Cellulose nanocrystal (CNC) reinforced bio-composite coating for perishable fruits

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Let's talk about Food…

Let's talk about Perishable Foods…

Current struggles of wasted food in Numbers

52,800,000000

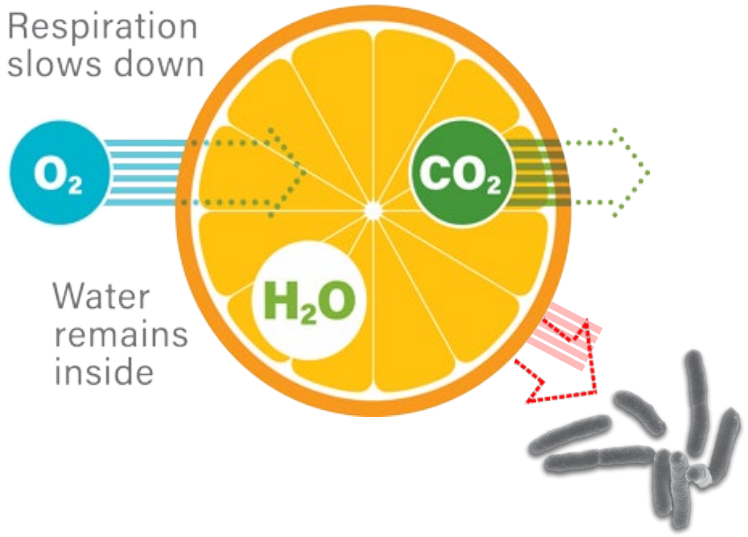
Pounds of wasted fruits/vegetables (most perishable) in the US every year" (2015, NRDC Report).

43% Are thrown away at the consumer level

30% Are discarded by farms and during distribution

25% fresh-water consumption for wasted produce	Global food loss & waste generates 4.4 Gt CO_2	10 billion people needs to be fed by 2050

Factor affecting Shelf Life of Fruits

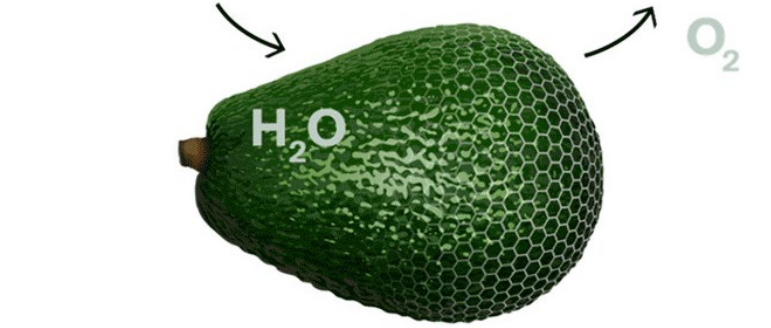


- Dehydration or water loss
- Respiration rate
- Microbial attack

- Commercial wax coating prevents water loss and oxygen entrance
- Long-term health effect

GREEN EDIBLE COATING IS NEEDED

Providing a little extra peel

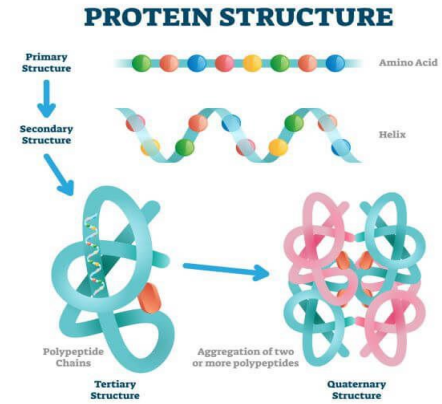


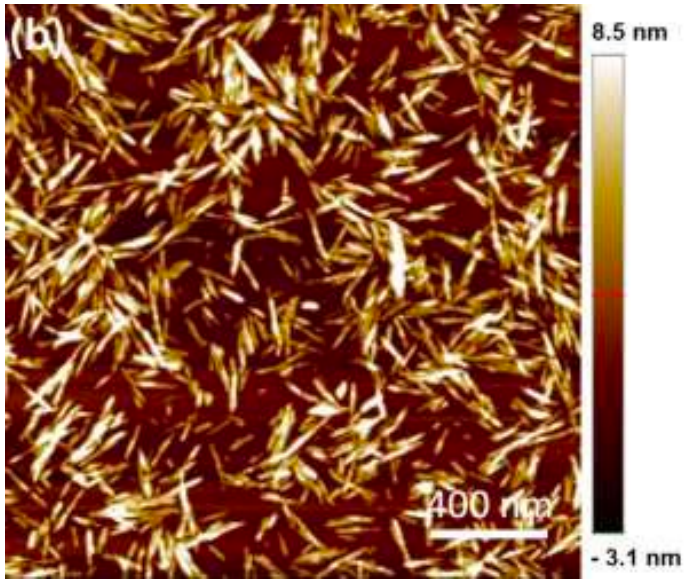
https://www.foodengineeringmag.com/articles/98080

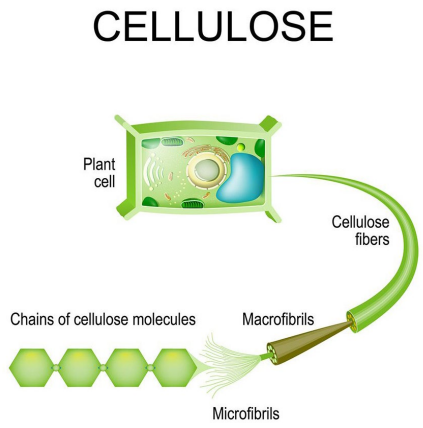
Can we make A COATING from Protein- a healthier choice?

We develop A NANOCOMPOSITE COATING

- Protein (a continuous phase)
- Cellulose nanocrystals (a discontinuous phase) – increased barrier and reinforcement

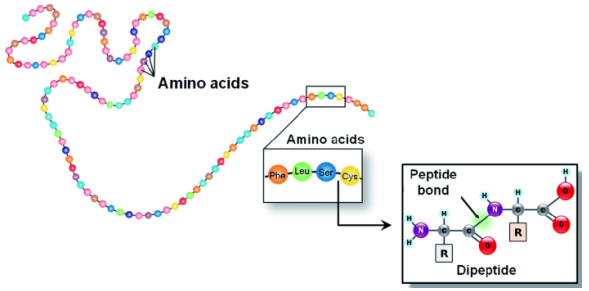


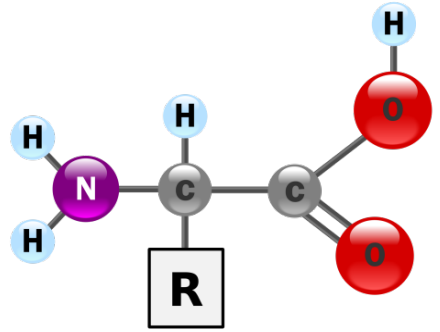




Why Protein can be used instead of Wax?

