch. Credit: pixabay

So biological processes can get things done without needing huge energy inputs. But they have another trick up their sleeve, too. The use of protein molecules as middle-men means that the structure of a material can be manipulated on a small scale. You can see this next time you go to a park with a pond – take a look at the wings of the mallard ducks, and you'll see a blue patch. Those feathers are actually pigmented brown, but they are structured on a nano-scale so that they reflect blue light.

Attempting nanotechnology experiments at home might be a bit ambitious, but we can certainly do another practical in which we get biology to do the hard work for us!

Practical 2: kneady yeast

The loaf fresh from the oven

- You'll need 400g flour (ideally bread flour, but plain will work too), 4g salt, ½ a teaspoon of yeast, a mixing bowl, some baking paper, and a cast iron casserole dish or a deep cake tin covered with a baking tray as a lid.
- Just before going to bed, put the flour, yeast and salt in the bowl, and stir in 360g cold water until everything is combined. Cover the bowl (I use a dinner plate as a lid) and leave out overnight.
- In the morning, tear off a sheet of baking paper. Generously flour your hands, scoop the now risen dough out of the bowl, shape it into a ball, and put it on the baking paper. Cover with the bowl, upside down, and leave for an hour.
- About 40 minutes into the hour, put your casserole dish or cake tin and baking tray combo into the oven and set it heating to 240°C.
- Once the hour is up, and the oven is hot, remove the dish/tin, place the dough inside (on its paper), and cover it with the lid or the baking tray before returning to the oven.
- Cook for 30 minutes, then remove the lid and cook for another 15 minutes.
- Remove from the oven, lift the bread onto a cooling rack and leave to cool for at least 15 minutes before eating.

Normal bread recipes ask you to knead the bread dough to begin with. This helps form and stretch out gluten molecules, making the dough elastic enough to trap the carbon dioxide bubbles produced by the yeast. This recipe lets the yeast do all the work. By making the dough a bit wetter than usual, and using a long, slow overnight rise, we get the bubbles to effectively knead the dough as they rise up through it. It takes longer than the 10 minutes or so it would take to knead by hand, but requires a lot less energy input!