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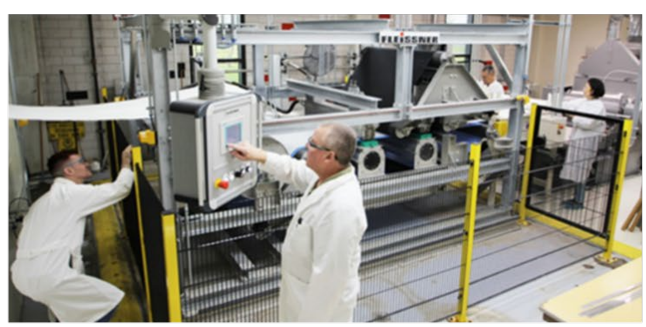
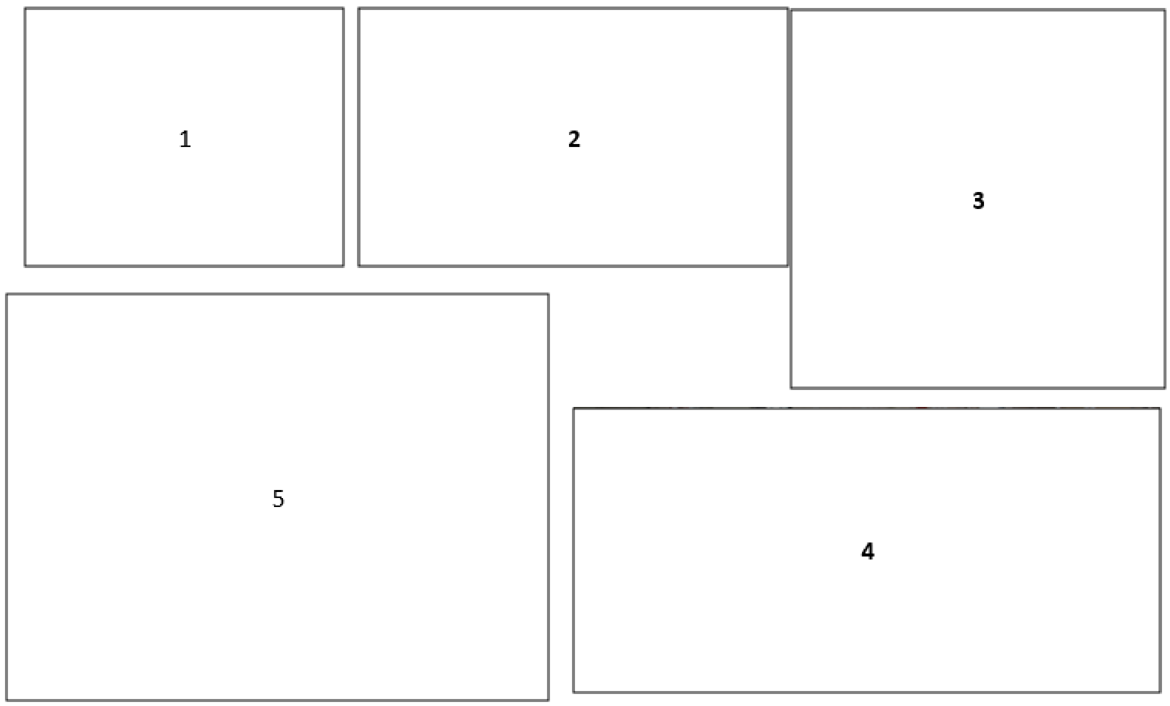
National Program 306 Product Quality and New Uses

Accomplishment Report 2018-2022





Captions of front page photos, clockwise from upper left.

1. Cristina Bilbao-Sáinz from the Healthy Processed Foods Research Unit (Albany, CA) produced a vegetarian colorless, tasteless, and edible powder with high level of vitamin D from mushroom-stalk waste.
2. Scientists in Peoria from the Bio-oils Research Unit (Peoria, IL) identified coconut oil fatty acids that repel insects better than DEET and offer long-lasting effectiveness against four different types of insects (mosquitoes, ticks, biting flies and bed bugs).
3. The Bioproducts Research Unit (Albany, CA) patented a rapid and cost-effective process to create renewable, plant-based containers that provide a sustainable/renewable alternative to plastic containers.
4. ARS researchers use the hydroentanglement process to fabricate nonwovens at the Cotton Chemistry and Utilization Research Unit in New Orleans; then they will synthesize silver nanoparticles directly within cotton fibers for their antimicrobial properties. From left to right: Matthew Hillyer, Doug Hinchliffe, Pablo Salame, and Sunghyun Nam
5. In collaboration with Biosynthetic Technologies, ARS scientists from the Bio-oils Research Unit (Peoria, IL) patented a new class of ester molecules that make biobased synthetic motor oils and lubricants a reality. Cylinder head comparison from two engines used in 150,000 mile real-world engine oil field trials show the conventional motor oil formulation (left) had typical levels of varnish, while the estolide formulation (right) showed a high degree of overall cleanliness and minimal varnish.

National Program 306
PRODUCT QUALITY AND NEW USES
ACCOMPLISHMENT REPORT 2018-2022

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National Program 306
Product Quality and New Uses

Accomplishment Report 2018-2022

The mission of the USDA Agricultural Research Service (ARS) is to conduct research to develop and transfer solutions to agricultural problems of high national priority and provide information access and dissemination to ensure high-quality, safe food, and other agricultural products; assess the nutritional needs of Americans; sustain a competitive agricultural economy; enhance the natural resource base and the environment; provide economic opportunities for rural citizens, communities, and society as a whole; and provide the infrastructure necessary to create and maintain a diversified workplace.

All ARS research projects are assigned to at least one of 15 ARS National Programs managed by National Program Leaders and other ARS senior staff. This oversight ensures all work conducted by ARS scientists is relevant, significant, and has high scientific merit. The research under the ARS National Program for Product Quality and New Uses (NP 306) focuses on the needs and issues of agricultural producers and processers who produce food, fibers, bioenergy, and other biobased products from harvested agricultural products. Goals for this National Program include enhancing product quality, improving product processing, developing new value-added products, and reducing the environmental impacts of postharvest agricultural production. Meeting these goals supports agricultural producers and others in rural communities by increasing market demand for their goods and increasing the value of their production.

This Accomplishment Report for NP 306 highlights the accomplishments of research projects during the past 5 years—accomplishments that demonstrate the vital role ARS science holds in addressing challenges to U.S. agricultural production and developing tools and techniques that support agricultural producers and industry stakeholders.

National Program 306
Action Plan 2020-2024
Components and Problem Statements

COMPONENT 1 – FOOD

PROBLEM STATEMENT 1.A:
*Define, measure, and preserve/enhance/reduce attributes that impact quality and marketability***.**

PROBLEM STATEMENT 1.B:
New bioactive ingredients and health-promoting foods.

PROBLEM STATEMENT 1.C:
New and improved food processing and packaging technologies.

COMPONENT 2 – NONFOOD

PROBLEM STATEMENT 2.A:
Maintain/enhance fiber and hide quality.

PROBLEM STATEMENT 2.B:
Enable technologies to produce new and expand marketable nonfood, nonfuel biobased products derived from agricultural feedstocks.

COMPONENT 3 – BIOREFINING

PROBLEM STATEMENT 3.A:
Viable technologies for producing advanced biofuels (including renewable diesel), or other marketable biobased products.

PROBLEM STATEMENT 3.B:
Technologies that reduce risks and increase profitability in existing industrial biorefineries.

PROBLEM STATEMENT 3.C:
Accurately estimate the economic value of biochemical, thermolysis conversion technologies

National Program 306
Product Quality and New Uses

Accomplishment Report 2018-2022

BACKGROUND AND GENERAL INFORMATION

Thanks to decades of research, U.S. agriculture production is high-yielding, tech-driven, relatively low-cost, and becoming more economical. But according to "Food Prices and Spending", a current analysis conducted by the USDA Economic Research Service, the costs for processing and packaging agricultural commodities into marketable goods eaten or worn are nearly triple their production costs and continue to rise. Because of these greater costs associated with processing and packaging, the economic viability of agricultural producers and processors depends on providing consumers with high quality products at competitive prices, producing those goods efficiently and in an environmentally sustainable manner, and maintaining the quality and utilization of agricultural commodities after they are harvested (postharvest). This is accomplished by the direct transport and sale of harvested goods to consumer markets, or by enhancing products to be marketed with packaging, preservation, or other processing. Consumers usually use at least one sensory response (sight, smell, taste, and texture) to assess food quality, while processors or manufacturers may use more quantitative measures such as sugar or moisture content, product durability, or foreign matter content to assess the quality of food or nonfood products.

Preserving or improving the postharvest quality of agricultural food and nonfood products such as fiber and leather is paramount and requires techniques to define and measure quality characteristics and understand how processing affects these characteristics. Many agricultural products require some level of processing before they are marketable, and many products benefit from postharvest processing to enhance value. To remain economically viable, processors strive to produce high-quality, innovative products that meet consumer demand, improve production efficiency, and improve their environmental footprint by reducing the use of water, chemicals, and energy.

The U.S. biorefining industry has the potential to supply a significant portion of the national demand for fuels, chemicals, and other high-value U.S. consumable products, such as proteins, sugar alcohols, biopolymers, cosmetics, pharmaceuticals, health foods, and livestock feeds. The production of these bioproducts is not meant to completely replace their petroleum-based counterparts, but rather to supplement their use with a renewable resource base—plants and animal byproducts—to meet demand and to take advantage of low-value crops or agricultural byproducts that could increase farmers' profits. The goal of ARS Component 3, Biorefining, is to conduct research that enables new, commercially viable technologies for the conversion of agricultural materials into sustainable alternative fuels for both aviation and ground vehicles and especially into high-value-added products that enhance rural economies.

ARS established National Program 306 (NP 306), Product Quality and New Uses, to conduct research on postharvest food, nonfood, and biorefining lifecycles from the field to the consumer. The goal of NP 306 is to enhance the economic viability and competitiveness of U.S. agriculture by maintaining the quality of harvested agricultural commodities or otherwise enhancing their marketability, meeting consumer needs, developing environmentally friendly and efficient processing concepts, and expanding domestic and global market opportunities through the development of value-added food, nonfood and biorefining technologies, byproducts, and green fuels.

Consumers care about food quality, safety, and prices. Losses during harvesting, processing, and storage reduce the already-narrow profit margins of agricultural producers and processors. In addition, agricultural industries are increasingly affected by energy and production costs, regulations, and the loss of market share to synthetic products and foreign competition. By developing knowledge, techniques, and technologies for agricultural producers and processors, NP 306 quality and new uses research benefits agricultural producers and rural communities by increasing the value of agricultural products, reducing postharvest losses, reducing industry risk, and enhancing processing efficiencies. Research conducted by ARS scientists achieved significant accomplishments toward NP 306 goal in four main areas:

1. New knowledge about the attributes contributing to product quality, and new methods and instrumentation for the rapid and accurate assessment of raw, in-process, or completed material quality. This research allows producers and processors to reduce costs, improve consistency, and assess and promote new cultivars.

2. Identifying and understanding biologically active food compounds and developing functional foods and food ingredients that support and enhance human health. This work improves existing agricultural products, creates new market opportunities, and advances the development of new products that increase producer revenue.

3. Increasing profitability and reducing risk for processors with new methods, processes, and technologies that enhance product quality and safety; improve process efficiencies; and reduce waste, energy use, and adverse environmental impacts. This research provides tools that help producers and processors increase productivity, comply with regulatory standards, and remain competitive in global markets.

4. By developing commercially viable technologies to produce biobased industrial products, ARS biorefining research increases the demand for agricultural products and, therefore, benefits agricultural producers and rural communities by 1) maximizing the long-term economic impact of ARS biorefining research; 2) emphasizing ARS' unique capabilities and avoiding unnecessary overlap with research at other institutions; and 3) maximizing returns to agricultural stakeholders from ARS investment of public funds.

PLANNING AND COORDINATION FOR THE NP 306 5-YEAR CYCLE

In 2019, the NP 306 National Program Leader and researchers engaged with stakeholders from agriculture, industry, universities, and other governmental agencies to identify needs for NP 306 research during the next 5-year cycle. Many of the research needs previously identified by stakeholders were still relevant, while new research needs were identified in response to changing societal, economic, and environmental issues and concerns. The National Program Leader obtained input from other ARS scientists and customers/stakeholders and identified priority needs that could be realistically addressed with ARS resources and base funding. These were summarized into problem statements and categorized in three research components under the NP 306 Action Plan that began its current 5-year research cycle in 2020.

ARS research leaders and scientists used the Action Plan and direction from the National Program Leader to develop objectives for their research projects. Project lead scientists then developed highly detailed 5-year project plans—similar to plans presented in peer-reviewed papers—based on the assigned objectives. These plans were reviewed for relevancy and scientific quality by an external peer panel coordinated by the ARS Office of Scientific Quality Review. Panel suggestions for greater clarity and focus on research approaches and methods of some project plans were addressed by the lead scientists and subsequently approved by the panel.

To expand on the increased demand for agricultural products that benefit both agricultural producers and rural communities, the new 5-year research cycle will start with customer/stakeholder input in late 2023. After the workshop, a new Action Plan will be drafted and this will be followed by the establishment of new research objectives, which will be completed in early 2024.

STRUCTURE OF NATIONAL PROGRAM 306

NP 306 categorizes agricultural product quality and new uses research into three basic Components: Food, Nonfood, and Biorefining.

COMPONENT 1: Food

A range of factors can be used to assess product quality. For food, these factors include aspects relating to appearance, texture, smell, and taste, but they can also incorporate physical and chemical characteristics such as moisture content or acidity. It is essential to identify and define characteristics that contribute to product quality to establish meaningful quality standards or grades. In Component 1, ARS researchers investigate the relationships between chemical, physical, and sensory attributes that affect how consumers perceive and consume food. Researchers develop new detection devices and methods to objectively identify, define, and measure important attributes and defects in grains, vegetables, fruits, nuts, poultry, and fish. In addition, they study food qualities that enhance human health, identify biologically active food compounds, and determine the role of these compounds in human physiology. This information can be used to guide breeding programs and production practices and to develop products with enhanced bioactive qualities. Food processing research advances technologies for preserving, preparing, and using food products and supports increased production, reduces production costs, and improves environmentally sustainable management by reducing waste. All these results are key to maintaining an adequate, healthy, and affordable food supply, and are essential for ensuring the economic viability of U.S. food providers.

COMPONENT 2: Nonfood

U.S. fiber, hide, and other harvested nonfood industries are challenged by increasing energy and labor costs, more stringent environmental regulations, and the demand for higher product quality, and face increasing competition in the global marketplace from synthetic products. To remain viable, the U.S. cotton, hides, and biobased products industries must develop new processes and products and improve the management and use of wastes and secondary products. ARS scientists have enhanced product quality preservation by developing improved harvesting, processing, and storage technologies and improved quality measurement and grading systems. Researchers have also learned more about basic material structures and properties and used this information to facilitate product enhancement. They have also developed more environmentally friendly technologies and new applications and products for hides, agricultural fibers, and associated byproducts.

COMPONENT 3: Biorefining

Biochemical conversion (biorefining) of agricultural materials typically involves the following steps: feedstock preparation and separation into useable components; production of fermentable sugars; conversion of those sugars with either natural or chemical catalysts; and recovery and purification of the fuels, chemicals, and/or other high-value coproducts. Research in Component 3 takes a closer look at those processes to determine what efficiencies can be induced using new catalysts and/or removing inhibiting substances from the process. Cost-effective processing techniques are paramount for acceptance by the biofuel industry as it attempts to develop new fuels, oils, and products from plant-based feedstocks to supplement the use of fossil fuels.