- Many of the seeds from agriculture sources are fully edible, safe, and healthy.
- These edible seeds are important sources of proteins for humans and livestock. Ex. soybean, corn, wheat etc.
- Protein form numerous intra- and intermolecular bonds due to presence of polar amino acids.

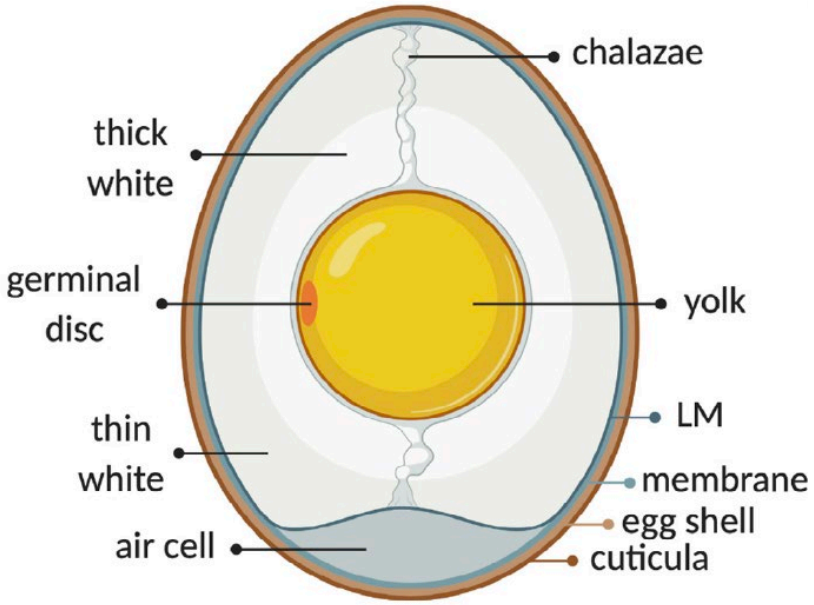


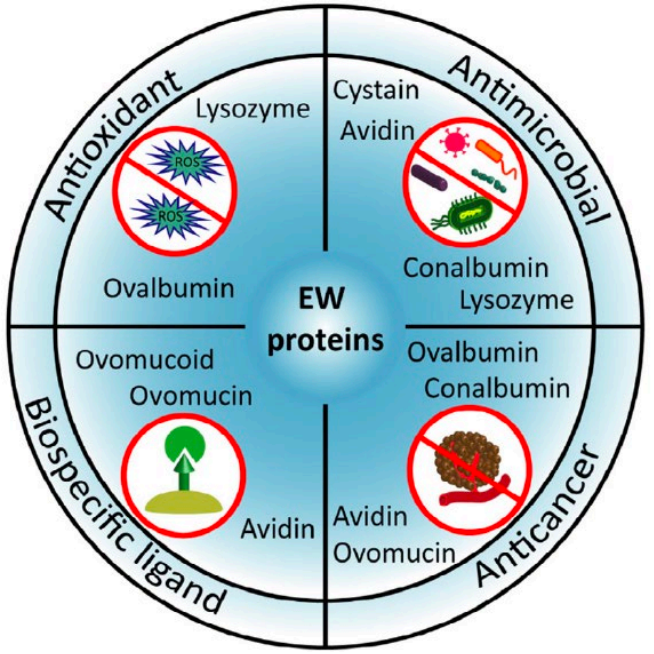


- Proteins offer a wide range of functional properties with better mechanical properties as bio-based polymers compared to wax.

Egg white Protein- Another Protein source

- Egg white, also known as “albumen”, is mainly a mixture of water (85%), proteins (10%) and carbohydrates (5%)
- Egg white is a low-cost protein. Waste eggs can be used (For example, 720 millions eggs were wasted in a year in UK)





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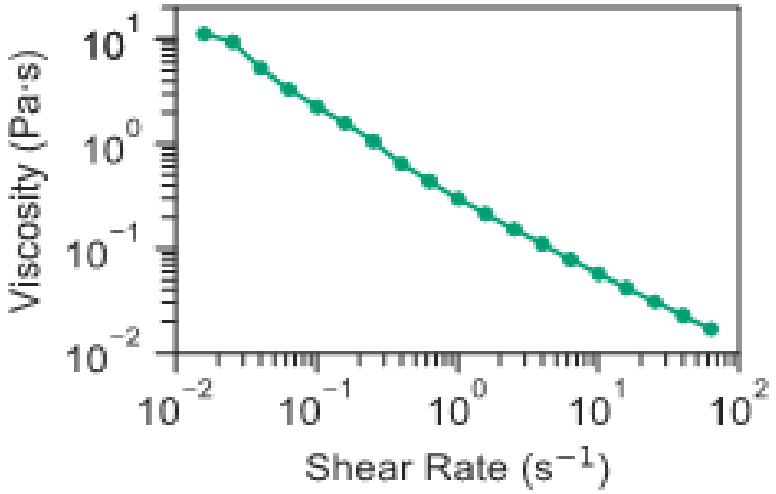
Development of Bionanocomposite

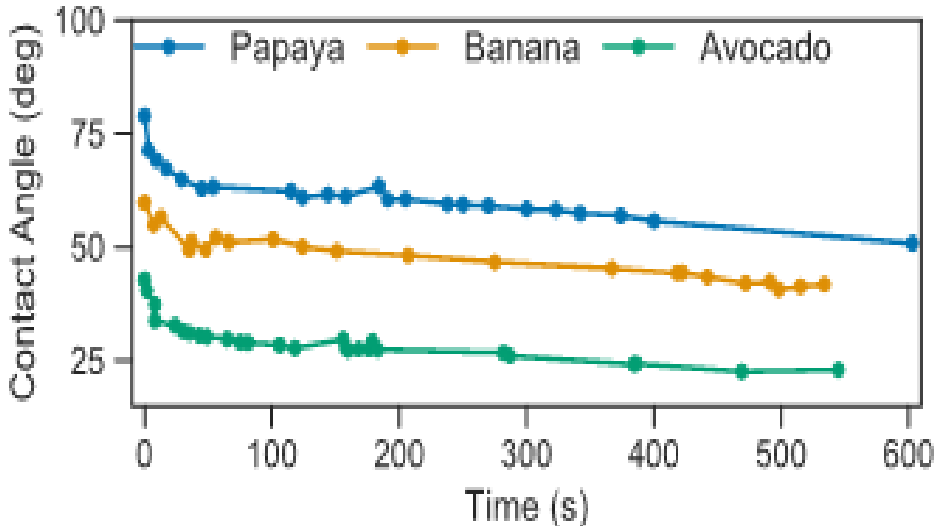
Fruit Model: Banana, Avocado, Papaya, Strawberry

