Superhydrophobic Coatings with Edible Biowaxes for Reducing or Eliminating Liquid Residues of Foods and Drinks in Containers

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Biowaxes, including carnauba wax and beeswax, are edible and renewable. Once dispersed in a polar solvent, these natural materials could be easily converted into nontoxic, "roll-off", and superhydrophobic coatings on the basis of spray coating. The combination of container materials with these coatings can reduce or even eliminate liquid resides (including highly viscous residues) of foods and drinks in containers (*e.g.*, bottles), significantly facilitating downstream operations. Comprehensive demonstrations of this green concept would generate huge opportunities for food/drink-related industries.

Keywords: Carnauba wax; Beeswax; Edible materials; Superhydrophobic coating

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Problems Associated with Residues of Liquid Foods and Drinks in Containers

Liquid foods and drinks are absolutely indispensable in everyday life. Examples of these are soup, congee, soy sauce, ketchup, milk, juice, coffee, honey, and syrup. Products used to contain such foods and drinks can be based on such materials as plastics, cellulosic paper, and metal. However, when dispensing the last of the contents from a container (*e.g.*, a bottle), there is always some residue left stuck to the sides, particularly in the case of very viscous liquids (*e.g.*, honey) (AZoM 2016). Accordingly, a substantial amount of useful liquids are wasted globally. These wastes also pose problems related to liquid disposal or container recycling.

Engineering of Containers with Biowax-Based Superhydrophobic Coatings by Spray Coating

Encouragingly, the concept of fabricating nontoxic, "roll-off", and superhydrophobic coatings with edible materials for readily slicking away residual food/drink-related liquids was recently proposed and demonstrated by researchers from two universities in the United States (Colorado State University and University of Illinois at Chicago) (Wang *et al.* 2016). In this concept, a key feature is that FDA-approved, edible, and renewable biowaxes (*i.e.*, carnauba wax and beeswax) are used in the preparation of superhydrophobic coatings. Here, FDA refers to the United States Food and Drug Administration. In accordance with this concept, either carnauba wax or beeswax is dispersed in a polar solvent (*i.e.*, acetone) with the aid of ultrasonication, and subsequent spraying of biowax dispersions onto container materials can result in the formation of superhydrophobic coatings.

Biowaxes are known to have a hydrophobic nature. The generation of "roll-off" superhydrophobicity as a result of the use of biowax-based coatings can be attributed to (a) low surface energy of biowaxes and (b) surface roughening/texturing induced by phase transition (upon spray coating) of biowaxes relevant to the use of the polar solvent. Interestingly, the as-fabricated coatings have been found to be very effective in facilitating easy removal of a variety of liquid products, including highly viscous honey and chocolate syrup (Fig.1). Further, these coatings have been identified to be nontoxic, as shown using toxicity tests.

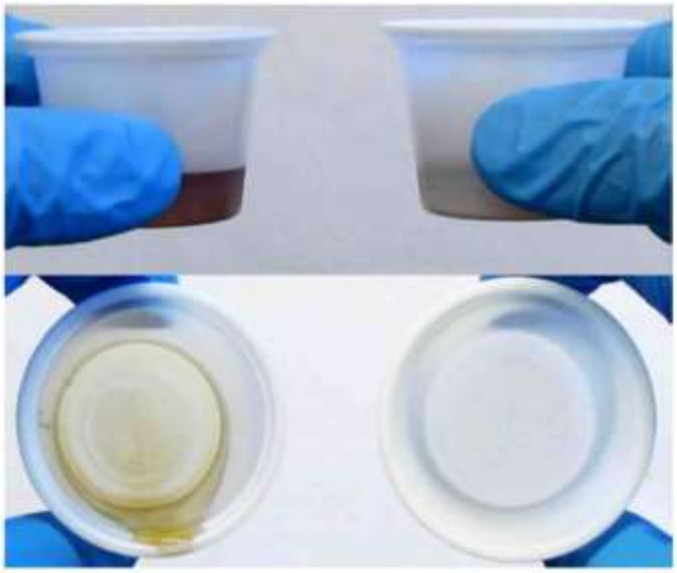

Fig. 1. Viscous liquids in uncoated cup and carnauba wax coated cup before and after being poured out. Reprinted with permission from Wang *et al.* (2016). Copyright © 2016 American Chemical Society.

The interesting concept of using superhydrophobic coatings derived from edible biowaxes for significantly reducing the adhesion of liquids to container materials can potentially be applied to containers with diversified characteristics (cellulosic paper cups, plastic bottles, *etc*.). Solvents greener than acetone, such as ethanol (Yu *et al*. 2017), could be used in spray coating. Strategies for tuning the durability of superhydrophobic coatings for various container materials need to be fully developed to suit specific end-use applications. Future successful commercialization of the process concept would generate huge opportunities for food, paper, and other industries.

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