Major advantages of biochemical conversion, which involves the use of enzymes and microbial catalysts, are its relative simplicity and environmental friendliness. Biochemical conversions fall into one of three categories, depending on the feedstock and method of conversion. 'First generation' biochemical conversion that use sugar-based feedstocks. 'Second generation' biochemical conversion utilizes cellulosic biomass from grasses and other nonfood plants in a three-step process: (a) Pretreatment of the plant fiber to separate the cellulose and possibly the hemicellulose from the lignin, making both plant sugars in both components available separately for conversion through hydrolysis; (b) Use of enzymes to convert the cellulose and/or hemicelluloses in the plant fiber into simple sugars; and (c) Conversion of the sugars to desired products. Technologies that can convert xylose—a five-carbon sugar, one of the mix of sugars found in hemicellulose and the second most abundant sugar in feedstocks, but currently a waste product—would greatly improve economic efficiencies by turning more of the feedstock into biofuels and coproducts. Currently, biorefining uses glucose, a six-carbon sugar which makes up 100 percent of cellulose. 'Third generation' biochemical conversion utilizes algal feedstocks. This type of conversion is not a major part of the research portfolio in USDA's biochemical conversion mission.

ARS scientists conduct NP 306 research at 22 locations. This research includes 60 projects addressing agricultural postharvest needs (33 in Food, 10 in Nonfood, and 17 in Biorefining). Locations include Albany, California; Athens, Georgia; Beltsville, Maryland; Dawson, Georgia; East Grand Forks, Minnesota; East Lansing, Michigan; Fargo, North Dakota; Fort Pierce, Florida; Lubbock, Texas; Madison, Wisconsin; Manhattan, Kansas; Las Cruces, New Mexico; New Orleans, Louisiana; Oxford, Mississippi; Parlier, California; Peoria, Illinois; Pullman, Washington; Raleigh, North Carolina; Stoneville, Mississippi; Wenatchee, Washington; Wooster, Ohio; and Wyndmoor, Pennsylvania. Research in each project is assigned to one or more of the components under the current NP 306 Action Plan specifically targeting research in a priority area of agricultural product quality and utilization.

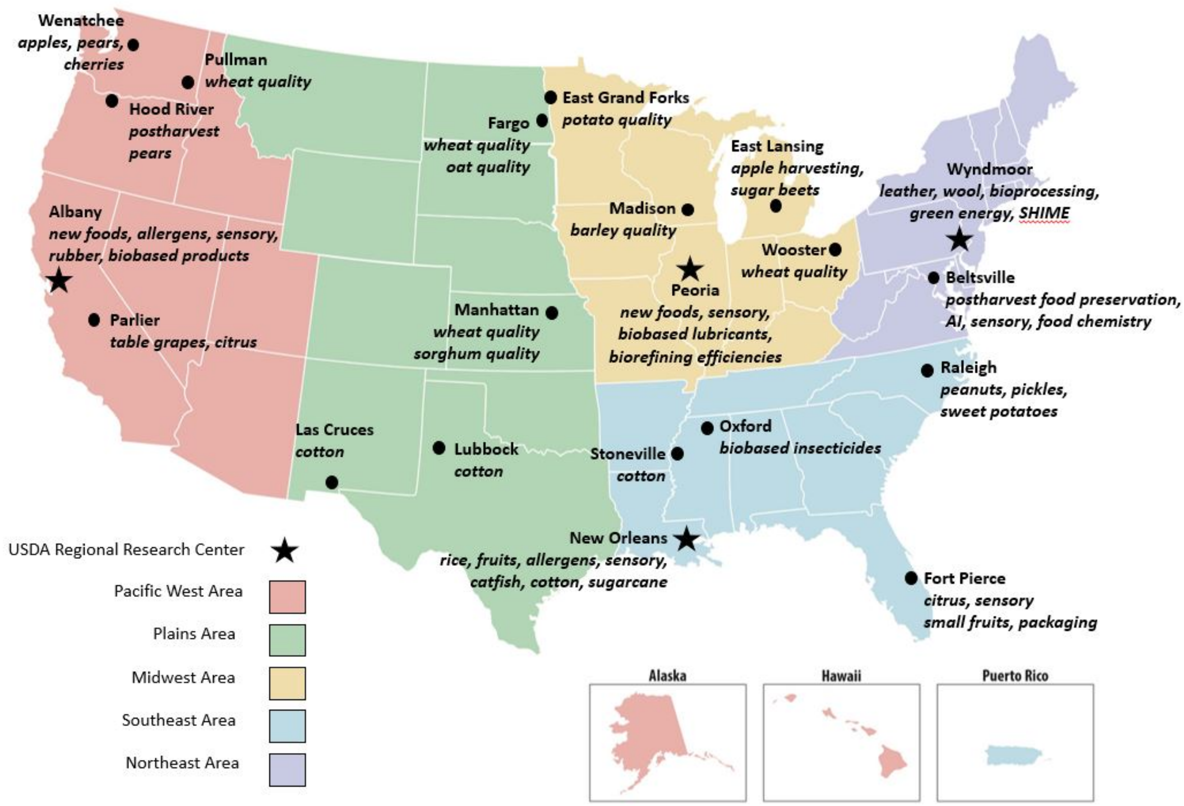


Figure 1. NP 306 research locations.

RELATIONSHIP OF NP 306 TO OTHER NATIONAL PROGRAMS

NP 306 research helps scientists in other National Programs by quantifying product bionutrients and marketable quality attributes and by developing measurements and processes relevant to associated research. Some of that assistance is illustrated in Figure 2:

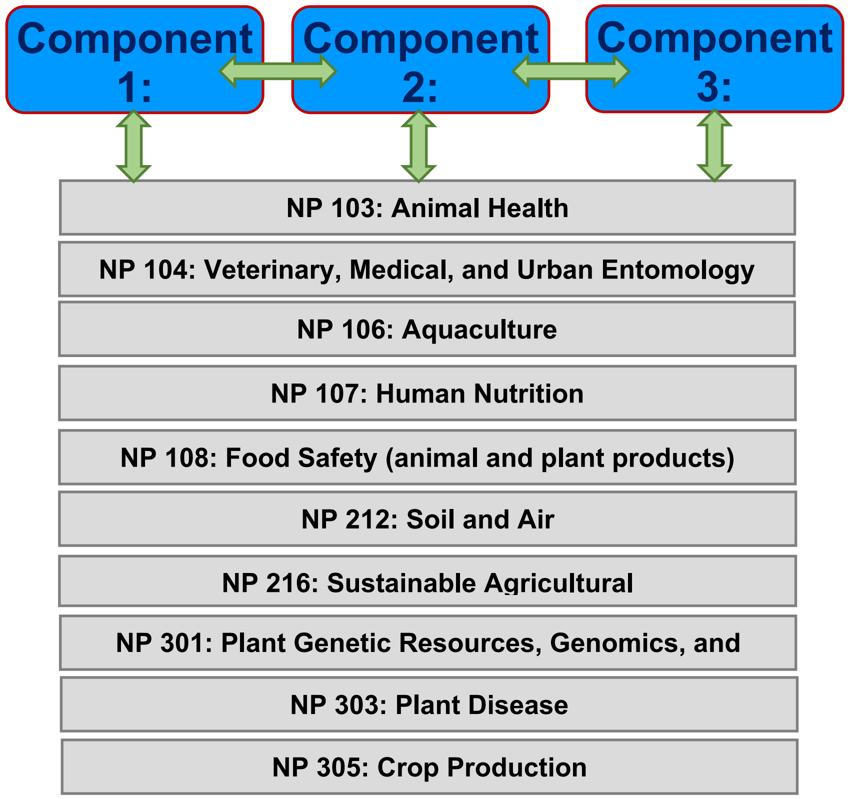


FIGURE 2: Association among other ARS National Programs contributing to and receiving assistance from the three components of NP 306.

NP 103 (Animal Health): NP 306 scientists who develop biobased products collaborate with NP 103 scientist on developing products to promote animal health and combat animal diseases, parasites, and pests.

NP 104 (Veterinary, Medical, and Urban Entomology)**:** NP 306 scientists who develop biobased products collaborate with NP 104 scientist on developing products to promote animal health by reducing vectors and diseases that are transmitted to livestock, humans, and other animals.

NP 106 (Aquaculture)**:** NP 106 scientists conduct research to support a domestic aquaculture industry by improving genetic stocks and scientific information on biotechnologies and management practices; they collaborate with NP 306 scientists to ensure the sensory qualities (consumer acceptance), safety, and nutrition of aquaculture food products.

NP 107 (Human Nutrition): Before recommending or using new plant-based foods and varieties, processed foods, or new food-handling procedures, NP 107 researchers rely on NP 306 scientists to establish changes in sensory qualities (consumer acceptance) and nutritional composition (bioactive compounds), and to establish quality standards.

NP 108 (Food Safety): NP 108 scientists develop treatments (chemicals, temperatures, and modified gas atmospheres) to control enteric bacteria, and collaborate with NP 306 scientists on establishing treatment tolerances to avoid adversely affecting the nutritional/marketable quality of agricultural foods and bioproducts.

NP 212 (Soil and Air); NP 305 (Crop Production)**:** NP 212 and NP 305 scientists measure changes in climate, soils, and atmospheric gas emissions and develop conventional and organic production systems. They work closely with and rely on NP 306 scientists to establish "cause-and-effect" changes in food, fiber, and biorefining-product quality and the suitability of agricultural resources for bioproduct development.

NP 216 (Sustainable Agricultural Systems Research); NP 305 (Crop Production): NP 306 scientists collaborate with scientists from these National Programs in improving production systems for traditional and new food and bioprocessing crops that represent oilseed, starch, sugar, and cellulosic feedstocks. These enterprises result in new technologies that optimize food quality and nutrition, and biorefining feedstock production, quality, efficiency, and profitability.

In addition, NP 216 includes the ARS Regional Biomass Research Centers (USDA Regional Biomass Research Centers : USDA ARS*)*, which were established in 2010 to develop the best feedstocks and sustainable feedstock production systems for specific agro-eco regions where advanced biofuels will likely be produced. Each Regional Biomass Research Center fosters collaborative research within the complete bioenergy supply chain to accelerate the creation of commercial supply chains to produce advanced biofuels.

NP 301 (Plant Genetic Resources, Genomics and Genetic Improvement); NP 303 (Plant Diseases): and NP 305 (Crop Production): Scientists in these National Programs contribute to NP 306 by breeding improved germplasm and superior food, fiber, and biorefining-feedstock crop varieties; developing and applying new genetic and bioinformatic tools; and safeguarding and utilizing plant genetic resources and databases to enhance production and quality of foods, fiber, feedstocks, and their industrial products.

HOW THIS REPORT WAS CONSTRUCTED AND WHAT IT REFLECTS

This report assembles some of the many accomplishments of NP 306 from 2018 through 2023, a period that straddles the previous Action Plan for 2015-2019 and the current plan for 2020-2024. Reporting on a period that does not match either action plan is necessary because of the need to review past accomplishments before beginning the process of developing a new Action Plan for the next 5-year cycle.

This NP 306 Accomplishment Report is a distillation of some of the most significant research accomplishments achieved by scientists working in this National Program over the past 5 years. By necessity, it is a 5-year snapshot that encompasses ongoing research and the early benefits of that research. The content of this report is mostly derived from NP 306 annual project reports from the past 5 years. This report stresses the impacts of those accomplishments and, where relevant, cites key publications or Web links documenting those accomplishments.

In the same way that only selected accomplishments are reported, details of those accomplishments are selected and summarized to illustrate the overall variety of products and knowledge generated by this National Program. Individual researchers or projects are not identified by name in the narrative text; rather, their achievements are described in the context of contributions towards accomplishing the Program's stated commitments to U.S. agriculture.

This report was prepared for an external (to ARS) retrospective review of NP 306 to assess its overall performance in attaining the projected goals outlined in its current Action Plan. The purpose of the retrospective review is not to judge the specific performance of individual NP 306 research projects, but rather to gauge the larger impact of the Program. Consequently, the report does not attempt to catalogue all the individual accomplishments reported by the scientists assigned to NP 306 research projects.

The retrospective panel will be grading the accomplishments against the proposed actions outlined in the Problem Statements, which are more general than the Anticipated Products listed in the Action Plan. An individual accomplishment might be applicable to more than one problem statement and more than one set of anticipated products. Each accomplishment is matched with a publication or patent to provide additional detail and to demonstrate it has passed rigorous scientific peer review. Appendix 1 includes a list of the current projects with scientists in NP 306. Appendix 2 has a complete bibliography of peer-reviewed publications generated by the NP 306 scientists organized by project. Appendix 3 contains a list of all patents and licenses under each project.

COMPONENT 1: Food

For consumers, food is much more than an essential source of sustenance. People select food based on its taste, nutritional benefits, shelf life, price, convenience, and appearance—all attributes that contribute to food quality. Scientists conducting research to assess food quality or to determine or improve food quality standards or grades must identify, define, measure, and preserve food attributes contributing to appearance, flavor, and nutritional characteristics. These attributes can include color pigments, surface components, aroma, fundamental tastes (sweet, sour, bitter, astringent, and savory), textures, and bioactive compounds that affect human health. In addition, food processing and packaging can greatly influence food quality, safety, and nutrition, while new food processing techniques are needed to preserve and add value to foods, utilize wastes, and reduce costs.

The research under Component 1 is focused on developing technologies that improve food quality, extend product shelf life, and reduce food waste. ARS scientists are also developing innovative processing and packaging methods and techniques that will reduce producer costs. The research in this Component is grouped into three Problem Statements that were identified to address the research needs of food producers:

- 1.A. Define, Measure, and Preserve/Enhance/Reduce Attributes that Impact Quality and Marketability.
- 1.B. New Bioactive Ingredients and Health promoting Foods.
- 1.C. New and Improved Food Processing and Packaging Technologies.

Problem Statement 1.A: ***Define, measure, and preserve/enhance/reduce attributes that impact quality and marketability.***

Measuring attributes that contribute to food quality is essential for understanding their effects and developing tools that preserve and enhance desirable characteristics. To address this problem, ARS researchers developed methods to accurately assess food quality, and explored connections between food quality attributes and production, manufacturing, and handling processes that affect those attributes. Researchers also developed novel methods and technologies to maintain and improve the quality of food as it is transported to market. The following accomplishments are a sampling of the many results from ARS research conducted under this Problem Statement.

A treatment for peanut allergy. ARS researchers in New Orleans, Louisiana, collaborated in the characterization and development of the first peanut-based therapeutic oral immunotherapy (OIT) drug for the treatment of peanut allergies. This peanut OIT drug has demonstrated the ability to desensitize allergic individuals and is the first treatment available to peanut allergy sufferers in the world. Aimmune Therapeutics supported ARS project research on discovering biomarkers for diagnosing peanut allergy and on developing the very first food, peanut, into a pharmaceutical. This startup company was then purchased by Nestle Health Sciences LLC, which continued supporting ARS research to alleviate peanut allergy. Palforzia®, derived from peanut flour, is the only food that the FDA has approved for marketing and prescription; ingesting increasing amount of Palforzia® over a period of time desensitizes allergic individuals, preventing severe reactions. This treatment is the first and only FDA approved treatment for food allergy to date. ARS research helped launch Allergen Research Corporation, later named Aimmune Therapeutics, from a private company with five employees to a $20 million startup (IPO of $160 million) that was later sold to Nestle for $2.1 billion.