Coating Rheology and adhesion



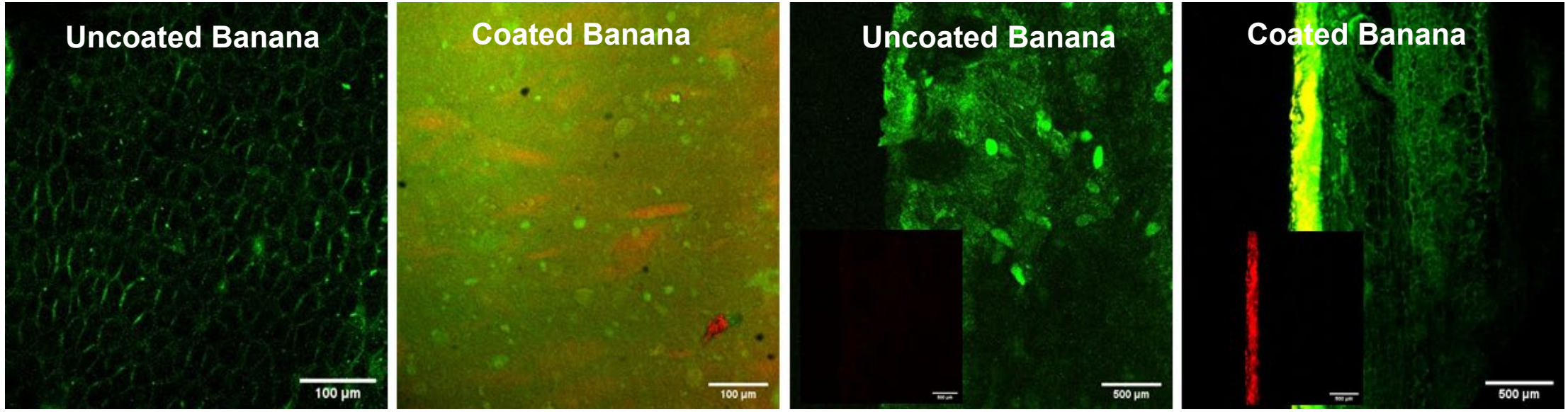
- The coating solution exhibits shear-thinning behavior and the measured viscosity at a low shear rate is around 200 Pa-s
- Nearly three orders of magnitude reduction in viscosity upon shearing. So, spray coating is also a viable coating method.

Affinity of the nanocomposite solution to fruits



The contact angle on the avocado surface immediately after wetting with a drop was ~45° and then decreased to ~25° within 8 min. This suggests that the coating has a high affinity to spread onto the avocado surface.

