Bio-based antimicrobial coatings for reducing risk of cross-contamination during harvesting

Contact

Nitin Nitin, PhD
University of California, Davis
Departments of Food Science and Technology | Biological and Agricultural Engineering
nnitin@ucdavis.edu

Authors

Gang Sun (Co-PI), Glenn Young (Co-PI), Hansol Doh, Kang Huang, Shahid Ul Islam, and Yoonbin Kim

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Summary

Bio-based antimicrobial coatings were developed using food-grade biopolymers for reducing risk of cross contamination from diverse food contact surfaces. The biopolymers evaluated include chitosan, zein and gelatin. Chitosan and zein biopolymers were combined with inactivated yeast to enhance binding and stability of chlorine. Chitosan and chlorinated yeast cell wall particles (YCWPs)-based coatings were highly effective in reducing the risk of cross-contamination of pathogenic bacteria on fresh produce surfaces in a simulated postharvest handling environment. Zein and chlorinated yeast-based coatings showed excellent durability against diverse mechanical abrasion and exhibited persistent antimicrobial efficacy. Complementary to these coatings, a chlorinated gelatin-based paint-coating was developed without yeast cells. This coating was also effective in reducing the risk of cross-contamination during simulated cutting of fresh produce and on conveyor belt surfaces.

Objectives

1. Develop approaches for rapid and uniform deposition of antimicrobial food ingredient-based coatings on food contact surfaces and evaluate stability of antimicrobial coatings during simulated field operations.
2. Demonstrate antimicrobial effectiveness of these food ingredient-based coatings against a diversity of pathogens, and evaluate prevention of cross-contamination of fresh produce upon contact with coated surfaces and the overall quality of the produce upon contact.
3. Field-test this antimicrobial coating approach to demonstrate effectiveness, and estimate the cost of implementing this solution.

Methods

- A chitosan and yeast cell wall particles (YCWPs)-based antimicrobial coating was developed on plastic films, Sparta brushes, and polyfoam sponges. Leaf-surface-leaf cross-contamination studies were performed with baby spinach leaves to simulate the preventive effects of the coating against cross-contamination.
- Zein and yeast-based antimicrobial coatings were developed on plastic (polypropylene) surfaces using a two-step, dip- and spray-coating method. EPA-recommended dry and wet abrasion tests were performed on the coated surfaces following EPA guidelines to evaluate the resistance of the coating against mechanical abrasion.
- Gelatin-based antimicrobial coatings were developed on the surfaces of stainless-steel knives and plastic conveyor belts using a one-step, brush-coating method. Cross-contamination tests were performed with the coated stainless-steel knives using romaine lettuce and with the coated conveyor belts using baby spinach leaves.

Results to Date

Chitosan and YCWPs-based coating significantly ($p < 0.05$) reduced the leaf-surface-leaf cross-contamination of *L. innocua* on spinach leaves and showed no transfer of viable cells on the fresh spinach leaves (LOD = 1 log CFU/leaf) (**Figure 1**).

Zein and yeast-based antimicrobial coating on a plastic surface resulted in >5 log reduction of *E. coli* O157:H7 and *L. innocua* within 5 min and showed strong resistance against the mechanical abrasion (dry and wet abrasions), without losing its antimicrobial activities for 3 weeks (EPA equivalent time) (**Figure 2**).

Gelatin-based antimicrobial coating significantly ($p < 0.05$) reduced the cross-contamination of stainless-steel knife during cutting of lettuce and on plastic conveyor belt during simulated transport and handling of fresh produce (**Figure 3**).

Table 1 defines the abbreviations used in the figures.

Benefits to the Industry

This project directly benefits the growers and processors of leafy greens and can have a broad impact on the fresh produce industry. The anticipated benefits will include reduced risks of cross-contamination of fresh produce during harvesting and improved sanitation of harvesting tools. The solutions developed in this project could also be adapted to the fresh produce processing industry in reducing the risk of cross-contamination, particularly after produce washing and sanitation, to include produce conveyors and packing tables.

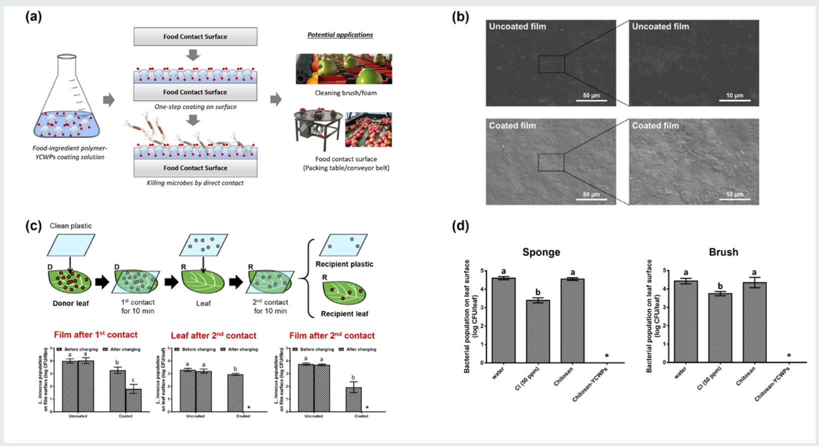

Figure 1. Chitosan and YCWPs-based antimicrobial coating: (a) Schematic of overall approach for chitosan and YCWPs-based coating on food contact surfaces. **(b)** SEM images of uncoated (upper) and coated (lower) PVA-co-PE films. **(c)** Schematic of leaf-surface-leaf cross-contamination study performed on films (upper), and populations of *L. innocua* on the film surface after the first contact (lower left), on the leaf surface after the second contact (lower middle), and on the film surface after the second contact (lower right). **(d)** Populations of *L. innocua* on leaf surfaces after contact with contaminated sponges (left) and brushes (right).

