Sticking power of plant polyphenols used in new coatings

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A simple kitchen sink experiment helped Northwestern University researchers discover that green tea leaves not only can be used to steep a good cup of tea, but they make an excellent antibacterial coating, too.

And so can red wine, dark chocolate and cacao beans, they found. It's the powerful and healthful polyphenols at work in a new way. (Polyphenols are naturally occurring molecules found in plants whose functions include structural support and defense against bacteria and oxidative damage.)

Polyphenols are sticky, and the researchers exploited this useful property, while also retaining some of the compounds' well-known biological properties. They made new multifunctional coatings based on tannic acid and pyrogallol—inexpensive compounds resembling the more complex polyphenols found in tea, wine and chocolate.

Simply dissolving polyphenol powder in water with the proper dash of salt quickly produces colorless coatings that have antioxidant properties, are non-toxic and can kill bacteria on contact.

The coatings—which can stick to virtually anything, including Teflon—could be used on a wide range of consumer, industrial and medical products, from catheters and orthopedic implants to membranes for water purification and materials used in food processing, packaging and preparation.

The study is published today (Aug. 22) in the journal *Angewandte Chemie*.

"We discovered a way to apply coatings onto a variety of surfaces that takes advantage of the sticky properties of the polyphenol compounds," said Phillip B. Messersmith, who led the research. "It's a very simple dip-coating process, and the antibacterial and antioxidant properties are preserved in the coating."

One could take a stainless-steel hip implant, he said, apply the process to it, and the coating that emerges spontaneously and with no other modifications will kill bacteria and quench reactive oxygen species, such as free radicals.

Messersmith is the Erastus O. Haven Professor of Biomedical Engineering at Northwestern's McCormick School of Engineering and Applied Science.

Messersmith's team tested all kinds of materials—medically relevant polymers, engineering polymers, metals, inorganic substrates and ceramics—and a coating stuck to each one. The researchers also demonstrated they can easily modify the coatings to give them additional functions, such as an antifouling property to prevent cells from building up on a surface, such as a pacemaker.

"What's interesting is that the raw materials we regularly encounter in our diets can benefit us in a way we had never envisioned—as coatings on medical devices," said Tadas S. Sileika, a graduate student in Messersmith's lab and first author of the paper.

"The coatings innately have properties that are very beneficial to saving lives and keeping people healthy. Without any further modification, they can help prolong the life of a medical device, reduce inflammation in a

patient and prevent bacterial infections," he said.

For 15 years, Messersmith's lab has been developing new biomedical materials, including another coating called polydopamine, also based on phenols, which are found in the sticky glue that marine mussels use to stick to rocks. Because of their chemical similarities, Messersmith and his colleagues wondered if the phenol compounds found in plant-derived red wine, green tea and dark chocolate might have similar sticking power.

This curiosity led to the kitchen sink experiments in which the researchers detected a colorless residue left behind on containers exposed to green tea and red wine. Experiments using polyphenol-rich food extracts from green tea, red wine, dark chocolate and cacao beans also produced coatings.

Messersmith and his team then went one step farther: after finding this behavior also holds for low-cost polyphenols and similar compounds, they developed a simple method for producing the multifunctional coatings.

They found that immersing objects into a saline solution of tannic acid or pyrogallol results in spontaneous coating deposition, just like what happened with the extracts and beverages. Using these inexpensive precursors instead of the extracts improves the speed and lowers the cost of the process, increasing its commercial viability, the researchers said.

"The stickiness of plant polyphenols is behind the so-called astringency effect that people can experience when drinking red wine high in tannins," Messersmith said. "The tannins stick to, or bind, saliva proteins, producing the sensation of puckering and dryness. We've put this stickiness to work in a novel way."

Polydopamine has shown great promise as a biomedical coating, but the plant polyphenol-based coatings can trump it in two important ways: The plant polyphenol-based coatings are colorless, so they don't alter a material's optical properties, and the compounds used to produce them are roughly 100 times cheaper. And that's in addition to their innate antibacterial and antioxidant properties.

The coatings also are only between 20 and 100 nanometers thick, depending on the material being coated, so would not alter biomedical instruments in a negative way.

More information: "Colorless Multifunctional Coatings Inspired by Polyphenols Found in Tea, Chocolate and Wine," onlinelibrary.wiley.com/doi/10 … e.201304922/abstract

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