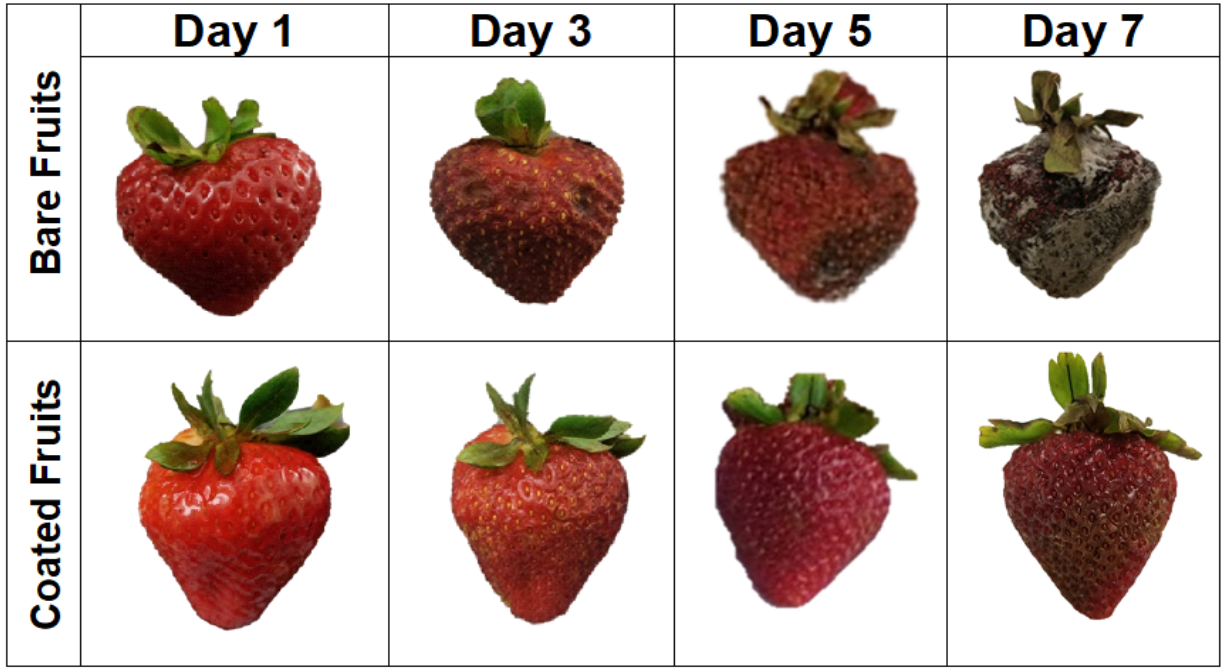
Morphology and Thickness

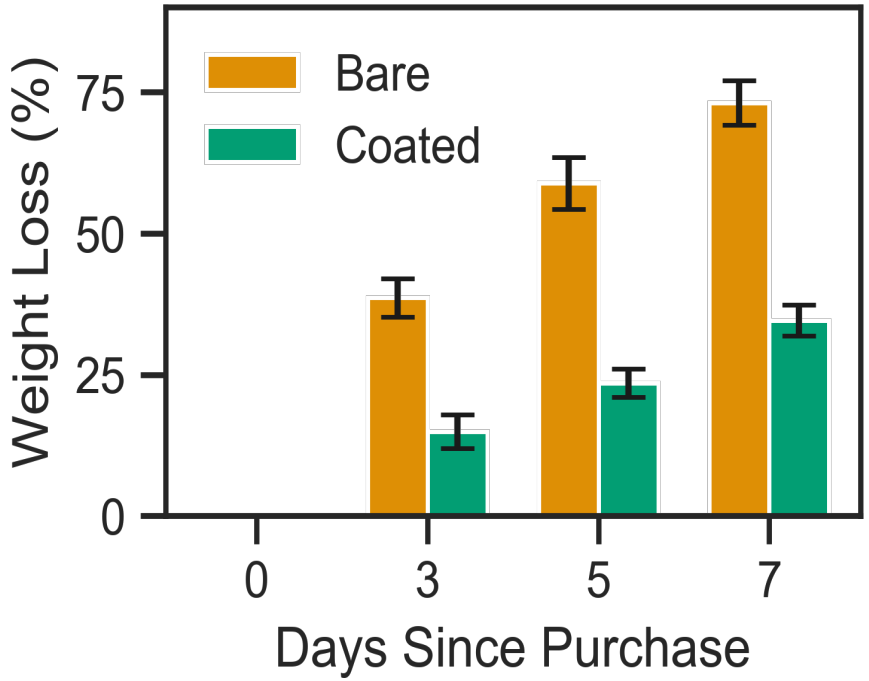


- Topology: Characteristic cell-wall morphology of the outer surface layer of the banana peel is evident through confocal microscope

- Thickness: Coating thickness varies from 20-30 microns

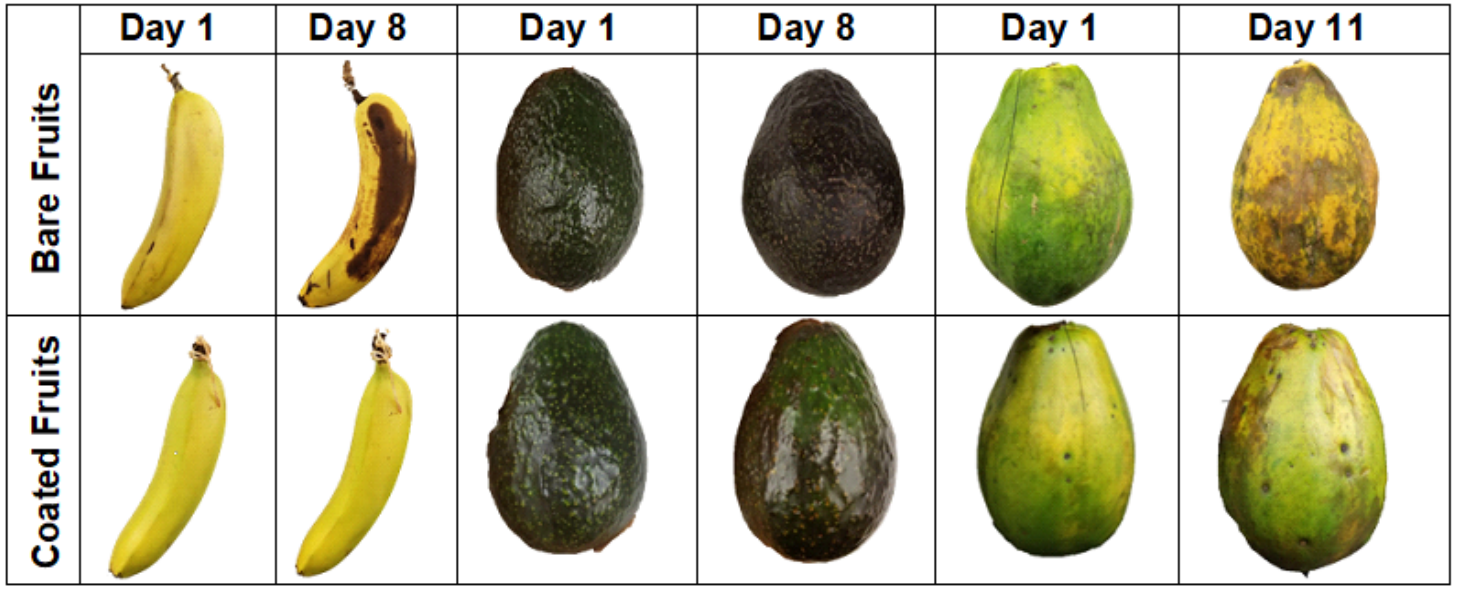
Time lapse behavior of fruits (Non-climacteric)