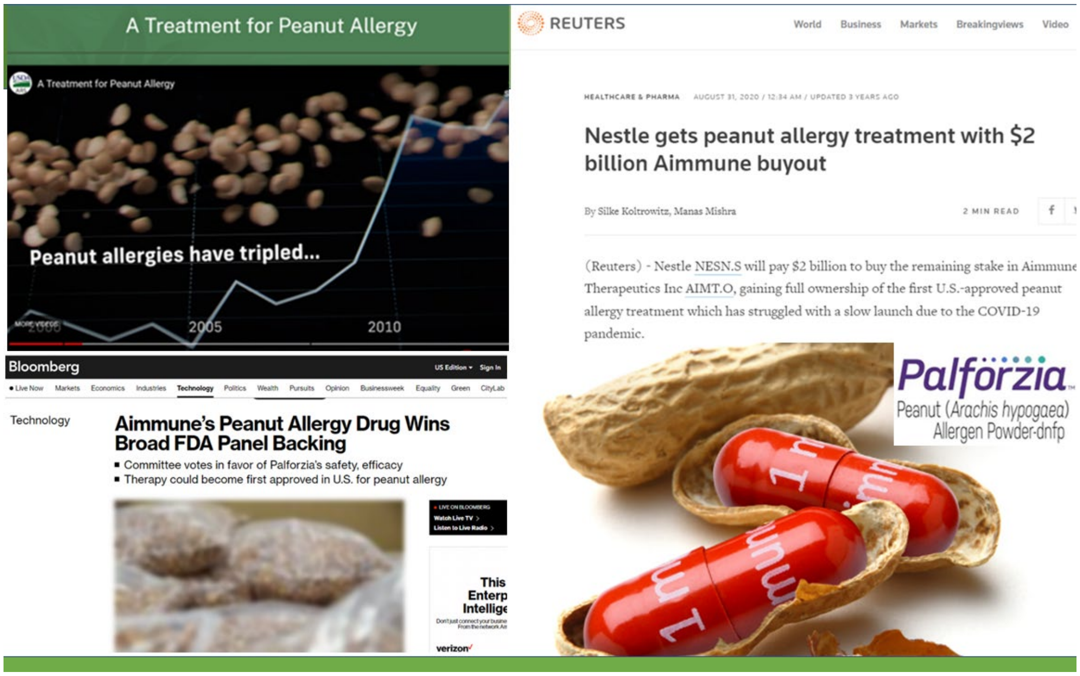


Figure 3. In the past 20 years, peanut allergies have tripled in the United States, leading ARS researchers to develop peanut allergy treatment with pharmaceutical companies.

Leonard, S., Ogawa, Y., Jedrzejewski, P., Maleki, S., Chapman, M., Tilles, S., Du Toit, Mustafa, S., G., Vickery, B. 2022. Manufacturing processes of peanut (Arachis hypogaea) allergen powder-dnfp. Front. Allergy, 11 October 2022, Sec. Allergen Immunotherapy, Volume 3 – 2022, https://doi.org/10.3389/falgy.2022.1004056

A new USDA standard protocol for determining wheat quality. "Falling number" (FN) is a procedure used by the USDA Agricultural Marketing Service (AMS) and industry to gauge the level of naturally occurring alpha-amylase—an enzyme responsible for breaking down grain-starch— in wheat. High levels of alpha-amylase activity critically lowers wheat starch concentration, which results in low FN readings and reduced grain quality, marketability, and price. This procedure is directly affected by barometric pressure and by the elevation of the testing laboratory. Lower barometric pressure at elevations above 1,000 feet can lead to misleading FN values; wheat tested at higher elevations and assigned high FNs can then be assigned critically low FNs when retested at sea level, resulting in a dramatic reduction in price. ARS scientists in Beltsville, Maryland working at simulated elevations between 0 and 5,000 feet developed a correction-equation model that allows all FN values, regardless of the barometric pressure, to be reported on a sea-level basis. Initially requested by USDA's Federal Grain Inspection Service (FGIS), this correction-equation was turned over to AMS for incorporation into a directive that guides federal, state, and private laboratories on the FN procedure. This issue is important because overseas customers of U.S. wheat often have strict wheat FN requirements, thus making the procedure’s accuracy a monetary concern to U.S. exporters, especially in the Pacific Northwest. Weather-related FN events, caused by rain after grain maturity with cool temperatures and/or large temperature swings during grain filling, cost Washington farmers alone more than $140 million in lost revenue.

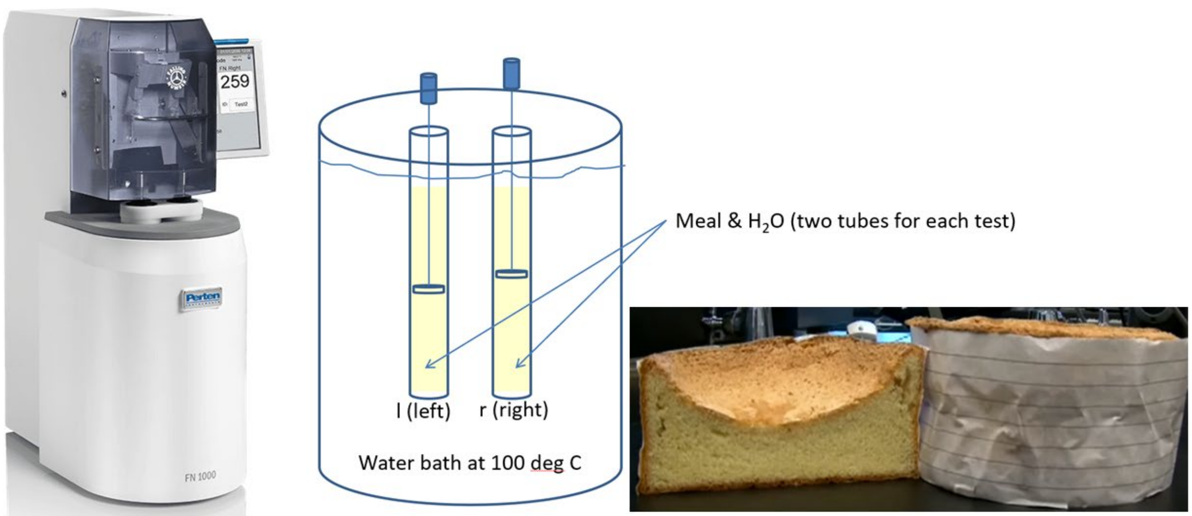


Figure 4. The falling number instrument provides an indicator of how flour bakes into representative cakes (degraded sticky cake vs. robust and full cake) and indicates if the grain has started to sprout. The FN is an indirect measurement of α-amylase activity by measuring viscosity of flour in a water mixture that is agitated and heated. In the revised FN test, the effects of elevation and water’s boiling point are accounted for and the new test is now recommended for grade, pricing and blending decisions according to the USDA AMS FGIS Directive 9180.38 for the United States Grain Standards Act.

Delwiche, S.R., Liang, J. 2020. On the use of native corn starch as a standard reference material for falling Number. Cereal Chemistry. 97(6):1227-1235. https://doi.org/10.1002/cche.10346.

Delwiche, S.R., Rausch, S.R., Vinyard, B.T. 2020. Evaluation of a standard reference material for falling number. Cereal Chemistry. https://doi.org/10.1002/cche.10259.

Delwiche, S.R., Higginbotham, R.W., Steber, C.M. 2017. Falling number of soft white wheat by near-infrared spectroscopy: A challenge revisited. Cereal Chemistry. 2018;95:469–477. DOI: 10.1002/cche.10049

Delwiche, S.R.,Vinyard, B.T. 2017. Falling Number Sampling Variation Within Trucks at First Point of Sale. Cereal Chem. 94(3):480–484. http://dx.doi.org/10.1094/CCHEM-06-16-0180-R

Delwiche, S.R. 2019. A New Correction Function for Falling Number at Non-Sea Level Conditions. Cereal Foods World, Vol. 64, No. 2. DOI: https://doi.org/10.1094/CFW-64-2-0020

Delwiche, S.R., Tao, H., Breslauer, R., Vinyard, B.T., Rausch, S.R. 2020. Is it necessary to manage falling number in the field? Agrosyst Geosci Environ. 3(1):e20014. https://doi.org/10.1002/agg2.20014.

Hu, Y., Sjoberg, S., Chen, C., Hauvermale, A., Morris, C., Delwiche, S., Cannon, A., Steber, C., Zhang, Z. 2022. As the number falls, alternatives to the Hagberg–Perten falling number method: A review. Compr Rev Food Sci Food Saf. 1–13. DOI: 10.1111/1541-4337.12959.

Controlling apple peel disorders linked to climate change. Increasing temperatures and sun exposure contribute substantially to apple peel disorders and postharvest loss and waste. ARS scientists in Wenatchee, Washington, and Washington State University collaborators developed a fruit sorting protocol that determines the risk of apples developing climate-related postharvest disorders. This protocol predicted the development of sunscald, a sun-related disorder that affects the highly sensitive 'Granny Smith' variety and many other commercially important apple cultivars, with a 95 percent accuracy rate even before symptoms developed. Adapting this system to existing commercial apple fruit sorting lines or in-field sorting lines could reduce or eliminate sun-related postharvest disorders and crop loss from the apple industry cold chains. This research received financial support from the Washington Tree Fruit Research Commission.

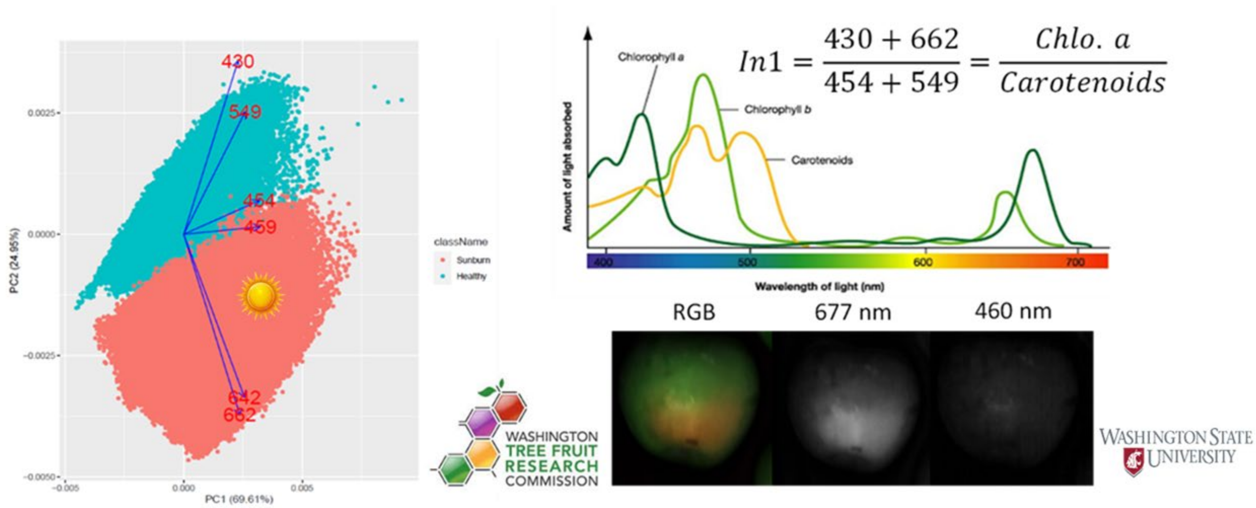


Figure 5. Identifying spectral regions most indicative of damage. A principal component loading plot indicating spectral bands associated with chlorophyll and carotenoids that are most responsible for indicating sunburn compared to unmarked fruit (left). Differences of absorbance in these spectral bands are illustrated in the upper right graph. For instance, in the 430-500 nm band, the increased levels of carotenoids in sunburned tissue counter the diminished chlorophyll levels, which results in absorbance in both areas and a solid dark picture (bottom right). However, at 642 and 662 nm, chlorophyll content can be estimated without interference from the carotenoids (top right). Consequently, the ratio between reflectance at 642 and/or 662 nm and 549 nm (chlorophyll/carotenoid) provides a good estimation of sun exposure in Granny Smith.

McTavish, C.K., Poirier, B.C., Torres, C.A., Mattheis, J.P., Rudell Jr, D.R. 2020. A convergence of sunlight and cold chain: The influence of sun exposure on postharvest apple peel metabolism. Postharvest Biology and Technology. 164. Article 111164. https://doi.org/10.1016/j.postharvbio.2020.111164.

New freezing technology retains fresh-like fruit quality when thawed. Freezing is a well-established technology used to prolong the shelf life of seasonal fruit and vegetables. However, current freezing technologies (both slow and fast) rupture cells, resulting in juice loss when thawed, which leads to suboptimal flavor, juice content, and texture qualities. Together with colleagues at the University of California, Berkeley, ARS scientists in Albany, California investigated a technology first developed to preserve human organs for transplanting called isochoric (constant-volume) freezing to extend the shelf life of food products, and to maintain physical and nutritional properties. The researchers evaluated isochoric freezing to preserve the quality of sweet cherries and found that this novel technology resulted in thawed fruit that were indistinguishable from fresh cherries in terms of juice loss, texture, structure, ascorbic acid content, and antioxidant activity. Scientists submitted a patent for using isochoric freezing to impregnate any liquid solution into preserved food that could incorporate nutrients (functional and fortify food products), infuse inhibitors (prevent microbial growth and/or chemical degradation), or create innovative foods (novel flavors, colors, and textures). Scientists have used isochoric freezing to fortify cherries, apples, and potatoes with vitamin C to avoid browning. The isochoric method uses 70 percent less energy compared to conventional freezing methods with promising applications in the food industry, medicine, biology, and space travel. These findings could disrupt the $54 billion U.S. frozen foods market by extending the shelf life of frozen products and resulting in foods, when thawed, that are fresh-like in taste, texture, juiciness, and nutrition.

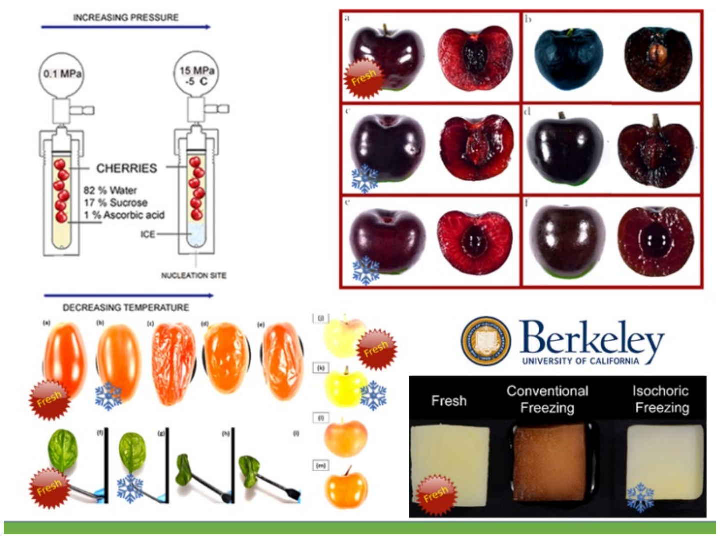


Figure 6. ARS scientists looking for ways to preserve and prevent food waste have found a process using subfreezing temperatures and elevated pressures that preserves without cellular degradation. Schematic of isochoric cold storage process used for cherries at different temperatures and sugar solutions vs. fresh cherry. Cherries and tomatoes preserved for 30 days in a sealed container filled with sugar water solution at subfreezing temperatures emerged looking fresh as if they had just been picked. Spinach leaves had a firm and crunchy texture with no signs of wiltedness and potatoes enriched with vitamin C had similar texture and color to fresh samples while conventionally frozen potato had a spongy texture, lost juice, and brown color. Isochoric cold storage results in substantial energy savings (~70 percent less), which is huge for the global food market ($334 billion).

