Continuously killing bacteria on coated stainless steel—add bleach to recharge

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Stainless steel is the gold standard for kitchen appliances and cookware, described as modern and sleek. But bacteria can grow on stainless steel surfaces, contaminating food. Current coatings available on the market are pricey and potentially harmful, so scientists have now developed an affordable specialized polymer coating for such surfaces that they can recharge with bleach treatments.

The researchers are presenting their results at the 255th National Meeting & Exposition of the American Chemical Society (ACS).

"I noticed that stainless steel is frequently used in the health care industry and for food processing, but not a lot of research has been done to prevent bacteria from growing on these surfaces," Buket Demir, Ph.D. says.

Current efforts to avoid such bacterial growth incorporate silver or copper ions, which can be pricey. "In addition, silver and copper are usually alloyed in the metal, and they have been tucked away so they are not very effective," Demir notes. "There is also a health concern with using silver." Silver could leach from the stainless steel and into foods that are later consumed, she says.

Scientists have previously added molecules called N-halamines to textiles for their antimicrobial properties because it is easy to attach these substances to cotton. N-halamines are a group of compounds that have one or more nitrogen-halogen covalent bonds. These compounds are affordable, chemically stable and nontoxic to humans. Demir, a postdoctoral researcher in the lab of Dave Worley, Ph.D., at Auburn University, wants to expand the use of N-halamines into the medical and food industries.

Other groups have linked N-halamine polymers to stainless steel surfaces with the aid of a binder, but Worley's team has now shown, for the first time, that N-halamine can be attached to stainless steel directly. To do this, the researchers first roughed up the surface with hydrogen peroxide and sulfuric acid. This creates negatively charged oxygen groups on the surface to which the N-halamine polymer can attach through a chemical reaction. When the researchers put bacteria on the coated surface, the microbes did not grow. Demir tested many types of bacteria, including E. coli and Staphylococcus aureus, which are common culprits implicated in many foodborne bacteria outbreaks at food processing facilities. All of the bacteria tested were killed within 15 minutes of coming into contact with the treated surface.

Early testing showed that the N-halamine polymer coating was effective for five rounds of killing bacteria before it lost some of that activity. Further, Demir says, "we could regenerate the antibacterial activity of the coated surface by simply wiping it down with a diluted bleach solution."

"Bleach contains chlorine, a halogen, which by itself is extremely unstable; however, when attached to the N-halamine polymer, it becomes stable," Demir notes. "When bacteria come into contact with the treated surface, the chlorine is released, killing the bacteria." She says that the project is still in the early stages of development, but she hopes that the coating could someday be used in kitchens around the world.

Future plans include manipulating the surface of stainless steel in a more user-friendly way. "The greatest challenge is roughing the surface of the stainless steel. Although this is easily done in the laboratory, it would not be easily done in a manufacturing plant," Worley states. "We need a better way of attaching N-halamines to the surface, and we have some ideas as to how we can do that." The researchers also need to perform toxicity testing on samples to investigate the safety of the coated surfaces and examine any biofilms that may develop. "An antimicrobial surface in a food processing plant is badly needed, and it could revolutionize the industry," Worley says.

More information: Title: N-halamine surface functionalization of stainless steel substrates with dual antimicrobial and regenerable character for potential use in the food industry

Abstract
Surface modification of organic substrates such as polymers by novel re-generable antimicrobial N-halamine technology has shown great success in preventing microbial growth and cross contamination. However, functionalization of inorganic substrates such as stainless steel with antimicrobial moieties and regeneration of the biocidal properties remains an important area of research. This work demonstrated a successful synthesis of a copolymer of 2-acrylamido-2-methyl-1-(5-methylhydantoinyl)propane and 3-cloro-2-hydroxypropyl methacrylate (HACM) and modification of a stainless steel (SS) surface through covalent attachment of the HACM copolymer via grafting. Synthesized monomers and copolymers were characterized by NMR and FTIR spectral analyses. HACM-modified SS surfaces were rendered antimicrobial upon treatment with dilute bleach, possessing a sufficient amount of chlorine content and excellent stability and durability. The modified SS samples were characterized through chlorine quantification by titration analysis, FTIR and XPS confirming covalent attachment onto the SS surfaces. Antimicrobial efficacies were evaluated against Staphylococcus aureus and Escherichia coli O157:H7

bacteria, and a rapid inactivation of microorganisms was observed within 15 min of contact time. The samples showed superior washing stabilities and re-generabilities. After 5 cycles of washing, there was a very minimal change in the initial chlorine contents, and the chlorine content could be recharged to its initial number of Cl atoms/cm2 suggesting that a strong and stable copolymer attachment onto the surface could be achieved. However, only a moderate stability of the coatings was observed after UVA irradiation. These results indicate that N-halamine precursor polymers can be facilely applied to SS surfaces by covalent bonding without a need of binding organic layer, and that robust, re-generable antimicrobial SS surfaces could be prepared via the novel technology. This technology exhibits potential for use in food processing, prevention of biofilm formation, and in the biomedical and health-care industries to support the prevention and reduction of cross-contamination and health-care related infections.

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