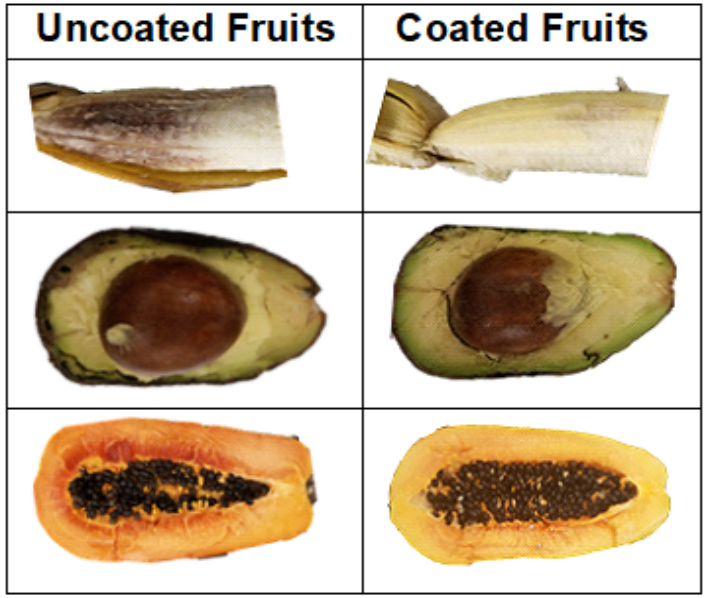




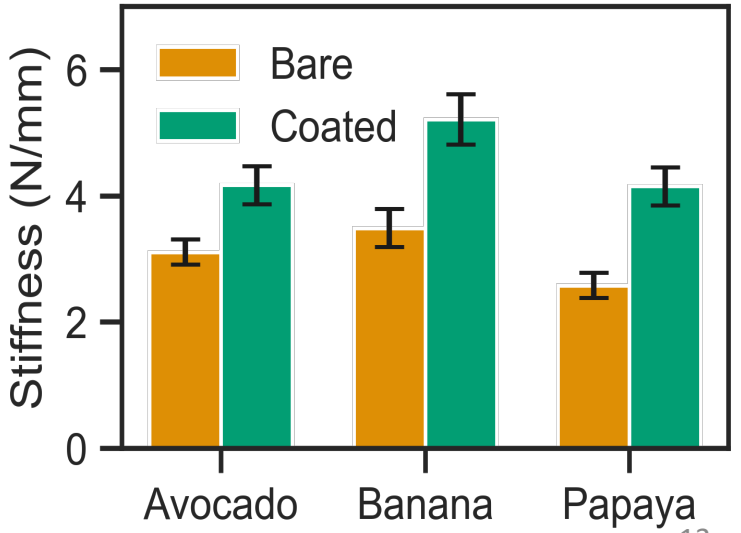
Weight of bare strawberries dropped by about 60% on the fifth-day post-purchase at room temperature, the coated strawberries retained more than 65% of the original weight after one week

Time lapse behavior of fruits (Climacteric)

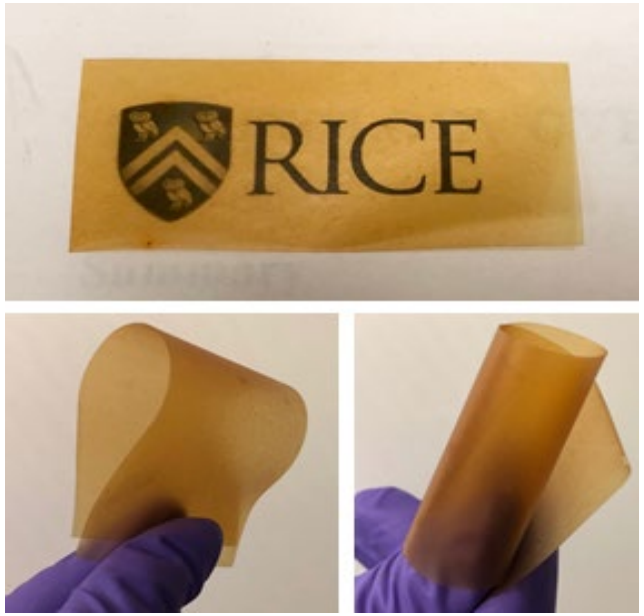




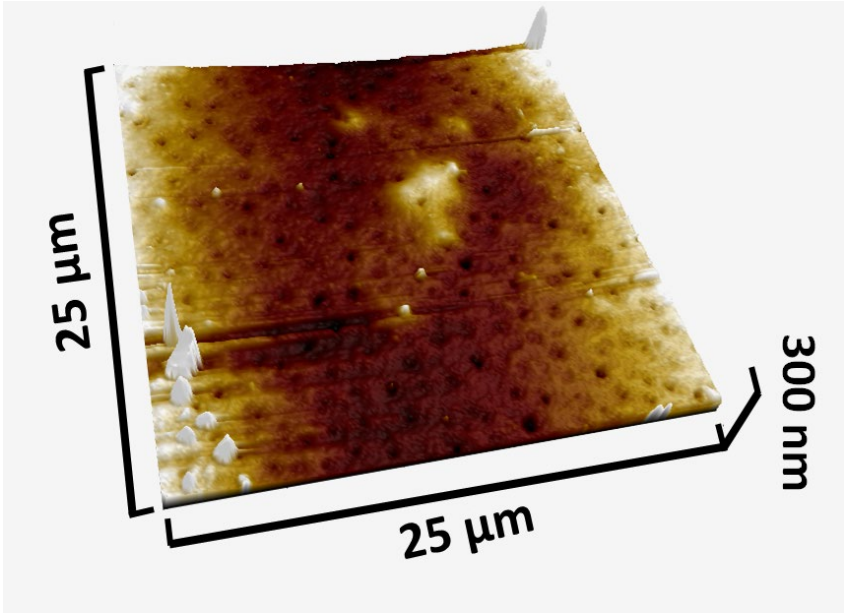
- We compared the firmness between coated and uncoated fruits 7-9 days after the fruits are received.
- As fruits over-ripen or perish, they become softer; therefore, these tests serve to provide further evidence that the coated fruits maintain their freshness longer than bare fruits.