Table 1. Abbreviations used in each study

Study	Abbreviation	Description
Chitosan and YCWPs-based coating	YCWPs	Yeast cell wall particles
Zein and yeast-based coating	PP	Polypropylene surface
	PP@Zein	Zein-coated PP
	PP@Zein@YC	Yeast cells-sprayed PP@Zein
	PP@Zein@YC@Cl	Chlorine-charged YC sprayed PP@Zein
Gelatin-based coating	Nc	Non-coated stainless steel knife
	Nc Nt	Non-coated, non-treated stainless steel knife
	G(T)_x	Gelatin-tannic acid-coated stainless steel knife ('x' indicates the number of the coating layers)
	G(T)_x@Cl	G(T)_x charged with chlorine

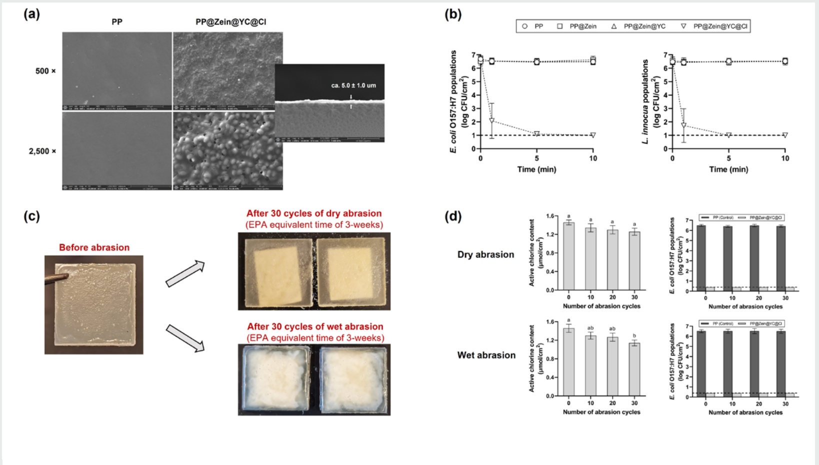

Figure 2. Zein and yeast-based antimicrobial coating: (a) SEM images of uncoated (left) and coated (right) polypropylene (PP) surfaces. **(b)** Populations of *E. coli* O157:H7 (left) and *L. innocua* (right) inoculated on coated PP surfaces. **(c)** Photos of coated PP surfaces before abrasion (left), after 30 cycles of dry abrasion (upper right) or wet abrasion (lower right). **(d)** Active chlorine contents of coated PP surfaces after dry abrasion (upper left) and wet abrasion (lower left), and populations of *E. coli* O157:H7 inoculated on coated PP surfaces after dry abrasion (upper right) and wet abrasion (lower right).

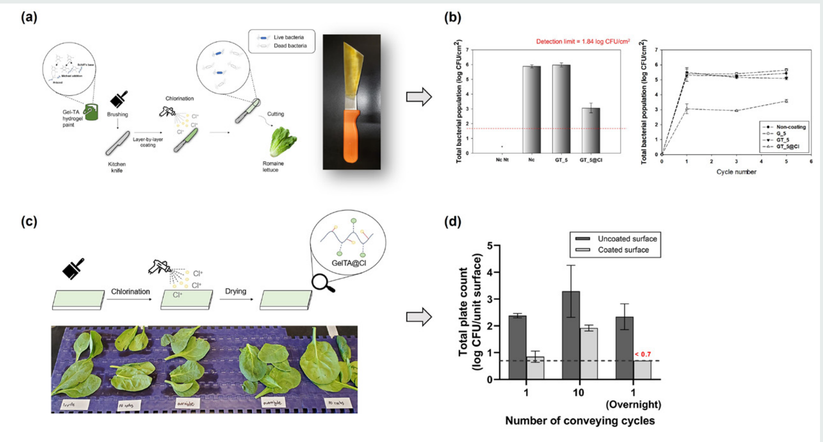

Figure 3. Gelatin-based antimicrobial coating: (a) Schematic of overall approach for gelatin-based coating on the blade surfaces of a stainless-steel knife (left), and photo of the coated knife (right). **(b)** Populations of indigenous bacteria transferred from romaine lettuce to the coated stainless-steel knife after 1 cycle of chopping (left) and for up to 5 cycles of chopping (right). **(c)** Schematic of overall approach for gelatin-based coating on a plastic conveyor belt (upper), and a photo of antimicrobial test set-up with baby spinach leaves on the coated plastic conveyor belt (lower). **(d)** Populations of indigenous bacteria transferred from baby spinach leaves to the coated conveyor belt surface after a number of conveying cycles.