Bilbao-Sainz, C., Chiou, B., Takeoka, G.R., Williams, T.G., Wood, D.F., Powell-Palm, M., Rubinsky, B., McHugh, T.H. 2022. Novel isochoric cold storage with isochoric impregnation to improve postharvest quality of sweet cherry. ACS Food Science and Technology. https://doi.org/10.1021/acsfoodscitech.2c00194.

Zhao, Y., Powell-Palm, M., Wang, J., Bilbao-Sainz, C., McHugh, T.H., Rubinsky, B. 2021.

Analysis of global energy savings in the frozen food industry made possible by transitioning from conventional isobaric freezing to isochoric freezing. Renewable & Sustainable Energy Reviews. 151. Article 111621. https://doi.org/10.1016/j.rser.2021.111621.

Bilbao-Sainz, C., Sinrod, A., Powell-Palm, M., Dao, L.T., Takeoka, G.R., Williams, T.G., Wood, D.F., Ukpai, G., Aruda, J., Bridges, D.F., Wu, V.C., Rubinsky, B., McHugh, T.H. 2018. Preservation of sweet cherry by isochoric (constant volume) freezing. Innovative Food Science and Emerging Technologies. 52:108-115. https://doi.org/10.1016/j.ifset.2018.10.016.

Bilbao-Sainz, C., Zhao, Y., Takeoka, G., Williams, T., Wood, D., Chiou, B-S., Powell-Palm, M J., Wu, V. C. H. Rubinsky, B., & McHugh, T. H. 2020. Effect of isochoric freezing on quality aspects of minimally processed potatoes. Journal of Food Science, 85, 2656-2664. https://doi.org/10.1111/1750-3841.15377.

McHugh, T. Bilbao-Sainz, C., Powell-Palm, M., Rubinsky, B. (US Patent 63/159,158) Isochoric impregnation of solid foods at subfreezing temperatures.

A low-calorie juice from winter melon fruit. The rise in diabetes and obesity has increased consumer awareness about foods with high sugar content, including fruit juices. Winter melon is an annual tropical vine and grows large fruit (10-50 lbs.) with greater than 90 percent water and less than 2.5 percent sugar. In collaboration with a beverage partner, researchers determined that this round waxy type of fruit provides high juice yields with stable physical and chemical properties that tastes better at lower pulp contents. Scientists perfected several methods to remove undesirable sulfur and green/grass volatile compounds that could impart a mild vegetable-like flavor to the juice. Juice processors have the option of using winter melon in juice blends with apples, oranges, grape or other fruits to decrease overall sugar and caloric content. It is a good source of amino acids (e.g., phenolic amino acids), organic acids (e.g., tartronic acid that may inhibit the conversion of carbohydrates into fats), mineral elements, and vitamins. This low brix juice will provide an alternative for consumers concerned about juice sugar intake. Scientists worked with a global leader in beverages to identify the best type of winter melon, processing technique, and growing method to be incorporated into current juice processing.

Figure 7. ARS researchers Jinhe Bai (Research Chemist), Peter Huang (grower collaborator), Nancy Owens (Biological Science Technician), and Xiuxiu Sun (Research Associate Food Technologist) in their winter melon field preharvest. Cross section of winter melon in high yield field prior to standard juice processing (winter melon juice vs. orange juice).

Sun, X.N., Baldwin, E., Manthey, J.A., Dorado, C., Rivera, T., Bai, J. 2022. Effect of preprocessing storage temperature and time on the physiochemical properties of winter melon juice. Journal of Food Quality. 2022. Article 3237639. https://doi.org/10.1155/2022/3237639.

Bai, J., Rosskopf, E.N., Jeffries, K.A., Zhao, W., Plotto, A. Soil amendment and storage effect the quality of winter melons (Benincasa hispida (Thunb) Cogn.) and their juice. Foods. 12:209. 2023. https://doi.org/10.3390/foods12010209

Problem Statement 1.B: *New bioactive ingredients and health-promoting foods.*

Consumers want more from food than just calories and nutrients. They want foods that provide fuel and support good health through improved nutrition. Research under Problem Statement 1B addresses those expectations by identifying and understanding the effects of biologically active food compounds and then developing bioactive ingredients and foods that support and promote good health. The following accomplishments highlight research that focuses on these issues:

A novel, water-conserving microgreen growing system. Feeding the world's increasing population requires novel alternatives to soil-based cultivation systems and creative solutions to minimize water usage. ARS scientists in Beltsville, Maryland developed a biodegradable, hydrogel-based "artificial soil" that minimizes water use and labor. By improving water retention/delivery and root zone aeration, this new technology supports a full 14-day growth cycle for microgreens—a nutrient dense food—which equals conventional production yields without the daily watering requirements. This current technology supports NASA in addressing microgreen seed fixation in space and facilitates live plant shipping and user-friendly vegetable growth kits for health-conscious consumers and novice urban farmers on earth. Early, enthusiastic feedback and adoption from test urban farmers indicates potential widespread adoption by the urban farming industry.

Figure 8. Top images: Red cabbage microgreens grown on different agarose-based substrates that minimizes water use and labor. By improving water retention/delivery and root zone aeration, this technology supports a 14-day growth cycle without daily watering requirements. Bottom images: Microgreen tests performed by NASA. (Left) Radish microgreens on a parabolic flight simulating temporary microgravity. (Right) Radish microgreens on the random positioning machine simulating chronic microgravity. Photos provided by R.M.Wheeler and C.M. Johnson from the NASA Kennedy Space Center.

Teng, Z., Luo, Y., Pearlstein, D.J., Zhou, B., Johnson, C.M., Wang, Q., Fonseca, J.M. 2022. Agarose hydrogel composite supports microgreen growth with continuous water supply under terrestrial and microgravitational conditions. International Journal of Biological Macromolecules. 220:135-146. https://doi.org/10.1016/j.ijbiomac.2022.08.046.

Zi Teng,1,2 Yaguang Luo, Y., Pearlstein, D., Wheeler, R., Johnson, C., Wang, Q., Fonseca, J. 2023. Microgreens for Home, Commercial, and Space Farming: A Comprehensive Update of the Most Recent Developments. Annu. Rev. Food Sci. Technol. 14:539–62. https://doi.org/10.1146/annurev-food-060721-024636

Natural Vitamin D protective film made from mushroom-stalk waste. New process technologies can use food waste to produce healthful ingredients that enhance the nutritional value and shelf life of fresh fruits and vegetables. ARS researchers in Albany, California in collaboration with ARO researchers from the Volcani Center (Israel) developed and optimized a novel ultraviolet (UV)-B light treatment applied to mushroom-stalk waste, which, after being dried and powdered, provided a new vegetarian ingredient high in vitamin D. This colorless, tasteless edible powder applied as a film coating to fruit bars and fresh-cut melons helped preserve quality, safety, and increased shelf life. Results from human clinical trials proved the bioavailability of vitamin D in these mushroom films and commercial companies (Guzen Development and Monterey Mushrooms) use this process and sell mushroom powders as a healthy source of vitamin D.

Figure 9. ARS researchers have developed an ultraviolet-B light treatment to transform mushroom-stalk waste into a vegetarian ingredient with a high level of vitamin D. When applied as a film coating to fruit bars and fresh-cut melons, the colorless, tasteless, edible powder helps preserve quality and safety and increases shelf life.

Poverenov, E., Arnon-Rips, H., Zaitsev, Y., Bar, V., Danay, O., Horev, B., Bilbao-Sainz, C., McHugh, T.H., Rodov, V. 2018. Potential of chitosan from mushroom waste to enhance quality and storability of fresh-cut melons. Food Chemistry. 268:233-241. https://doi.org/10.1016/j.foodchem.2018.06.045.

Bilbao-Sainz, C., Chiou, B., Williams, T.G., Wood, D.F., Du, W., Sedej, I., Ban, Z., Rodov, V., Poverenov, E., Vinokur, Y., McHugh, T.H. 2017. Vitamin D-fortified chitosan films from mushroom waste. Carbohydrate Polymers. 167(2017):97-104. doi: 10.1016/j.carbpol.2017.03.010

Ban, Z., Horev, B., Rutenberg, R., Danay, O., McHugh, T.H., Bilbao-Sainz, C., Rodov, V., Poverenov, E. 2018. Efficient production of fungal chitosan utilizing an advanced freeze thawing method; quality and activity studies. Food Hydrocolloids, 81, 380-388. https://doi.org/10.1016/j.foodhyd.2018.03.010.

Bilbao-Sainz, C., Chiou, B-S., Punotai, K., Olson, D., Williams, T., Wood, D., Rodov, V., Poverenov, E., McHugh, T.H. 2018. Layer-by-Layer alginate and fungal chitosan based edible coatings applied to fruit bars. Journal of Food Science, 83 (7), 1880-1887. https://doi.org/10.1111/1750-3841.14186.

Microbes: a biocontrol disease solution to maintain quality of stored potatoes. Each year Americans consume 110 pounds of potatoes per person, and to supply this year-round demand, potatoes must be stored for up to a year. Fossil-fuel based chemicals are currently used to treat stored potatoes for disease control, but because the disease-causing fungi easily adapt and become resistant, these chemicals have completely lost, or are losing, efficacy. An alternative to fossil-fuel based chemicals are natural microbes (e.g., biological control agents) that, when applied to potatoes, prevent rot and even delay sprouting, which improves marketability and nutritional quality. One issue with the commercial use of the fresh microbes for postharvest potato disease control is their storage life. ARS scientists in Peoria, Illinois developed a culture mix of three Pseudomonas strains that had characteristics enabling them to survive the drying process. Additionally, they developed drying and rehydration solutions that protect and boost reactivation of the dried microbes, especially after they have been stored in dry form longer than six months. This long shelf life of the potato disease-controlling microbes simplifies supply logistics and enables commercialization. ARS is currently collaborating with University of Idaho extension scientists through the ARS-State Partnership Potato Research Program and the ARS Innovation Fund to scale up production of the biocontrol agent and adjust application technologies for commercial use.

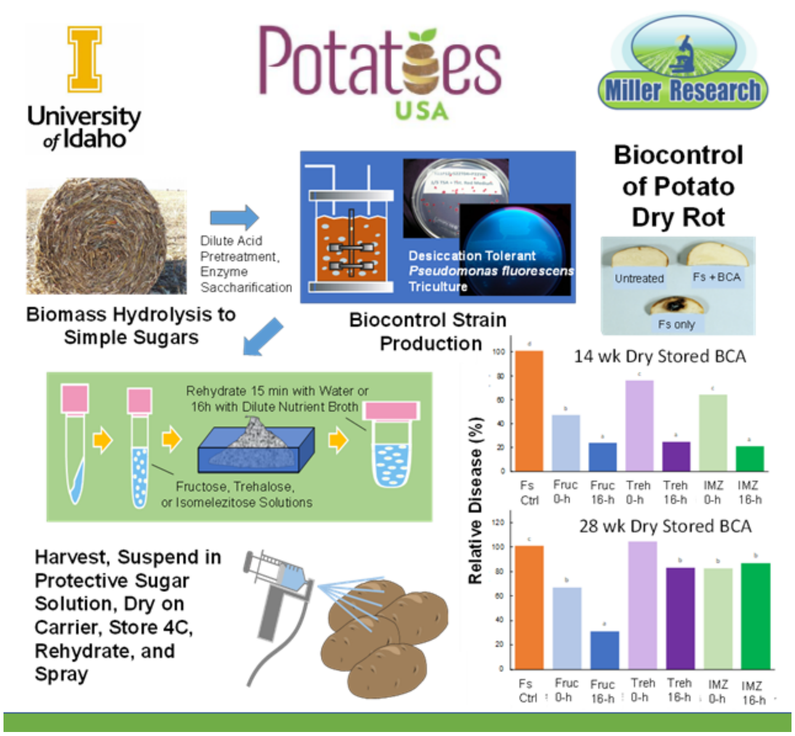


Figure 10: Comparative impact of osmoprotectants, fructose (fruc), trehalose (Treh), or isomelezitose (IMZ), on the desiccation tolerant biocontrol agent performance to control dry rot disease of potatoes. Data show that 16 h rehydration in dilute nutrient broth significantly improved the performance of triculture products stored dry on carrier up to 28 weeks at 4°C. At 28 wk, low-cost fructose supported better cell survival of dry storage on carrier and allowed better disease control than other more costly disaccharides.

Slininger PJ, Schoepke AR, and Dien BS. 2023. Production of biological pest control agents on hydrolysates of switchgrass. Bioresource Technology Reports. 21:101312.

Slininger PJ, Côté GL, Shea-Andersh MA, Dien BS, Skory CD. 2020. Application of Isomelezitose as an Osmoprotectant for Biological Control Agent Preservation

Slininger PJ, Schisler DA, and Shea-Andersh MA. (US Patent 10,982,185 B2). Desiccation Resistant Pseudomonad Strains and Treatment of Agricultural Maladies Therewith.

Hemp seed oil-based margarine for health-conscious consumers. Cold-pressed hemp seed oil (HSO) is known to have many bioactive phytochemicals that promote human health and is low in saturated fats. ARS researchers in Peoria, Illinois, used their oleogel technology—a process where semi-solid fat or oil replaces unhealthy solid fats and is combined with natural waxes to make margarine—to create a HSO-based oleogel. HSO oleogel-based margarines required less than 3 percent wax to achieve the same hardness as commercial margarine spreads, whereas achieving hardness of commercial stick margarines required up to 7 percent wax. This information is important for food companies seeking a way to develop healthier spreads that incorporate oils with low levels of saturated fats and healthful bioactive components. Margarines based on HSO will be highly desirable for health-conscious Americans. A leading consumer packaged goods food company and a food ingredient manufacturer have indicated interest in this technology.

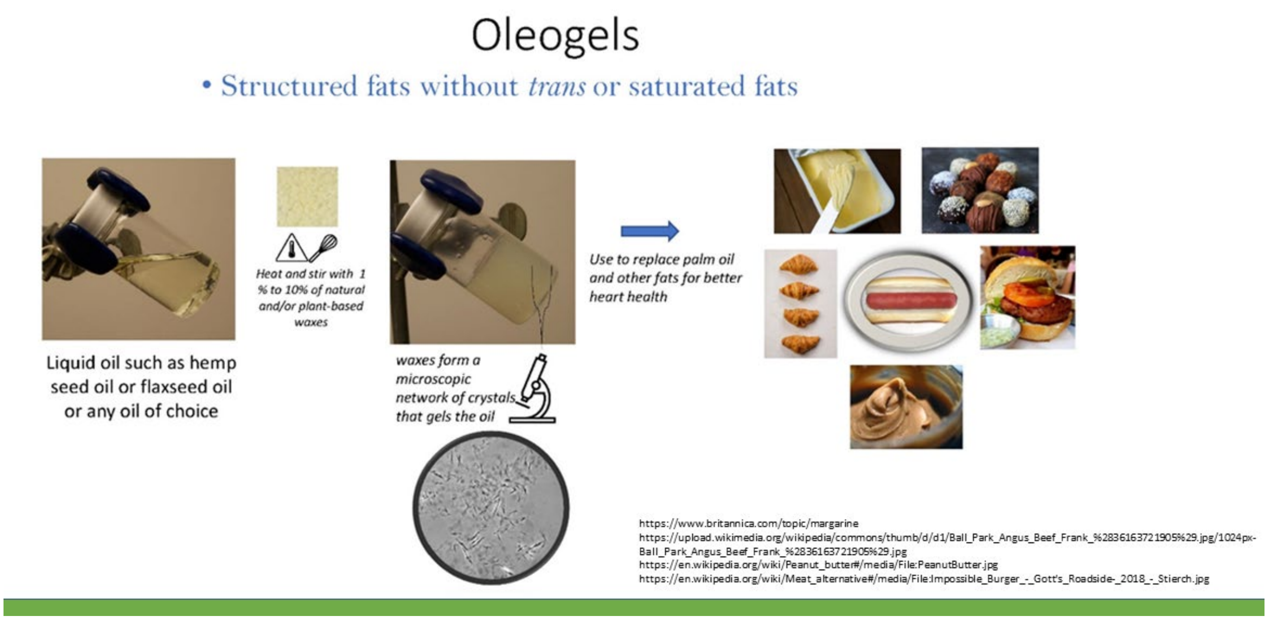


Figure 11. Mixing oil with plant-based waxes lead to the creation of oleogels that are a structured fat system used to replace palm oil and detrimental high saturated fats, such as animal fats.