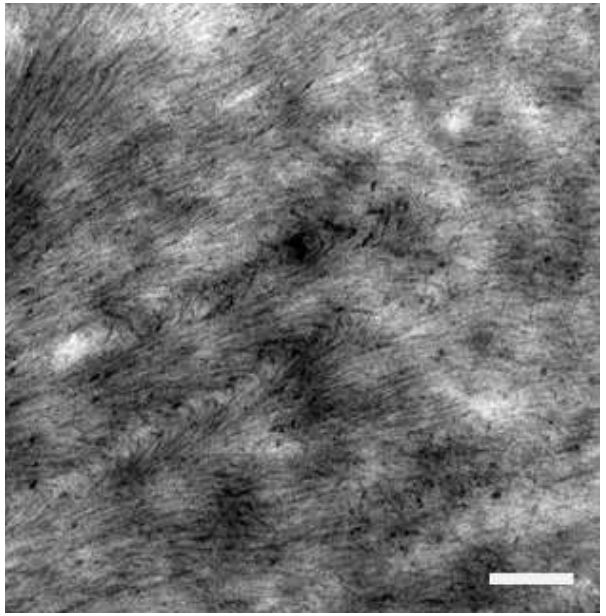
Characterization of our coating film



Topography

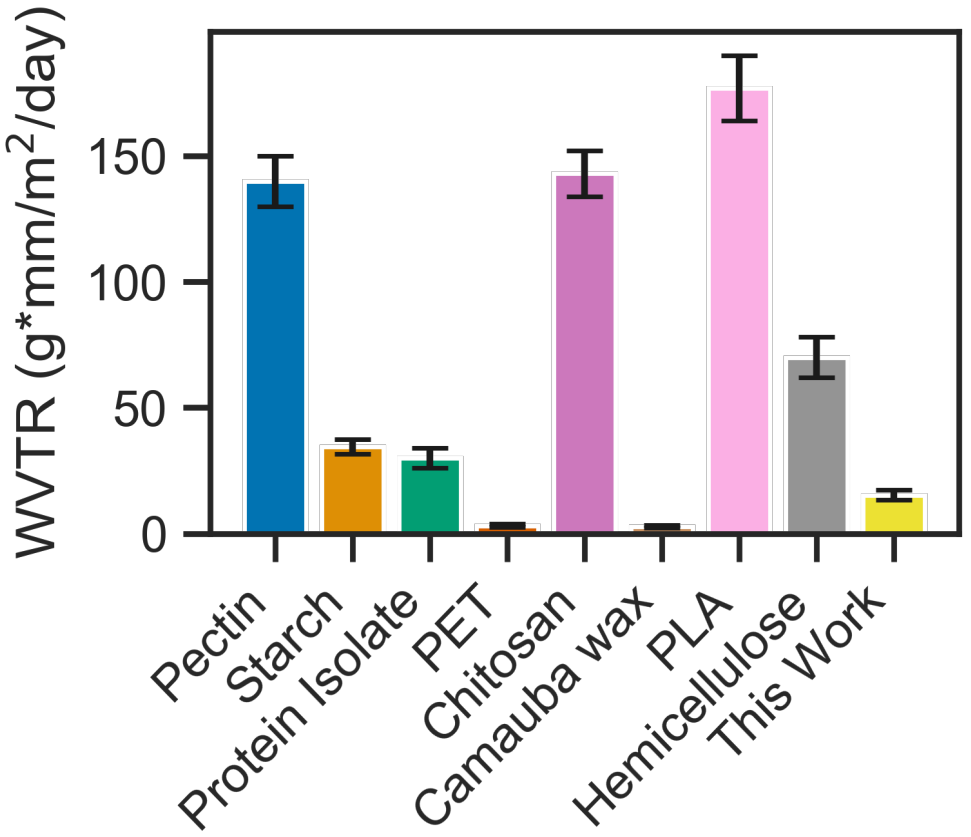


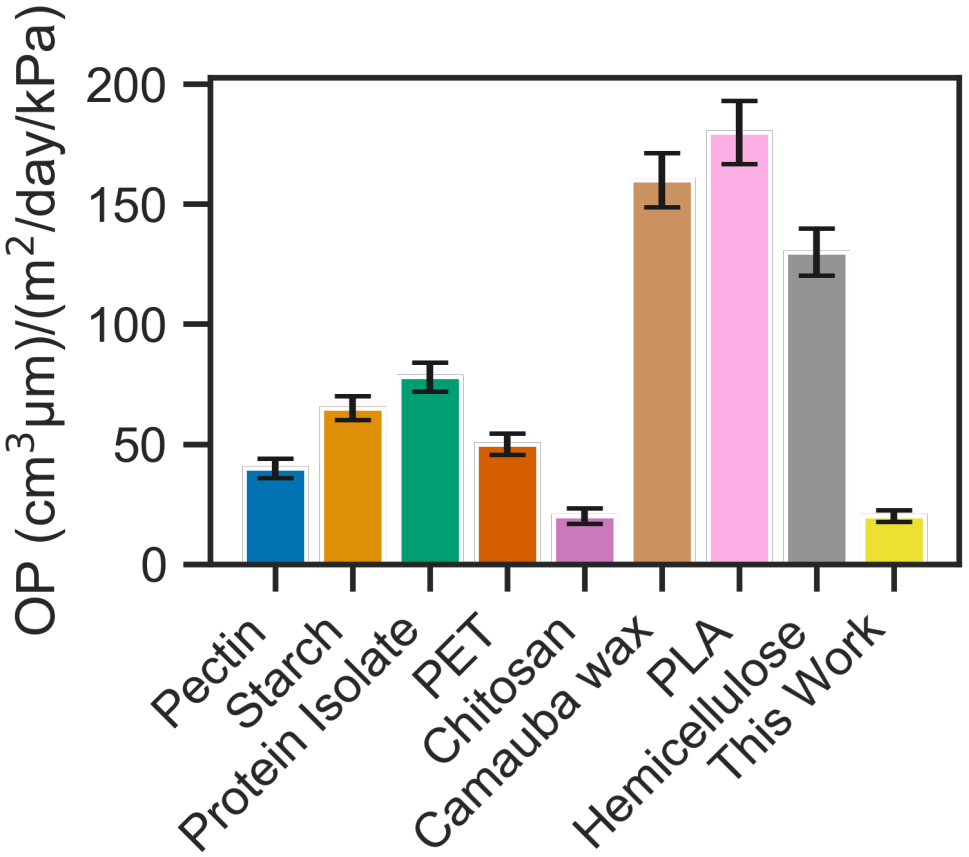
TEM



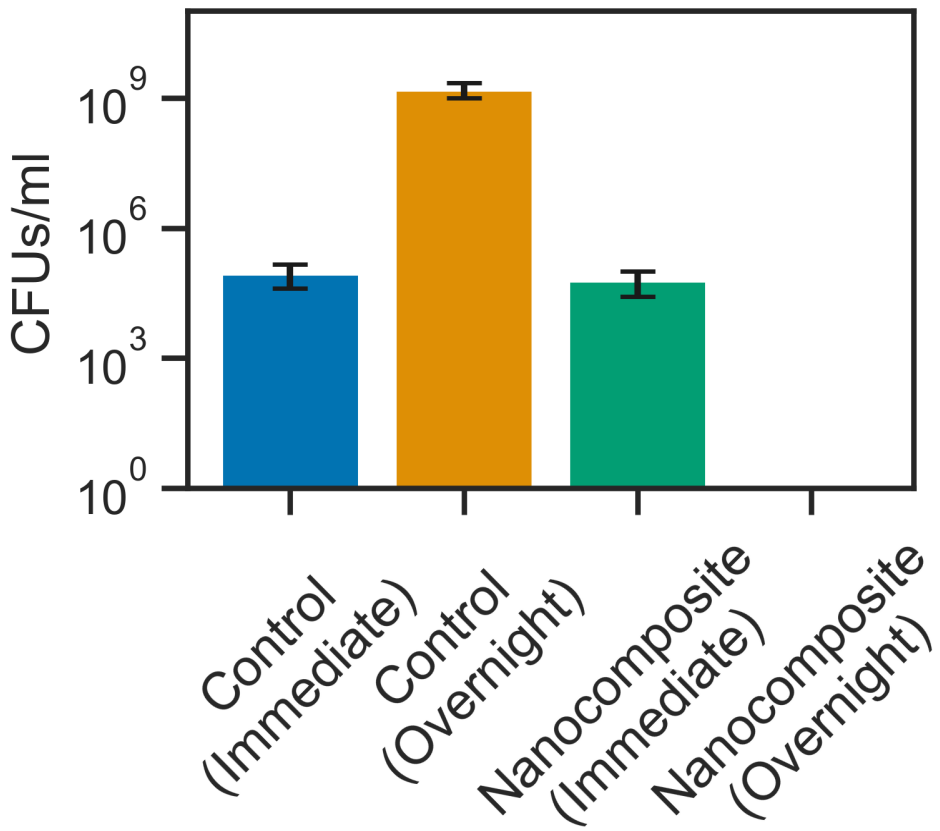
- The film is extremely flexible as it can be repeatably bent and folded without breaking
- The Surface roughness is around 12 nm, so it is very smooth and show nice gloss compared to wax

