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Cellulose-Based Barrier Coatings for Fruit: Using Hardwood Pulp to Reduce Food Waste

Food waste is a globally significant issue; up to 50 percent of fruit is lost from the time it is harvested until it is consumed. A new innovation from the Forest Service Forest Products Laboratory, Washington State University, and the University of Florida could address this issue while providing a new outlet and use for wood pulp. Barrier coatings for fruit made from naturally-derived, biodegradable compounds could be a safe and effective way to preserve fruit. These coatings are applied to the exterior of fruit peels with the intention of keeping the fruit fresher for longer.

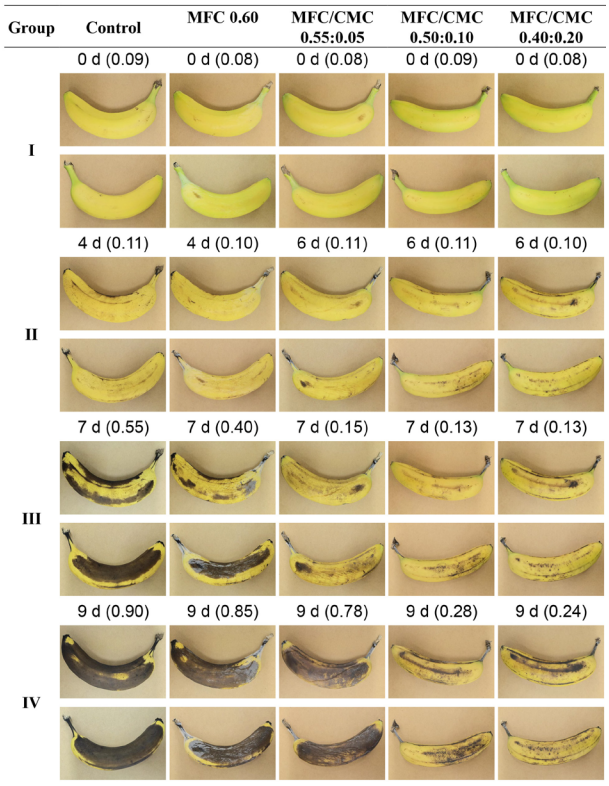
In their research, Forest Products Laboratory scientists and collaborators tested different water-based mixtures of two cellulose-derived materials—microfibrillated cellulose and sodium carboxylmethyl cellulose (a food additive)—to determine which combination produced the most effective barrier coating. A study published in the journal Food Chemistry describes the results of this research using bananas as an example.

Cellulose Derivatives

The barrier coating was made from a mixture of carboxylmethyl cellulose (CMC) and microfibrillated cellulose (MFC). Carboxylmethyl cellulose is a food additive that, when made into a film, can reduce the passage of water vapor, oxygen, and carbon dioxide across the film. While CMC alone can delay fruit ripening and decay, it tends to be brittle and does not form a good film on fruit peels. Another cellulose derivative, microfibrillated cellulose (MFC), can also be made into a film and reduce the permeation of water and gases across the film barrier. This derivative can be made from commercial wood pulp, or even directly from low-cost wood biomass. By mixing CMC and MFC in water, scientists were able to make low-cost barrier coatings that adhered better than mixtures using CMC and water alone.

PUBLIC BENEFITS

Biodegradable, cellulose-based barrier coatings for fruit, which are derived from wood pulp, could help keep fruit fresher for longer. This innovation could reduce food waste and support the economy by increasing profit for the agriculture and grocery sectors while encouraging sustainable forest management by supporting markets for small-diameter timber.



Progression of bananas at 0 days (I), 4 days (II), 7 days (III), and 9 days (IV) after receiving a barrier coating with varying ratios of MFC and CMC. Bananas in the far left column represent a control with no coating. The numbers in the parentheses are the browning fractions based on image color pixels. Forest Service image by J.Y. Zhu as originally published in Geng et al. (2025).

The Ideal Ratio

All five of the barrier coating mixtures of MFC and CMC investigated in this study consisted of 0.6 percent cellulose derived materials mixed with water but differed in the relative proportions of MFC and CMC. The coatings tested were as follows:

- 0.6 percent MFC, 0 percent CMC (0.6:0)
- 0.55 percent MFC, 0.05 percent CMC (0.55:0.05)
- 0.50 percent MFC, 0.10 percent CMC (0.50:0.10)
- 0.45 percent MFC, 0.15 percent CMC (0.45:0.15)
- 0.40 percent MFC, 0.20 percent CMC (0.40:0.20)

Each coating was examined using both light and scanning electron microscopy to better understand its properties. Each coating was also tested for its wettability, transparency, and the rate of browning and weight loss of bananas coated with the mixture.

In general, coatings with higher proportions of CMC tended to be less porous and delayed browning and softening of bananas. However, the barrier coating produced using the highest proportion of CMC was too dense and decreased aerobic respiration, which resulted in anaerobic digestion within the banana that eventually caused spoilage.

Overall, all solutions containing CMC effectively delayed banana browning and weight loss. In particular, weight loss of bananas coated with the solution containing 0.55 percent MFC and 0.05 percent CMC was 30 percent lower than that of a control and banana browning was delayed by two days. Notably, the ripening process itself was not significantly delayed. These results suggest that even a small amount of CMC mixed into the solution can help delay banana browning.

Proof of Concept

These results provide proof of concept for a low-cost fruit barrier coating for bananas made from primarily MFC with a bit of CMC mixed in the water-based solution. Bananas are a climacteric fruit, which means that they continue to ripen after they are picked. The Forest Products Laboratory continues to test this coating on other fruits including mango and non-climacteric fruit such as star apple. Because non-climacteric fruit does not continue to ripen after it is picked, this fruit barrier coating has the potential to preserve the shelf life of this fruit for even longer (i.e., 1 to 2 weeks). Beyond testing more fruit, the next steps to take this invention from idea to commercialization include large scale trials and technoeconomic and life cycle analyses (i.e., systematic analyses to evaluate the economic viability and environmental impacts of the product). If successful, this invention could support multiple industries while reducing food waste.

KEY FINDINGS

- Researchers developed a low-cost, cellulose-based barrier coating from wood pulp that can increase the shelf life of fruit.
- Specifically, a microfibrillated cellulose (MFC) solution with a small amount of carboxylmethyl cellulose (CMC) delayed banana browning by 2 days and decreased weight loss by 30 percent.
- This barrier coating did not noticeably delay the banana ripening process.
- Cellulose-based fruit coatings may also be effective at increasing shelf life of non-climacteric fruits that do not continue to ripen after being picked.

PROJECT LEADS

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FURTHER READING

Geng, J.; Stark, N.; Kitin, P.; Zhang, X.; Plaza, N. Z.; Zhu, J.Y. 2025. Incorporating carboxymethyl cellulose into microfibrillated cellulose for barrier coating to delay banana browning and extend shelf life. Food Chemistry. 486: 144664. 11 p. https://doi.org/10.1016/j.foodchem.2025.144664.

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For questions on Rooted in Research, please contact Jenna Zukswert. Technical editing by Susan Barro. Design and layout by Jeremy Siegrist.