NANOTECHNOLOGY

A fresh brew

Compounds in tea known as polyphenols could lead to more sustainable ways of making nanoparticles.

BY NEIL SAVAGE

Sudhagar Pitchaimuthu is probably not the first researcher in the United Kingdom to make tea in his laboratory. But when he does, the engineer at Swansea University isn't looking for a relaxing cuppa. Instead, he's brewing up a batch of quantum dots.

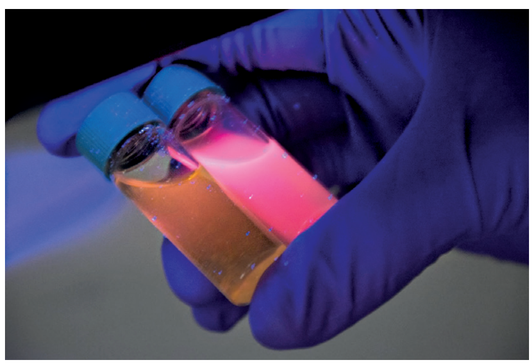
Quantum dots — particles of semiconductor material only a few nanometres in diameter — have many potential uses. When stimulated by light, they fluoresce strongly, which makes them useful for medical imaging. Such particles could latch on to cancer cells and then be lit up, helping physicians to detect tumours at an earlier stage. They could also act as catalysts for the clean-up of industrial waste, in which light is used to create unstable compounds called free radicals that degrade pollutants. And their ability to be tuned to different wavelengths of light means that they could be used to improve the efficiency of solar cells.

Molecules found in certain plants, including the polyphenols that give tea its taste and astringency, have been shown to limit the growth of quantum dots. Particles produced using such natural products also seem to be less harmful to cells in culture, so Pitchaimuthu decided to test whether the tea plant (*Camellia sinensis*) could also be used in quantum-dot synthesis. He found that an extract of tea leaves could facilitate a simple, environmentally friendly production process. In place of the hazardous chemicals and high temperatures used by conventional syntheses, his tea-based method works at room temperature and relies on biocompatible and readily available chemicals in the leaves. And it can use leaves that are not suitable for producing tea for drinking, as well as parts of the tea plant that would otherwise be discarded, including stalks. "If we develop a good methodology of going from the tea leaf to the quantum dots, we can use all these waste tea leaves for the nanoparticles," he says.

To produce quantum dots, Pitchaimuthu chops up tea leaves, gathered on a farm in Valparai, southern India, and mixes them with methanol. He waits a day, stirs in cadmium sulfate, and then lets the mixture sit in the dark for three days. After that, he adds sodium sulfide and sets the concoction aside for another four days. By the end, he has a yellow mixture filled with cadmium-sulfide quantum dots that fluoresces pink when exposed to ultraviolet radiation.

When added to the tea extract, cadmium and sulfur from the precursor compounds begin to coalesce into tiny spheres, and a mixture of polyphenols, vitamins and amino acids in the tea acts as a capping agent — forming a shell that prevents the spheres from clumping or growing too large. That restriction is important, because a quantum dot's size determines the colour of the light that it emits: dots with a diameter of about two nanometres glow blue, whereas those with a diameter of around ten nanometres glow red.

Pitchaimuthu is particularly interested in the potential of quantum dots for carrying drugs into cells in the body. And he thinks that polyphenols hold promise as the basis of such drugs, as they are likely to have anticancer properties (see page S6). When Pitchaimuthu and his team added their quantum dots to a culture of human lung cancer cells, they found that the particles could penetrate the cells, killing up to 80%[1]. Whether that effect was mostly down to cadmium sulfide or to a component of tea is something that Pitchaimuthu intends to explore.



Tea-leaf extract can be used to synthesize quantum dots.

SUDHAGAR PITCHAIMUTHU

Although the polyphenol-coated quantum dots seem not to harm red blood cells at concentrations lower than 60 micrograms per millilitre, he also plans to use his method to produce materials that might be even safer but provide similar benefits. Other researchers have already used tea-based synthesis to make carbon dots, another type of quantum dot that seems to be less damaging to cells. Coating carbon dots with polyphenols might therefore lead to the development of new types of anticancer drug.

Tea could have a valuable role in other sustainable methods for nanotechnology. In 2017, researchers at Henan University in Kaifeng, China, added silver nitrate to an extract of boiled, used tea leaves and then heated the mixture for 30 minutes. After the mixture turned from yellow to dark brown, they removed the liquid component and were left with nanoparticles of silver. When the researchers added the nanoparticles to cultures of the bacteria *Staphylococcus aureus* or *Escherichia coli*, they found evidence of the particles' antibacterial activity, similar to that of such particles derived by other methods[2].

Another team of researchers in China has turned to tea to improve membranes made from sheets of graphene oxide. Such membranes are used in the desalination and purification of water, but water passes through them slowly, which limits their efficiency. Moreover, the graphene layers tend to come apart after a few hours in water.

Led by Wencai Ren, a materials scientist at the Institute of Metal Research in Shenyang, the team found two molecules in tea that could address both problems: the amino acid theanine, which is structurally similar to the amino acids glutamic acid and glutamine, and the polyphenol tannic acid[3]. Ren says that the molecules work together to strengthen the membrane by forming crosslinks that tie sheets of graphene together. They also increase the spacing between sheets so that more water can flow through, while still blocking the passage of impurities that are dissolved in the water. And the molecules improve the efficiency of the water-purification process, by removing groups containing oxygen that hinder the reaction between the membrane and dissolved molecules. Ren says that membranes treated with an extract of powdered green tea are about three orders of magnitude more permeable than are conventional ones, and remain stable in water for months.

They chose green tea, Ren says, because 30–40% of its mass comprises polyphenols, and another 4–6% is made up of amino acids. Although tea is a convenient source of these compounds, other plants or fungi could provide them. Mushrooms contain theanine, for instance, and the shrub Sicilian sumac (*Rhus coriaria*) carries tannic acid. "Any biomass that contains theanine or tannic acid would be okay," he says.

There is wide interest in developing methods of synthesis based on natural products because they enable a reduction in the use of more harmful chemicals. However, studies of tea-based synthesis so far have been small and sparse. There is no certainty that industry will be attracted by the concept of using plants or fungi in nanomaterials synthesis. But it's clear that when it comes to tea, some materials scientists are stirring the pot. ■

Neil Savage *is a freelance science and technology writer in Lowell, Massachusetts.*

1. Shivaji, K. *et al. ACS Appl. Nano Mater.* **1**, 1683–1693 (2018).
2. Qing, W., Chena, K., Wang, Y., Liua, X. & Lu, M. *Appl. Surf. Sci.* **423**, 1019–1024 (2017).
3. Thebo, K. H. *et al. Nature Commun.* **9**, 1486 (2018).