Barrier properties of our coating film



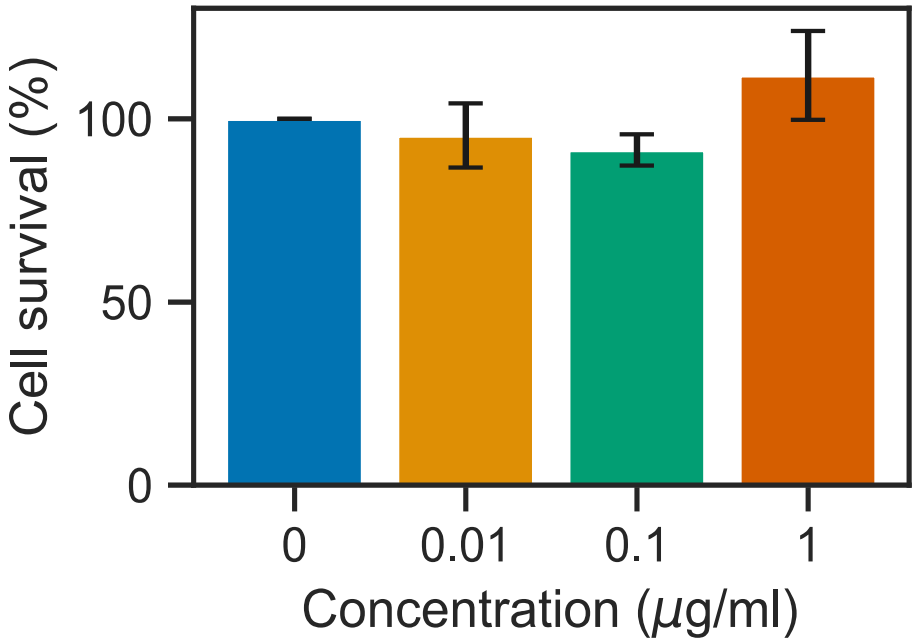


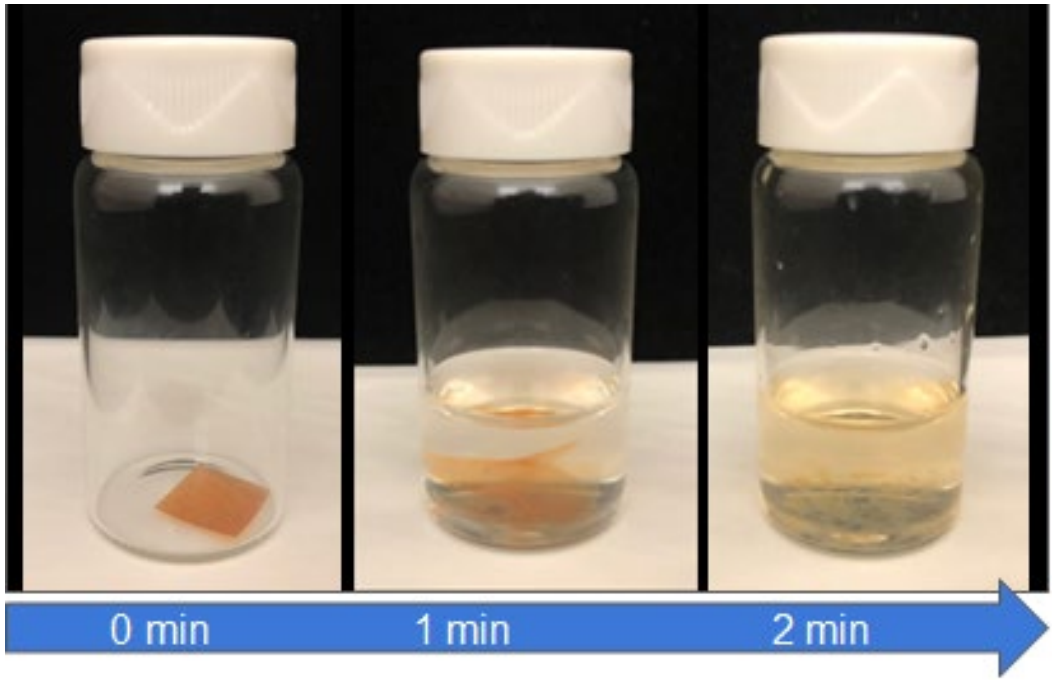
Antimicrobial properties of coating film



- Escherichia coli strain
- Overnight incubation on the film resulted in zero bacteria titers
- This suggests that the film is effective in eliminating bacteria growth on the surface especially when compared to the parafilm control, which showed over 10^4 times higher concentration of colony forming bacteria.