Hwang, H., Kim, S., Moser, J.K., Lee, S.L., Liu, S.X. 2022. Feasibility of hemp seed oil oleogels structured with natural wax as solid fat replacement in margarine. Journal of the American Oil Chemists' Society. https://doi.org/10.1002/aocs.12619.

Select rice varieties reduces obesity. Health surveys suggest that an estimated 160 million Americans are either obese or overweight. This condition leads to an increased risk of type 2 diabetes, heart disease, and cancer. It is known that gut bacteria are altered with obesity. After eating rice, normal rice starch is rapidly digested and absorbed as glucose that can then result in high blood sugar levels. Newer rice varieties have been developed that contain higher amounts of resistant starch (RS) that are not rapidly digested. In collaborative research with ARS scientists at Stuttgart, Arkansas, and Beltsville, Maryland, ARS scientists in New Orleans, Louisiana, conducted an 8-week rodent feeding study with low and high fat diets utilizing cooked rice with low to high amounts of RS. The results showed the body fat mass gain with a high fat diet was reduced in the medium and high RS groups. Gut analysis determined that mice fed with higher RS levels had lower obesity risk and improved gut bacteria known to alleviate obesity. These results demonstrate a novel route to likely combat obesity and improve the health of overweight Americans.

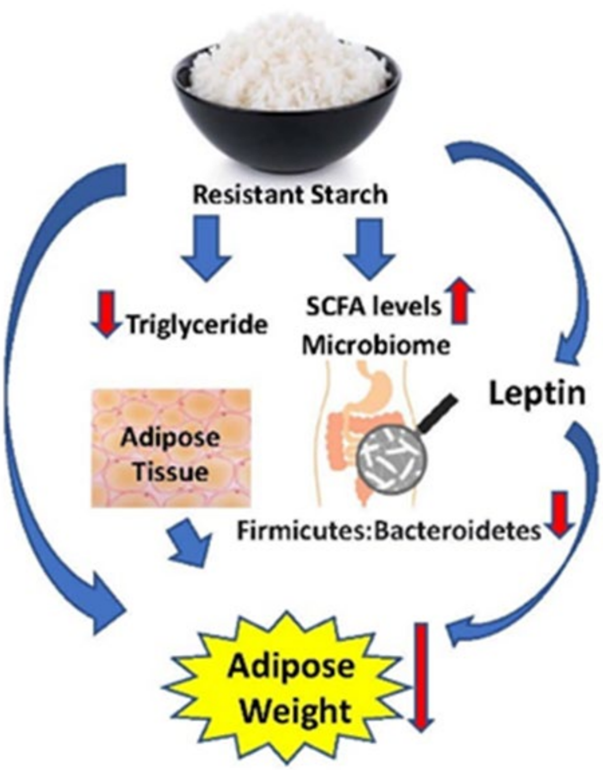


Figure 12. In a high fat diet, rice containing resistant starch decreased body fat, lowered plasma triglycerides, and improved gut health. The rice containing resistant starch attenuated adipose weight and adipocyte size gain, lowered leptin levels in plasma, increased fecal short-chain fatty acid levels, decreased the Firmicutes to Bacteroidetes ratio, and increased fecal triglyceride excretion.

Wan J., Y. Wu, Q. Pham, L. Yu, M.-H. Chen, S.M. Boue, W. Yokoyama, B. Li, and T. Y. Wang. 2019. Effects of differences in resistant starch content of rice on intestinal microbial composition. Journal of Agricultural and Food Chemistry, 68, 46, 13046–13055. https://doi.org/10.1021/acs.jafc.9b05505

Wan J., Y. Wu, Q. Pham, L. Yu, M.-H. Chen, S.M. Boue, W. Yokoyama, B. Li, and T. Y. Wang. 2021. Effects of differences in resistant starch content of rice on intestinal microbial composition. Journal of Agricultural and Food Chemistry, 69, 28, 8017–8027. https://doi.org/10.1021/acs.jafc.0c07887

Problem Statement 1.C: ***New and improved food processing and packaging technologies.***

The U.S. food industry must meet the challenge of providing secure, nutritious, and affordable food for a growing population while limiting its environmental footprint and remaining economically viable. ARS research under Problem Statement 1.C addresses this challenge with the development of processing, packaging, and preservation technologies that make foods safer and last longer; reduce and/or utilize wastes; increase process efficiency; and enhance nutritional benefits. The following accomplishments highlight research that focuses on these issues.

A fresh fruit and vegetable cleaning and disinfection system that prevents bacteria spread. In todays' commercial fresh fruit and vegetable processing plants, the accumulation of organic material in the wash water allows for harmful bacteria survival and spread as chlorine or other antimicrobial agents are depleted. ARS scientists in Beltsville, Maryland, invented and patented a novel "in-flight" non-soaking cleaning system that removes organic material early in the process without damaging the fresh produce. This new process cleans all produce surface areas and effectively removes organic matter from cut surfaces, while improving processing control and efficacy. This system uses a combination of sanitizers and a consistent concentration of chlorine that removes bacterial contamination while eliminating the buildup of toxic chlorine byproducts found in conventional flume wash systems. This 'in-flight' system, which has a relatively small footprint, also allows for exceptionally efficient use of space in the processing plant. The technology is ready to go and companies should be able to scale up with a smooth path to commercialization.

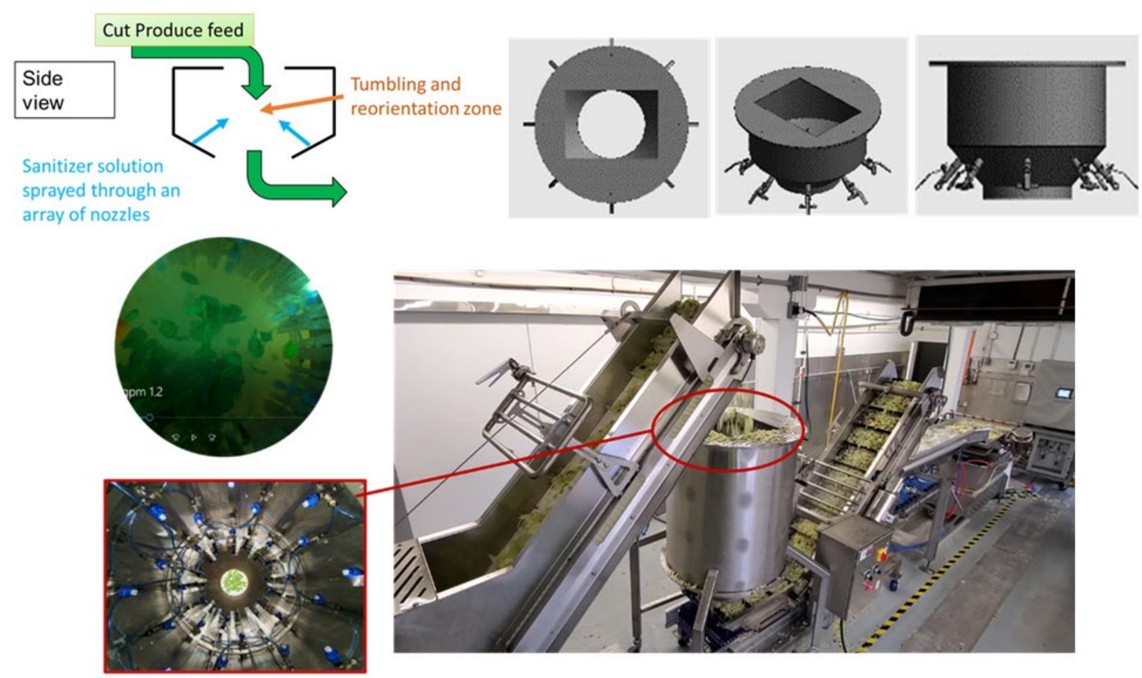


Figure 13. Inflight Washing Technology. Produce falls through washer due to gravity. Nozzles spray wash liquid upwards and inwards and the interaction between upward flow of wash liquid and downward fall of produce causes produce pieces to "tumble" and reorient while falling, resulting in uniform exposure of all sides of each produce piece to the wash liquid. The result is improved produce disinfection efficacy, bacterial inactivation, and removal of organic exudate from cut surfaces of the produce.

Zhou, B., Luo, Y., Teng, Z., Millner, P.D., Pearlstein, A. 2020. A novel in-flight washing system on bacterial reduction and quality of fresh-cut lettuce. Food Control. https://doi.org/10.1016/j.foodcont.2020.107538.

Development of a new, automated apple infield sorting machine. Automated infield sorting enables low-quality or inferior fruit to be separated from fresh-market higher-quality fruit at harvest, which improves efficiency and allows for better control during postharvest storage and packing and reduces overall food loss. ARS scientists in East Lansing, Michigan designed, patented, and constructed a new, automated infield apple sorting system and innovative, automated fruit handling functions. This system is simple and compact, reliable in performance, and capable of sorting up to 12 apples per second. The system achieved superior sorting accuracy and grading repeatability along with minimal bruising damage to fruit in laboratory and field tests. This new sorting system has been incorporated into the self-propelled apple harvester constructed by a horticultural equipment company (Precise Manufacturing, Inc., Casnovia, MI), which has been tested and demonstrated at a commercial orchard (Schwallier's Country Basket, Sparta, MI). With the adoption of this new infield sorting technology, U.S. apple growers can achieve significant cost savings in postharvest handling of harvested fruit, improve postharvest management, and reduce postharvest fruit loss.

Figure 14. The new apple harvest assist and automated in-field sorting machine featuring a patented, automated fruit sorting system for grading and sorting apples into two quality grades (fresh market and cull or processing) at a speed of up to 12 fruits per second, an innovative bin filler design for automatically handling graded and sorted fruits, and automatic handling of empty and fully filled fruit bins or containers.

Pothula, A., Zhang, Z., and Lu, R. 2023. Evaluation of a new apple in-field sorting system for fruit singulation, rotation and imaging. Computers and Electronics in Agriculture 208(2023): 107789. https://doi.org/10.1016/j.compag.2023.107789.

Lu, Y., Zhang, Z., and Lu, R. 2022. Development and preliminary evaluation of a new apple harvest assist and in-field sorting machine. Applied Engineering in Agriculture 38(1):23-35. https://doi.org/10.13031/aea.14522.

Zhang, Z., Lu, Y., and Lu, R. 2021. Development and evaluation of an apple infield grading and sorting system. Postharvest Biology and Technology 180(2021):111588, 9 pp. https://doi.org/10.1016/j.postharvbio.2021.111588.

Zhang, Z., Pothula, A. K., and Lu, R. 2019. Improvements and evaluation of an in-field bin filler for apple bruising and distribution. Transactions of the ASABE 62(2):271-280.

Zhang, Z., Pothula, A. K., and Lu, R. 2018. A review of bin filling technologies for fruit harvest and postharvest handling. Applied Engineering in Agriculture 34(4):687-703.

Pothula, A. K., Zhang, Z., and Lu, R. 2018. Design features and bruise damage evaluation of an apple harvest and infield presorting machine. Transactions of the ASABE 61(3):1135-1144..

Zhang, Z., A. K. Pothula and Lu, R. 2017. Development and preliminary evaluation of a new bin filler for apple harvesting and infield sorting machine. Transactions of the ASABE 60(6):1839-1849..

Zhang, Z., Pothula, A. K. and Lu, R. 2017. Economic evaluation of apple harvesting and in-field sorting technology. Transactions of the ASABE 60(5):1537-1550.

Lu, R., Pothula, A. K., Mizushima, A., Vandyke, M. and Zhang, Z. (US patent 9,919,345) System for sorting fruit.

Catfish bone powder increases the appeal of fried catfish strips. Catfish bones or frames are a waste product of the filleting process. ARS scientists in New Orleans, Louisiana, and Louisiana State University colleagues transformed catfish frames into a high calcium, safe-to-eat bone powder and incorporated it into breading mixes. Fried catfish strips coated with bone powder mixes yielded positive feedback and favorable acceptance from consumers. Additionally, information about bone powder utilization increased consumer interest in product purchases. Using this catfish byproduct in prepared foods can reduce waste from the seafood sector, enhance value for producers, and increase calcium in foods without hindering sensory quality.

Catfish frame | Dried catfish bone | Catfish bone powder (CBP) | Catfish fillet | Fried catfish dredged with breading containing CBP

Liking scores of Fried Catfish dredged with CBP breading mix							
CBP (%)	Aroma	Color	Crispiness	Texture	Flavor	Overall Liking	Purchase (%yes)
0%	6.96[NS]	7.18[NS]	6.59[ab]	6.56[NS]	6.95[NS]	6.80[NS]	71.09[NS]
10%	7.12	7.22	6.44[b]	6.54	6.94	6.89	71.56[a]
20%	7.1	7.12	6.87[a]	6.84	7.02	7	73.93[a]

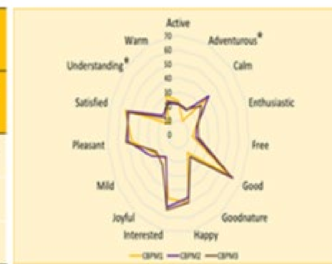


Figure 15. Transformation of catfish frames into safe-to-eat bone powder for breading mixes. (Top) Catfish frames were cleaned, dried, and ground into bone powder. Catfish bone powder (CBP) was incorporated into breading mixes which were used to coat catfish strips. (Bottom left) Two hundred eleven consumers rated sensory acceptability (Bottom right) Consumers selected emotions associated with consumption of catfish strips coated with different levels of CBP in the breading mixes.

Prinyawiwatkul, W., Ardoin, R.P., Murillo, S., Watts, E. 2022. Effects of catfish (Ictalurus Punctatus) bone powder on consumers liking, emotions, and purchase intent of fried catfish strips. Foods. 11(4):540. https://doi.org/10.3390/foods11040540.

A new fruit storage clamshell container with superior freshness retention. ARS scientists in Fort Pierce, Florida, designed a new clamshell container for fresh-fruit storage that maintains optimum humidity, prevents fruit weight loss in storage, and does not induce a modified atmosphere. The new clamshell has openings in the shell with an opening-to-surface ratio of 0.44 percent in comparison with present-day commercial clamshells with an opening-to-surface ratio of 2.83 percent. The smaller opening ratio, developed over a period of 11 years in 37 experiments, is large enough so that air in the clamshell maintains firmness of sweet cherry stems, and freshness of litchis, strawberries, blueberries, Chinese bayberries, apricots, loquats, and cherry tomatoes. Quality attributes of the packaged fruits were generally better maintained in these ARS-designed clamshells, especially for those attributes susceptible to water loss such as shriveling, desiccation-induced browning, and/or drying of pedicels in cherries, calyx of strawberries, pericarp of litchis, peel shriveling of cherry tomatoes, and softening of blueberries and strawberries.

