

United States Department of Agriculture
Project Initiation

Project Data for Accession Number 1034512

Project Title

Multifunctional and Biodegradable Nanocomposite Films Enabled by Melanin-based Hybrid Nanoparticle Microcapsules for Sustainable Food Packaging

Project Details

Sponsoring Institution National Institute of Food and Agriculture	Project Status ACTIVE
Funding Source NIFA Non Formula	Grant Year 2026
Grant No. 2026-67017-46014	Cumulative Award Amt. \$611,000.00
Proposal No. 2024-12016	Multistate No. (N/A)
Project Start Date Mar 01, 2026	Project End Date Feb 28, 2029
Program Code [A1364] Innovations in Food Manufacturing Technologies	

Project Director

Cao, C.

Recipient Organization

CASE WESTERN RESERVE UNIVERSITY
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Performing Department

(N/A)

Non Technical Summary

Food spoilage and contamination contribute significantly to food waste and public health risks. Current petroleum-based packaging materials provide limited protection and create environmental challenges due to poor recyclability and persistence in landfills. This project will develop sustainable, bio-based food packaging films that improve food safety, extend shelf life, and reduce environmental impact. The research team will create multifunctional packaging materials by embedding naturally derived melanin-based hybrid nanoparticles inside biodegradable polymer films and recyclable paper coatings. These materials will provide antimicrobial protection, ultraviolet light shielding, antioxidant activity, and improved mechanical strength and barrier performance. The project will combine material synthesis, scalable manufacturing, and biological safety testing to ensure that the packaging systems are effective and safe for food contact. Laboratory testing will evaluate antimicrobial performance against major foodborne pathogens, barrier

United States Department of Agriculture Project Initiation

properties that limit oxygen and moisture transmission, and controlled release of active components. Safety studies will assess material migration and biocompatibility using regulatory-aligned methods. Compostability and biodegradation will also be evaluated to ensure environmental sustainability. The expected outcomes include new high-performance packaging technologies that reduce food waste, improve food safety, and support U.S. agriculture and food manufacturing competitiveness. This work directly supports USDA priorities by enabling innovative manufacturing technologies, improving food system sustainability, and reducing losses across the supply chain.

Animal Health Component

Animal Health Component: 0%

Research Effort Categories

Basic	40%
Applied	40%
Developmental	20%

Classification

Knowledge Area (KA)	Subject of Investigation (SOI)	Field of Science (FOS)	Percent
503	5010	2020	100%

Knowledge Area

[503] Quality Maintenance in Storing and Marketing Food Products

Subject Of Investigation

[5010] Food (not readily associated with specific plant and animal products)

Field Of Science

[2020] Engineering

Keywords

Food packaging, Hybrid nanoparticles, Multifunctional nanocomposites, Sustainable packaging

Goals / Objectives

The major goal of this project is to develop scalable, bio-based multifunctional food packaging materials that improve food safety, extend shelf life, and reduce environmental impact by integrating melanin-based hybrid nanoparticle microcapsules into biodegradable polymer films and recyclable paper-based packaging systems. Objective 1: Develop melanin-based hybrid nanoparticles and encapsulate them in biocompatible microcapsules for controlled dispersion and release. Objective 2: Fabricate and optimize biodegradable PLA-PHBV nanocomposite films and recyclable paper-coated packaging formats with enhanced mechanical, optical, and barrier properties. Objective 3: Evaluate antimicrobial performance, migration safety, cytocompatibility, and regulatory readiness of the developed packaging materials for food-contact applications.

United States Department of Agriculture Project Initiation

Project Methods

This project integrates nanoparticle synthesis, microencapsulation, polymer processing, and biological testing. Melanin-based hybrid nanoparticles will be produced and encapsulated using chitosan-gelatin systems. These microcapsules will be incorporated into biodegradable PLA-PHBV films using solvent casting and extrusion methods. Material performance will be evaluated using mechanical testing, permeability measurements, thermal analysis, and optical characterization. Safety and functionality will be validated through migration studies, cytotoxicity assays, antioxidant testing, and pathogen challenge experiments. Compostability and biodegradation will be assessed using standardized soil burial and respirometric methods.