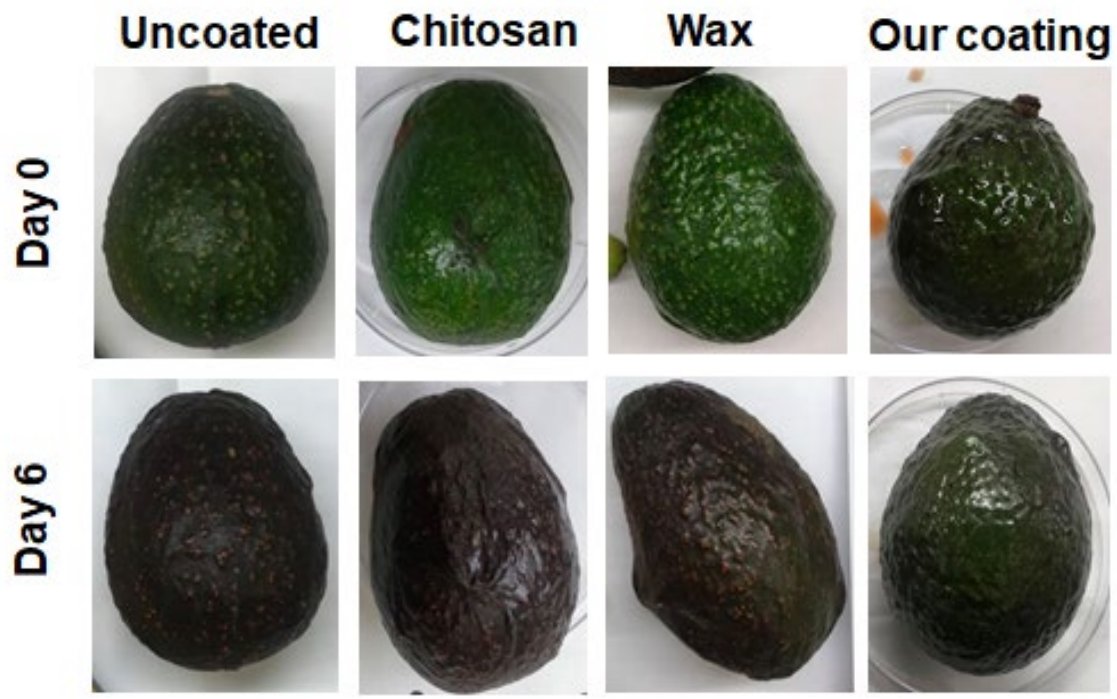
Edibility and Wash-ability of our coating

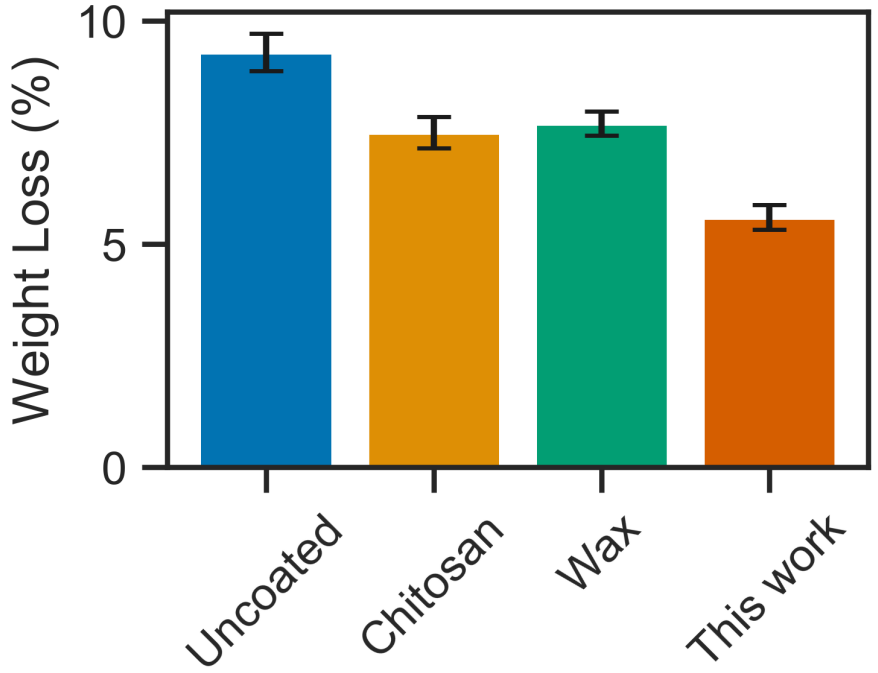




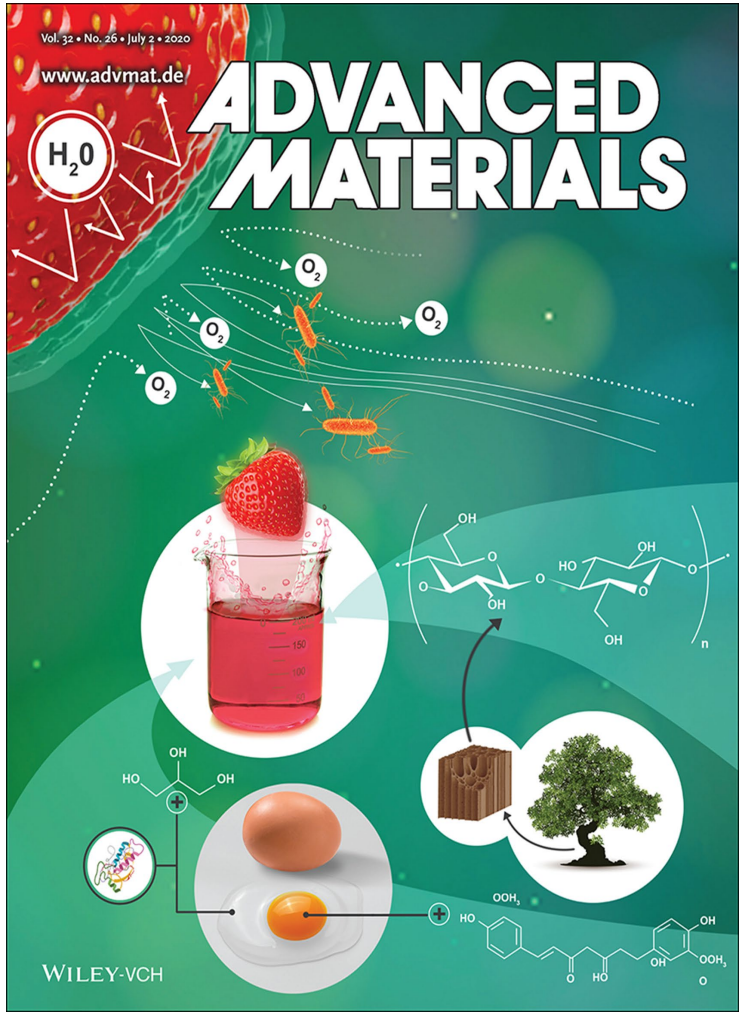
- Toxicity of the coating using in vitro studies with a human pancreatic cancer cell line (Panc02) to evaluate the edibility
- After 24 h incubation with 0.1 to 1 μg mL−1 coating, there is no significant change in the Panc02 cell

Comparison with commercial coatings





Coating addressed
the factors that influence the shelf life of fruits



- Decrease Dehydration or water loss
- Decrease respiration
- Increase microbial resistance

Along with those-

- It is edible
- It is washable

EPIFRESH

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- Meredith Carson, Georgia Tech University
- Nikhil Koratkar, RPI
- Nick Kotov, University of Michigan
- Matthew Bennett, Rice University

THANK YOU!

Think about Green