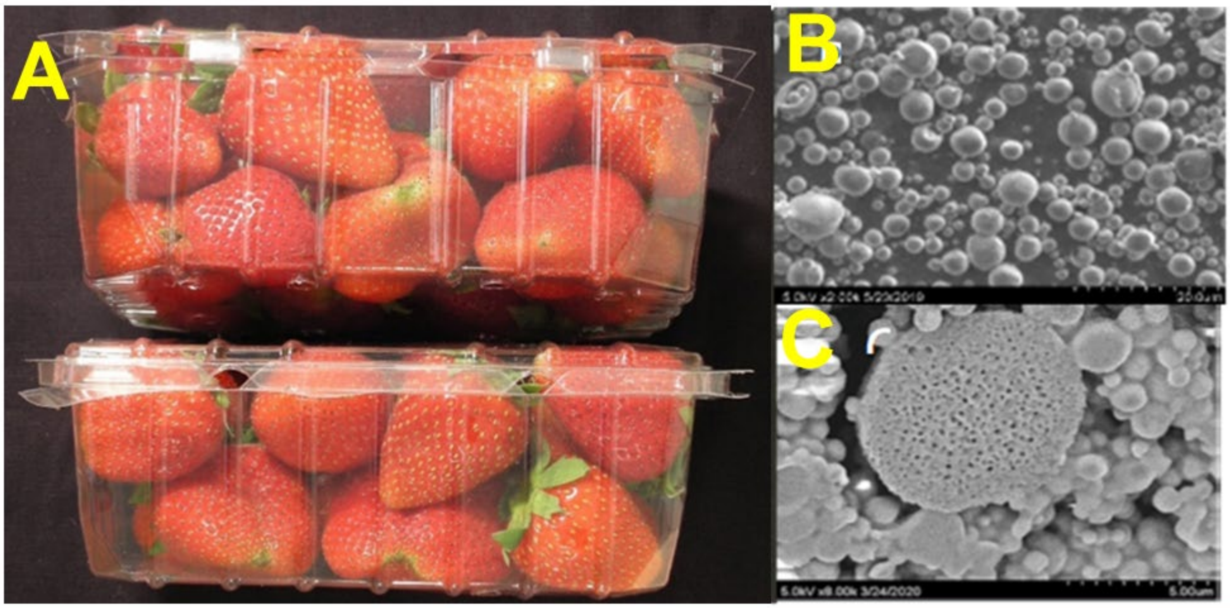


Figure X16 A. Upper: commercial clamshell with 2.83% venting rate; Bottom: modified humidity clamshell with 0.44% venting rate. B. Scanning electronic microscopy (SEM) images of the controlled-release microcapsules of antimicrobials. C. Inner structure of the microcapsules.

Bai, J., Baldwin, E.A., Tsantili, E., Plotto, A., Sun, X., Wang, L., Kafkaletou, M., Wang, Z., Narciso, J., Zhao, W., Xu, S., Seavert, C., Yang, W. Modified humidity clamshells to reduce moisture loss and extend storage life of small fruits. Food Packaging and Shelf Life. 22: 100376. 2019. https://doi.org/10.1016/j.fpsl.2019.100376

Environmentally friendly bioplastic from dairy waste. Agro-based materials are increasingly used to replace petroleum-based feedstocks because they are sustainable, eco-friendly, easier to recycle, and non-toxic. ARS researchers in Peoria, Illinois, utilized a sugar called lactose, a cheap and widely available byproduct of cheesemaking and casein production, to make polyurethanes via a newly developed green microwave process that eliminates the standard industry use of toxic catalysts needed to accelerate reaction. This microwave procedure was found to reduce the reaction time and save energy relative to conventional heating. Moreover, the lactose-based polyurethane can be mixed with additional polymers to generate different plastics. These bioplastics are suitable for biomedical applications and for replacing polymers made from petroleum-based materials and can generate added revenue for the dairy industry.

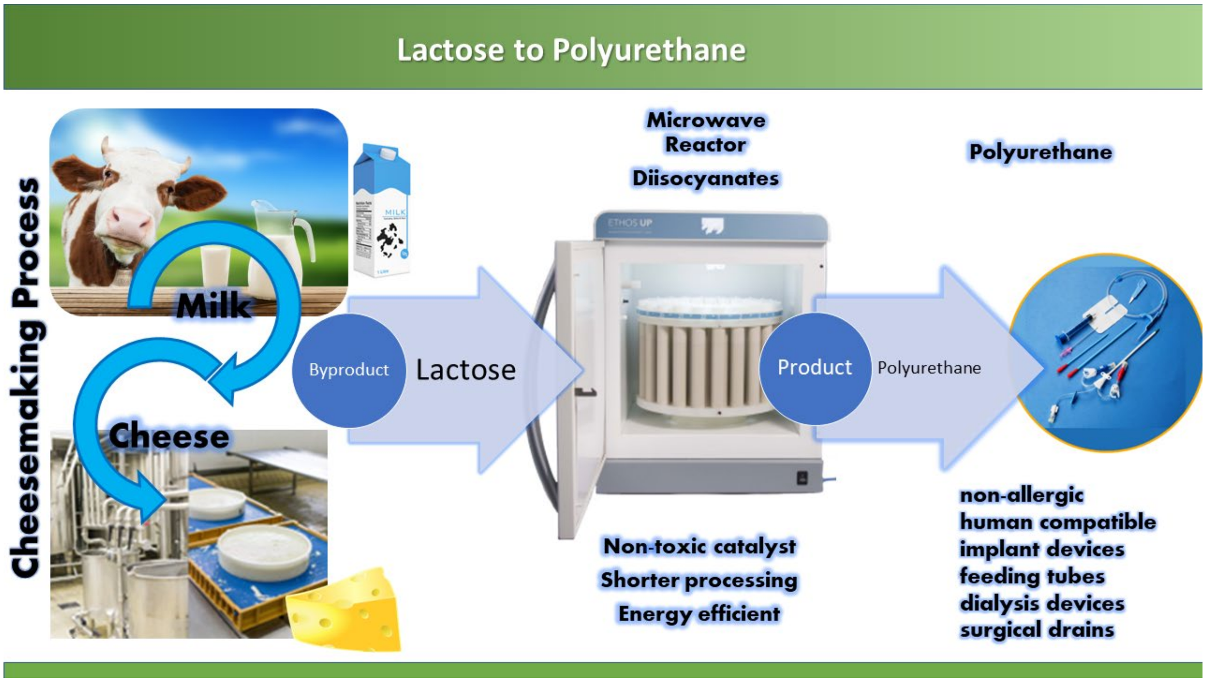


Figure 17. ARS researchers have developed a green microwave process without toxic chemicals and lower energy costs to produce polyurethane from lactose a byproduct of cheesemaking.

H. N. Cheng, A. Biswas, S. Kim, M. Appell, R. F. Furtado, C. R. Alves, M. S. R. Bastos. Synthesis and Analysis of Lactose Polyurethanes and their Semi-Interpenetrating Polymer Networks. Int. J. Polym. Anal. Charac., 2022, 27, 266–276.

COMPONENT 2: Nonfood (fibers & hides)

The U.S. fiber and hide industries are facing significant challenges from the production and market globalization of raw cotton, wool, yarn and yarn products, raw animal hides, and finished leather products. These challenges include rising energy and labor costs, regulatory compliance, maintaining and improving product quality, developing new processes and products, and improving the management and use of waste and byproducts. ARS scientists enhance product quality by improving harvesting, processing, and storage technologies; improving quality measurement and grading systems; and conducting studies of basic fiber structure and properties. Their research has resulted in processing technologies with reduced environmental footprints and the development of new applications and products for hides and agricultural fibers, including new high-value byproducts.

The NP 306 Action Plan Component 2, Nonfood, focuses on developing technologies that improve product quality and reduce the energy needs and environmental impacts of production. As part of this work, ARS researchers have developed new products that enhance the global competitiveness of U.S. producers and processors of cotton, hides, wool, and other nonfood agricultural products and byproducts. Two Problem Statements were identified for Component 2 to address the research needs of agricultural producers of nonfood products and commodities:

- 2.A. Maintain/Enhance Fiber and Hide Quality.
- 2.B. Enable Technologies to Produce New and Expand Marketable Nonfood, Nonfuel Biobased Products Derived from Agricultural Feedstocks.

Problem Statement 2.A: *Maintain/enhance fiber and hide quality.*

Nonfood products such as animal hides or cotton have little or no value until they are processed by tanning, ginning, or other methods. Research under this Problem Statement targeted the development of methods, processes, and technologies to improve producer and processing efficiency, reduce production costs, and enhance product quality and value. This includes collecting production data and devising methods to reduce the environmental impact of nonfood production. The following accomplishments highlight research that focuses on these issues.

COVID antiviral cotton facemasks. ARS researchers in New Orleans, Louisiana, in collaboration with H&H Med Corp (part of Safeguard Medical) a medical trauma wound dressing company, revealed that a jointly developed cotton nonwoven product exhibited antiviral activity. ARS scientists and collaborators found that hydrogen peroxide, a natural compound in cotton, exhibited 99.999 percent antiviral activity against the SARS-CoV-2 virus after one hour of contact with cotton fabric. Nonwoven cotton will be studied with collaborators to assess its effectiveness at inhibiting the COVID-19 virus. Following a secondary company testing to obtain an FDA approved ISO test for antiviral textiles, the company plans to develop a prototype for use in face masks.

	Test Result for #1 BIOGuaze / H&H Medical	Test Result for #2 TACGuaze / H&H Medical	Test Result for #3 N95 / HHMCom
TCID50 per 0.1 ml	2.50 Log_{10}	4.50 Log_{10}	5.00 Log_{10}
Log Reduction	1.00	No Reduction	No Reduction
Percent Reduction	90%	No Reduction	No Reduction

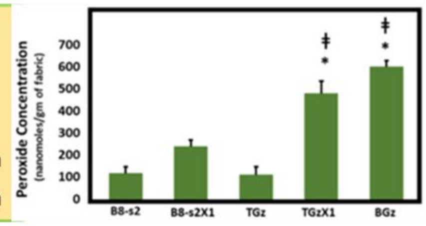


Figure 18. New textile treatments impart virucidal efficacy for use as disposable cotton mask overlay. Cotton has natural constituents that produce hydrogen peroxide within cotton fibers and ARS increased its antimicrobial activity (Gram-negative and Gram-positive bacteria) and its antiviral activity (MS2 bacteriophages) with post-processing treatments of citric acid and ascorbic acid. Comparison of hydrogen peroxide production between TACGauze (TGz) treated with citric acid and ascorbic acid or BIOGauze (BGz) treated with ascorbic acid versus either bleached cotton (B8-s2) or TGz alone Note: TCID50 (Tissue Culture Infectivity Dose).

Edwards, J.V., Prevost, N.T., Yager, D., Mackin, R.T., Santiago Cintron, M., Chang, S., Condon, B.D., Dacorta, J. 2022. Ascorbic acid as an adjuvant to unbleached cotton promotes antimicrobial activity in spunlace nonwovens. International Journal of Molecular Sciences. https://doi.org/10.3390/ijms23073598.

Mackin, R.T., Edwards, J.V., Atuk, E.B., Beltrami, N., Condon, B.D., Jayawickramarajah, J., French, A.D. 2022. Structure/function analysis of truncated amino-terminal ACE2 peptide analogs that bind SARS-CoV-2 spike glycoprotein. Molecules. 27:2070. https://doi.org/10.3390/molecules27072070.

Removing plastic contamination and increasing cotton's value. Plastic contamination is the single largest threat to the U.S. cotton industry to date. According to the USDA Agricultural Marketing Service Cotton Classing Offices, most of the plastic contamination in test samples from ginned cotton in the United States originates from plastic material used to wrap the harvested cotton modules formed by state-of-the-art cotton harvesters. Plastic contamination is the major reason for the loss of the 'premium grade' status U.S.-grown cotton once received on the international market for its reputation as the world's reliable source of contaminant-free natural fiber. On an annual basis the loss is more than $750 million. ARS researchers in Lubbock, Texas developed (with assistance from ARS researchers in Las Cruces, New Mexico) a low-cost system that identifies and removes plastic and other contaminants in harvested cotton before being ginned. This system, commercially known as VIPR™ (Visual Inspection and Plastic Removal), utilizes imaging sensors from the cell phone industry with low-cost embedded microcontrollers to identify contaminants. When a contaminant is detected, a pneumatic system blows the contaminant out of the cotton and onto the floor. Commercial testing shows that the system can operate with more than 90 percent detection/removal efficiency. This technology was developed, tested, and successfully transferred to a commercial partner and is now being sold domestically and internationally. This system will return ‘premium grade’ status to U.S. cotton and over the next decade earn the industry more than $7 billion.

Figure 19. Technology developed by ARS and now commercially produced under the trade name “VIPR” detects and removes plastic and other contaminants from seed cotton before it enters the gin stand. Collaborative research and development agreements with Bratney Companies and Lummus Corporation led to VIPR™ Commercial Installation in Lummus Gins at A) Southeastern Gin, GA and B) Spade COOP Gin, TX. Lower images demonstrate C) technology is an ultra-low-cost, “bolt on” detection and removal system built using off-the-shelf parts that D) removes contaminants.

Pelletier, M.G., Preston, S.C., Cook, J.A., Tran, K.D., Wanjura, J.D., Holt, G.A. 2019. Thermal performance of double-sided metal core pcbs. AgriEngineering 1(4): 539-549. https://doi.org/10.3390/agriengineering1040039.

Pelletier, M.G., Holt, G.A., Wanjura, J.D. 2020. Plastic contamination image dataset for deep learning model development and training. AgriEngineering 2: 317-321. https://doi:10.3390/agriengineering2020021.

Pelletier, M.G., Holt, G.A., Wanjura, J.D. 2021. Cotton gin stand machine-vision inspection and removal system for plastic contamination: Software design. AgriEngineering 3: 494-518. https://doi.org/10.3390/agriengineering3030033.

Pelletier, M.G., Wanjura, J.D., Holt, G.A., Kothari, N. Cotton gin stand machine-vision inspection and removal system for plastic contamination: Auto-calibration design. Accepted for publication in AgriEngineering.

A new field cleaner that makes the next generation of cotton harvesters more efficient. Stripper-type cotton harvesters are used to harvest about 10 million bales, or half of the annual U.S. cotton crop. Recent design changes for packaging harvested cotton into cylindrical modules have increased the cost of harvesters from about $250,000 to around $800,000. To enable greater harvest productivity, efficiency, and cotton cleanliness, ARS engineers in Lubbock, Texas, and collaborators from John Deere developed and evaluated the performance of a new field cleaner for use on stripper harvesters. This new machine increased material processing capacity by 25 percent while improving cleaning efficiency by 20 percent. In addition to meeting new processing capacity goals, the new machine increased the value of cotton harvested by more than $5 per bale resulting in a $35 to $50 million of annual revenue increase for U.S. cotton growers.

Figure 20. Work with John Deere on developing and evaluating the performance of a new field cleaner for stripper harvesters that increased material processing capacity by 25 percent, cleaning efficiency by 20 percent, and increased the value of cotton over $5 per bale resulting in $35 to $50 million of annual revenue increase for farmers. A) JD CS690 cotton stripper harvester previously built that uses the old 2 drum 60” wide cleaner design. B) JD CS770: Current state-of-the-art cotton stripper that uses the new 3 drum 75” wide cleaner design. C) Press photo of the new John Deere CS770 Cotton Stripper and CP770 Cotton Picker that help farmers harvest every pound of seed cotton possible while preserving cotton quality.

Wanjura, J. 2019. Cooperative research and development agreement with John Deere in Moline, IL. This agreement and research led to new John Deere CP/CS770 stripper harvester machines. Press Release: https://www.deere.com/en/news/all-news/2021aug02-deere-unveils-new-cotton-pickers-strippers/

Washable, reusable, antibacterial cotton wipes. Most commercially available wipes are made of non-biodegradable synthetic fibers and designed for single use, contributing to environmental pollution. To address this issue, ARS scientists in New Orleans, Louisiana, developed a groundbreaking method to synthesize silver nanoparticles directly within cotton fibers. This innovation transforms the cotton fiber itself into an antimicrobial agent, rather than merely serving as a carrier of antimicrobial agents. Commercially available textile products containing with embedded antibacterial silver nanoparticles leach out a significant amount (87 percent) of the total silver in the textiles when washed in detergent solutions after five machine washes. ARS scientists in New Orleans, Louisiana, developed a way to embed silver nanoparticles into cotton fiber wipes that retain a majority of silver nanoparticles (above 70 percent) even after 50 machine washes. Silver nanoparticle-embedded cotton fiber wipes are soft, yet they exert powerful antibacterial functions (killing 99.9 percent of the most common bacteria-causing infections). Development of permanent antibacterial cotton wipes has led to two approved invention disclosures: 1) raw white and brown cotton fibers that self-generate silver nanoparticles for wash-durable antibacterial textiles; and 2) fast, reproducible, and heat-free internal synthesis of silver nanoparticles in cotton fiber for wash-durable antibacterial textiles. This technology transfer is supported by the ARS Innovation Fund.

Figure 21. ARS researchers from left to right: Matthew Hillyer, Doug Hinchliffe, Pablo Salame, and Sunghyun Nam use the hydroentanglement process to fabricate nonwoven wipes in the nonwoven pilot plant at the Southern Regional Research Center in New Orleans. Cross-section of a cotton fiber with silver nanoparticles (black dots) synthesized in the primary cell wall. These silver nanoparticles have powerful antimicrobial properties, and these embedded nanoparticles kill bacteria on cotton after 50 washings.

Nam, S., Hillyer, M.B., Condon, B.D., Lum, J.S., Richards, M.N., and Zhang, Q. 2020. Silver nanoparticle-infused cotton fiber: durability and aqueous release of silver in laundry water. Journal of Agricultural and Food Chemistry. 68: 13231–13240.

Nam, S., Ernst, N., Chavez, S.E., Hillyer, M.B., Condon, B.D., Gibb, B.C., Sun, L., Guo, H., and He, L. 2020. Practical SERS method for assessment of the washing durability of textiles containing silver nanoparticles. Analytical Methods. 12: 1186-1196. 2020.

Hillyer, M.B., Nam, S., Condon, B.D., 2020. Quantification and spatial resolution of silver nanoparticles in cotton textiles by surface-enhanced Raman spectroscopy (SERS). Journal of Nanoparticle Research. 22: (2).

Nam, S., Chavez, S.E., Hillyer, M.B., Condon, B.D., Shen, H., Sun, L. 2021. Interior vs. exterior incorporation of silver nanoparticles in cotton fiber and washing durability. AATCC Journal of Research. 8: 1-12.

Nam, S., Condon, B., Hillyer, M. (US Patent No.20210062411A1) Cellulosic Fibers Comprising Embedded Silver Nanoparticles and Uses Thereof.

Cotton-based blood clotting (hemostatic) dressings. Excessive bleeding from traumatic wounds is the leading cause of death on the battlefield, and the second leading cause of death in civilian trauma settings. Materials that promote rapid blood clotting has relevance to both patient survival and optimal recovery. ARS scientists in New Orleans, Louisiana, developed a nonwoven, unbleached cotton dressing that enhances clotting and absorbency for bleeding control. It was commercialized in November 2018. The dressing is 33 percent lighter and 63 percent more absorbent than the standard crinkle-type cotton dressing made with bleached cotton. In addition to having enhanced bleeding control properties, it also resists adhering to damaged tissue and can be torn into small units for easy application. A second generation of this product with 99.99 percent antibacterial activity has now been developed by ARS scientists for prolonged field care and was approved in 2020 by the Food and Drug Administration for commercial manufacturing. These two cotton dressings fulfill a congressional mandate to use U.S. cotton in textile products used by the Department of Defense. The potential impact of these types of cotton-based hemostatic dressings is to be found in improved dressings used by the Armed Forces and first responders.

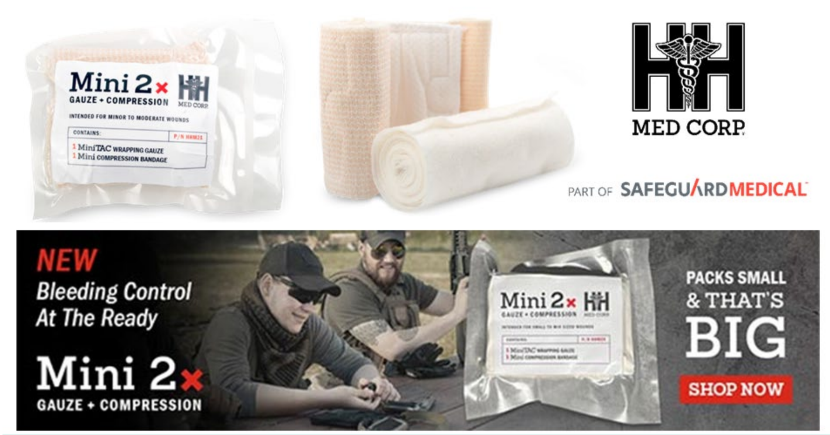


Figure 22. Scientists working with H&H Med Corp (part of Safeguard Medical) developed a nonwoven, unbleached cotton dressing that enhances clotting and absorbency for bleeding control by using the hemostasis-accelerating properties of greige cotton. The on-the-go trauma response dressing is currently marketed as the Mini 2x - Gauze + Compression and contains a dressing that is 33 percent lighter and 63 percent more absorbent.

Edwards, J.V., Graves, E.E., Prevost, N.T., Condon, B.D., Yager, D., Dacorta, J., Bopp, A. 2020. Development of a nonwoven hemostatic dressing based on unbleached cotton: a de novo design approach. Pharmaceutics. 12(7):1-19. https://doi.org/10.3390/pharmaceutics12070609.

Edwards, J.V., Prevost, N.T., Yager, D., Nam, S., Graves, E.E., Santiago Cintron, M., Condon, B.D., Dacorta, J. 2021. Antimicrobial and hemostatic activities of cotton-based dressings designed to address prolonged field care applications. Military Medicine. 186(1):116-121. https://doi.org/10.1093/milmed/usaa271.

Problem Statement 2.B: ***Enable technologies to produce new and expand marketable nonfood, nonfuel biobased products derived from agricultural feedstocks.***

Biobased products must be competitive in the marketplace, especially with conventional, petroleum-based products. Agricultural producers and processors increasingly need alternative market opportunities for existing and new products, especially those that increase the value of byproducts. ARS researchers working on Problem Statement 2.B addressed these issues by finding new uses for agricultural products, enhancing existing products for different applications to increase value, or developing completely new and innovative products that use agricultural products or byproducts for production. The following accomplishments highlight research that focuses on these issues.

Repelling biting flies. Biting or blood-sucking insects (flies, mosquitos, ticks, and bed bugs) some of which can transmit various diseases that cause major health concerns and economic losses for both animals and humans worldwide. Currently, there are no effective pesticides available for use against either biting stable flies or biting face flies. ARS scientists in Peoria, Illinois, and Lincoln, Nebraska, identified and developed a new bio-based insect repellent formulation designed to meet the challenges posed by these insects. These researchers discovered that naturally derived fatty acids from coconut oil function as a very effective biobased repellent and provided broad repellency and long-lasting effectiveness against multiple blood-sucking insects. The all-natural aqueous formulation, developed by ARS scientists in Peoria, Illinois, was effective in field trials conducted on cattle in North Platte, Nebraska. The current biting fly issue in the United States costs the cattle industry more than $2.4 billion annually. This new product is being tested by U.S. cattle farmers and ranchers as a sustainable, natural technology to address biting insect issues.

Figure 23. Scientists have identified coconut oil fatty acids that repel insects better than DEET and offer long-lasting effectiveness against four different types of insect pests (mosquitoes, ticks, biting flies and bed bugs). A University of Nebraska student applies coconut fatty acid insect repellent to livestock during field trials. Field trials showed this all-natural formula provide protection to cattle against biting flies for up to 4 days.

Zhu, J.J., Cermak, S.C., Kenar, J.A., Brewer, G., Haynes, K.F., Boxler, D., Baker, P.D., Wang, D., Wang, C., Li, A.Y., Xue, R.D., Shen, Y. Wang, F., Agramonte. N.M., Brenier, U.R., Filho, J.O., Borges, L.M.F., and Taylor, D.B. Better than DEET Repellent Compounds Found in Coconut Oil. Nature Scientific Reports. 8:14053. 2018. 10.1038/s41598-018-32373-7

Roh, G. W., Zhou, X., Wang, Y., Cermak, S. C., Kenar, J. A., Lehmann, A., Han, B., Taylor, D. B., Zeng, X., Park, C. G., Brewer, G. J. and Zhu, J. J. Spatial repellency, antifeedant activity and toxicity of three medium chain fatty acids and their methyl esters of coconut fatty acids against stable flies. Pest Management Science. 405-414. 2019. https://doi.org/10.1002/ps.5574

Zheng, S., Blore, K., Xue, R-D., Qualls, W., Cermak, S. C., and Zhu, J. J. Larvicidal activity of natural product repellents against the dengue vector, aedes aegypti. J. Am. Mosquito Control Association. 36(4):227–232. 2020 http://dx.doi.org/10.2987/20-6916.1

Whitney A. Qualls, W. A., Xue, R-D., Farooq, M., Peper, S. T., Aryaprema, V., Blore, K., Weaver, R., Kenar, J. A., Cermak, S. C. and Zhu, J. J. Evaluation of lotions of botanical-based repellents against Aedes aegypti (Diptera: Culicidae): Coconut derived fatty acids, 2-undecanone, and catnip oil. the Journal of Medical Entomology 58(2):979-982. 2021. https://doi.org/10.1093/jme/tjaa244

Lehmann, A.T., Brewer, G.J., Boxler, D.J., Zhu, J.J., Hanford, K., Taylor, D., Kenar, J.A., Cermak, S.C. and Hogsette, J.A. (2023), A push–pull strategy to suppress stable fly (Diptera: Muscidae) attacks on pasture cattle via a coconut oil fatty acid repellent formulation and traps with m-cresol lures. Pest Manag Sci. https://doi.org/10.1002/ps.7480

Zhu, J.J. and Cermak, S.C. (US Patent No. 20200107544 A1) Methods For Repelling Blood-Sucking And Biting Insects, Ticks And Mites.

<u>Almond hulls: a waste product with high value uses</u>. Almond hulls can be a viable source of industrial sugars, as they contain more "free" extractable sugar than sugar beets; however, once the sugars are extracted uses must be found for the remaining spent hull biomass. ARS scientists in Albany, California, developed a novel application for spent hulls, using them as a replacement for non-sustainable peat moss to commercially produce mushrooms (California Almond Board and Premier Mushroom). Propagation of vegetative mycelium from mushrooms generally requires a specific peat moss mix (called casing) with uniform pore distribution for gas exchange, balanced minerals, and high water-holding capacity. Spent almond hulls possess these important traits, with a water-holding capacity of greater than 500 percent, numerous pores in the size range optimal for gas exchange, and high mineral content ideal for mushroom growth. ARS scientists also used a thermal (200-300 degrees Celsius under limited oxygen) process called torrefaction that produces a residue from almond shells—an inexpensive, abundant waste by-product from the U.S. almond-nut industry—that improves adhesion properties when added to recycled plastic while also improving recycled plastic heat stability and stiffness. ARS researchers and their industrial collaborators (California Almond Board, Holtz Rubber, Tranpak West Biofuels) are exploring the use of torrefied almond shells to replace/reduce the percentage of polymers in shipping pallets and as a carbon black replacement in rubber pads for almond harvester tree shakers.

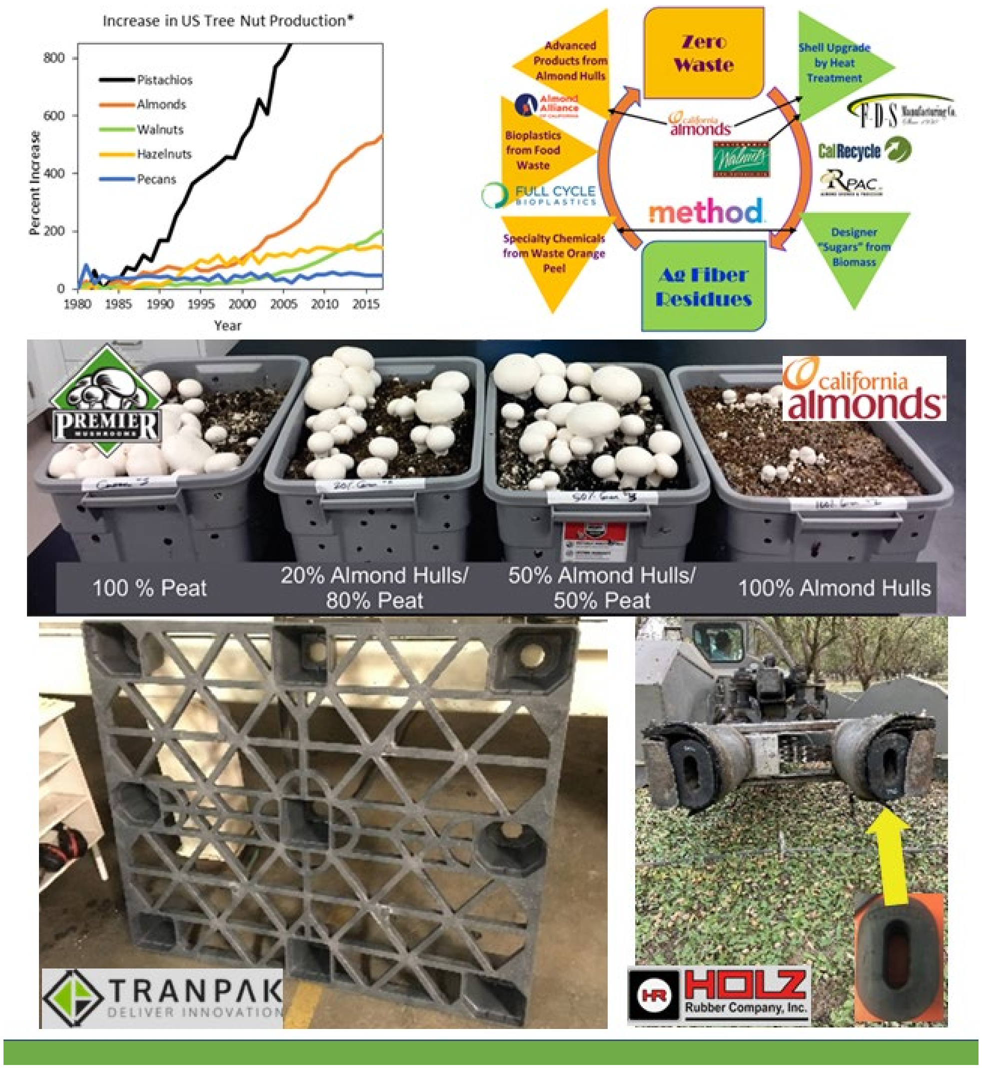


Figure 24. U.S. tree nut production has increased since 1980 and as the production of nuts increases, so does biomass residues from the nuts. The Bioproducts Research Unit is always looking to expand the use of crop residues by developing new biobased products and has a dedicated Zero Waste program where industrial partners collaborate to upcycle wasted or discarded material. Button mushrooms (Agaricus bisporus) grown in a combination of spent (following sugar extraction) almond hulls and commercially available, unrenewable peat. There is an increasing demand for materials with increased biobased content and in cooperation with the Almond Board of California and Tranpak, Fresno, CA shipping pallets were made using recycled plastic and 15% almond biochar. Additionally, tree shaker pads for the nut industry were produced from Torrefied Almond Shell and rubber in cooperation with the Almond Board of California and Holz Rubber Company, Lodi, CA.

Shogren, R.; Wood, D.; Orts, W.; Glenn, G. Plant-based materials and transitioning to a circular economy. Sustainable Production and Consumption 2019, 19, 194-215, DOI: 10.1016/j.spc.2019.04.007.

McCaffrey, Z.; Thy, P.; Long, M.; Oliveira, M.; Wang, L.; Torres, L.; Aktas, T.; Chiou, B. S.; Orts, W.; Jenkins, B. M. Air and steam gasification of almond biomass. Frontiers in Energy Research 2019, 7, DOI: 10.3389/fenrg.2019.00084.

<u>A better process for making degradable food containers.</u> There is a major trend towards making single-use food containers from renewable materials that compost easily. Traditionally, the cost of agricultural materials is competitive with petroleum-based plastics, but the processing costs are significantly higher. ARS scientists in Albany, California, developed a novel, inexpensive

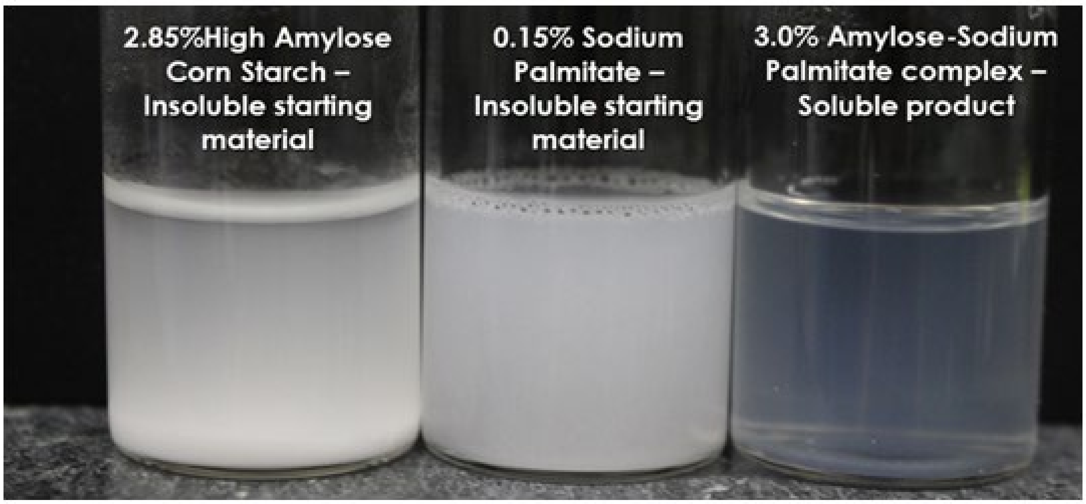
process for making single-use food containers from renewable plant fiber composites that when composted degrade quickly. The containers are compression molded in only a few seconds and compost more readily than paper products. A patent application has been submitted for this invention and a commercial partner is developing commercial products. This research improves the sustainability of the single-use food container industry, and provides a new degradable, sustainable product from food waste or non-food feedstocks.

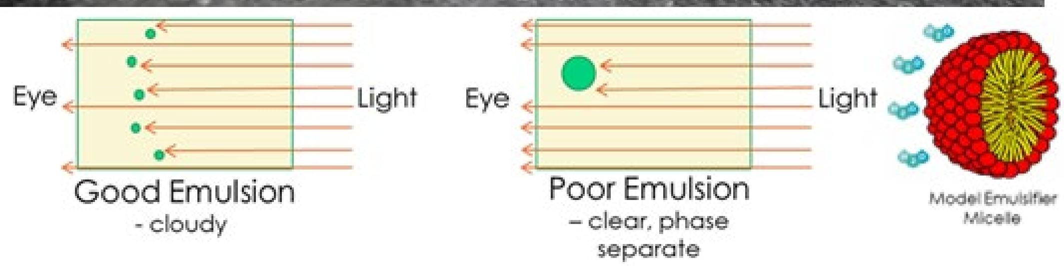
Figure 25. Billions of single-use food containers are consumed in the United States every year. Renewable, plant-based containers provide a sustainable/renewable alternative to plastic containers, but long processing times can make the containers prohibitively expensive. Containers made from a high-moisture (50% moisture content, MC) dough can take 60 seconds to process in a heated press. When the dough is made into sheets and dried to a low moisture content (15% MC), food containers can be compression molded in as little as 6 seconds, dramatically increasing the production output and reducing the cost per container.

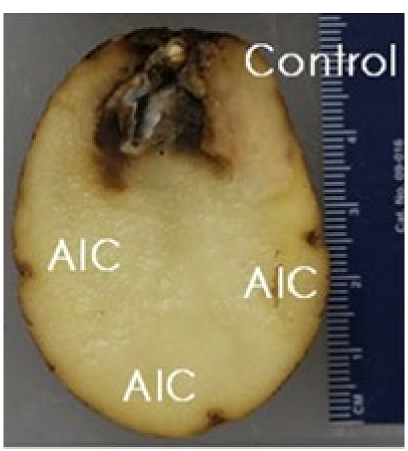
Glenn, G. Jin, X. (US Patent No. 11,339,275) Compositions and Methods for food packaging.

<u>Corn starch: It's an emulsifier and a pesticide</u>. An emulsifier allows two normally insoluble materials to become a stable mixture. For instance, mayonnaise is made of oil and vinegar, which do not mix, but when eggs—an emulsifier—are added, you create a stable mixture. Without the emulsifier, the two materials will separate. Many industrial emulsifiers utilize carcinogenic or highly hazardous ingredients. As a result, there is a constant need for improved industrial emulsifiers that provide an alternative that is biobased and safe. ARS scientists in Peoria, Illinois, developed an economical emulsifier that uses corn starch and a vegetable oil. This new emulsifier (called an AIC) forms suspensions of oil in water that are stable for months and make

water slicker, allowing the AIC-water solutions to lubricate parts and allowing for efficient cleaning. In addition, the AIC is food-grade and can control gram positive bacteria, yeast, mold, fungi, and some insects (including termites). The ability to function as both an emulsifier and pesticide is highly attractive, giving corn starch a higher value. This new technology allows for the replacement of imported emulsifiers or those that use hazardous ingredients or processes. These new products are being promoted by industry resulting in new applications for corn starch benefiting corn producers, processors, and consumers.







Microbe	TYPE	Effectiveness
Prototheca wickerhamii	algae	YES
Aspergillus niger	fungus	YES
Penicillium verruculosum	fungus	YES
Escherichia coli	gram(-)	YES
Staphylococcus aureus	gram(+)	YES
Streptococcus saprophyticus	gram(+)	YES
Aureobasidium pullulans	yeast	YES
Candida kefir	yeast	YES

Inhibition indication of 'yes' implies at least a 25% reduction in the growth of the organism (as measured by turbidity)

Note: Treatments evaluated at 0, 0.0016, 0.008, 0.04% (v/v)

Based on Spec Reads and combination of IC50 and MIC results

Figure 26. AIC has improved water solubility compared to components used to produce it. It is a 'physical' mix and as safe as raw materials. AIC is antimicrobial and kills fungus (Fusarium sambucinum) and greatly reduces postharvest loss in potatoes. In addition, wounded potatoes treated with AIC heal at the inoculation site.

Eller, F.J., Hay, W.T., Kirker, G.T., Mankowski, M.E., Selling, G.W. 2018. Hexadecyl ammonium chloride amylose inclusion complex to emulsify cedarwood oil and treat wood against termites and wood-decay fungi. International Biodeterioration and Biodegradation. 129:95-101.

Muturi, E.J., Hay, W.T., Behle, R.W., Selling, G.W. 2019. Amylose inclusion complexes as emulsifiers for garlic and asafoetida essential oils for mosquito control. Insects. 10(10):337. https://doi.org/10.3390/insects10100337.

Hay, W.T., Fanta, G.F., Rich, J.O., Schisler, D.A., Selling, G.W. 2018. Antifungal activity of a fatty ammonium chloride amylose inclusion complex against Fusarium sambucinum; control of dry rot on multiple potato varieties. American Journal of Potato Research. 96(1):79-85. https://doi.org/10.1007/s12230-018-9683-8.

Selling, G., Hay, W., Fanta, G., Meyer, S., Zasada, I. (US Patent No. 20,200,323,200) Methods of killing nematodes.

USDA Certified Biobased personal care ingredients from renewable vegetable oils**.** New, economically viable, agri-based materials must be developed to sustain a bioeconomy that includes natural, renewable products to replace petroleum-based products. For example, ultraviolet absorbents used in personal care products such as sunscreen are derived from petroleum-based products and are potentially associated with adverse environmental and health effects. ARS researchers in Peoria, Illinois, developed biobased methods to convert vegetable oils and compounds—which are found in all plants and are particularly abundant in corn and wheat bran—into products for the personal care market. The agri-based products recently earned the USDA Certified Biobased Product label and were shown to perform equally well, if not better, as their petroleum-based counterparts. These biobased commercial ultraviolet absorbents and antioxidants make up part of a $60 million market in the United States and European Union for personal care products made with natural ingredients, a market that is projected to grow 5 percent annually. This research has created new and expanded market opportunities for agricultural commodities and combats climate change by reducing dependence on petroleum-based chemicals.

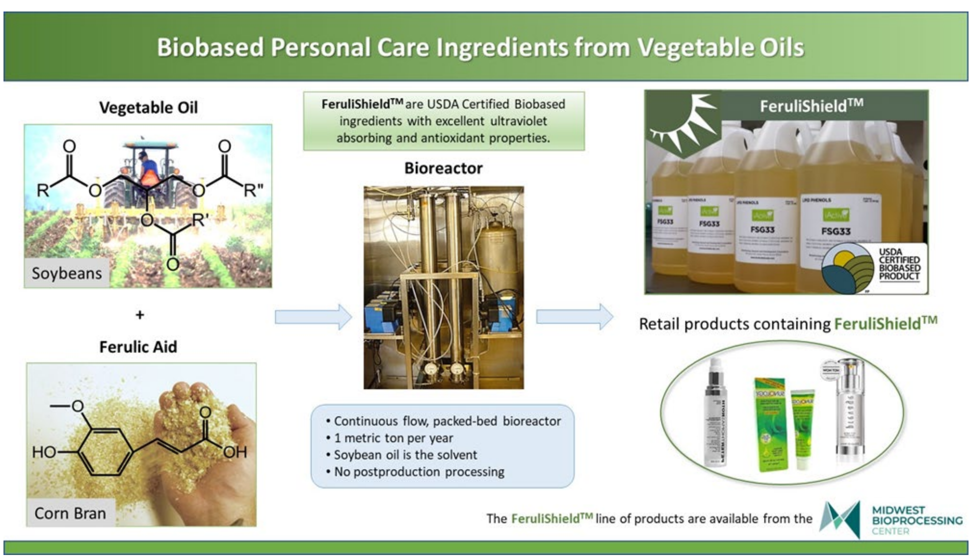


Figure 27. The ARS patented feruloylated soy glycerides technology, marketed under the brand name FeruliShield™, is manufactured by the Midwest Bioprocessing Center, Peoria, IL, and sold as ultraviolet absorbing and antioxidant ingredients for use in personal care formulations.

Figure 28. FeruliShield™ is found in many commercially available personal care products from companies such as Elizabeth Arden, Peter Thomas Roth, Lummea Skin Co, BAK, and dermatologist companies such as Doris Day MD, Hamilton Dermatology, Skin by Marla, Habibi MD, Howington Skincare, Kalia Dermatology, RSVP Med Spa, MD Skinline, Mandel Skincare, Doctor Studio, and Facecraft MD.

Compton, D. L., Goodell, J. R., Evans, K. O. and Palmquist, D. E. 2018. Ultraviolet absorbing efficacy and photostability of feruloylated soybean oil. J. Am. Oil Chem. Soc. 95:421-431. https://doi.org/10.1002/aocs.12047

Compton, D. L., Evans, K. O., Appell, M. and Goodell, J. R. 2019. Protection of antioxidants, vitamins E and C, from ultraviolet degradation using feruloylated vegetable oil. J. Am. Oil Chem. Soc. 96:999-1009. https://doi.org/10.1002/aocs.12255

Compton, D. L., Appell, M., Kenar, J. A. and Evans, K. O. 2020. Enzymatic synthesis and flash chromatography separation of 1,3-diferuloyl-sn-glycerol and 1-feruloyl-sn-glycerol. Methods Protoc. 3:8. https://doi.org/10.3390/mps3010008

Compton, D. L. and Appell, M. 2020. Rapid raman spectroscopic determination of 1-feruloyl-sn-glycerol and 1,3-diferulyol-sn-glycerol. Spectrochim. Acta A. 229:118020. https://doi.org/10.1016/j.saa.2019.118020

Eller, F. J., Compton, D. L. 2023. Using critical carbon dioxide to optimize the enzymatic transesterification of soybean oil and ethyl ferulate to feruloyl soy glycerides. J. Am. Oil. Chem Soc. Published online March 9, 2023. https://doi.org/10.1002/aocs.12690

COMPONENT 3 – BIOREFINING

Through research under Component 3, the U.S. biorefining industry has the potential to supply a significant portion of the national demand for fuels, chemicals, and other high-value U.S. consumable products such as proteins, sugar alcohols, biopolymers, cosmetics, pharmaceuticals, health foods, livestock feeds, biodiesel alternatives, and other advanced biofuels. The production of these bioproducts is not meant to completely replace their petroleum-based counterparts, but rather to supplement their use with a renewable resource base—plants and animal byproducts—to meet demand and to take advantage of low-value crops or byproducts of agricultural production that could increase farmers' profits. As an example, U.S. petroleum refineries are mainly set up to produce gasoline and when fluctuating demand for diesel and jet fuel begins to reduce supply, the price of these fuels inches up. Biodiesel is normally blended with fossil-fuel diesel in various ratios to extend diesel supplies. Refining biodiesel and sustainable aviation fuel from used vegetable oils or the nonfood crop switchgrass helps close that gap and ensures an adequate supply is available to maintain the strength of the U.S. economy.

The goal for biorefining research is to enable new, commercially viable technologies for the conversion of agricultural feedstocks into value-added products and biofuels (mainly renewable diesel and biojet fuel). To achieve this goal ARS scientists will conduct research on:

- 3.A. Viable Technologies for Producing Advanced Biofuels (including renewable diesel), or Other Marketable Biobased Products.
- 3.B. Technologies that Reduce Risks and Increase Profitability in Existing Industrial Biorefineries.
- 3.C. Accurately Estimate the Economic Value of Biochemical, Thermolysis Conversion Technologies.

Problem Statement 3.A: ***Viable technologies for producing advanced biofuels (including renewable diesel), or other marketable biobased products.***

This problem statement focuses on research that can enable biorefineries converting sugar/starch-based feedstocks (such as non-corn grains, oilseeds/energy crops, sweet sorghum, sugar cane, or sugar beets) or plant-derived fiber (such as grain fiber, stover, straw, or bagasse) into biofuel- or diesel-compatible fuel to supplement fossil-based fuels or other marketable biobased products. These agricultural feedstocks may include plant and animal processing wastes or agricultural residues. The following accomplishments highlight research that focuses on these issues.

Overcoming antibiotic resistance using a novel antibiotic. Beta-lactam antibiotics are a class of broad-spectrum (i.e., effective against a large variety of organisms) antimicrobials, which include penicillin derivatives and cephalosporins. The use of these important drugs has been limited over the years with the development of antibiotic resistant bacterial strains. Tunicamycin is a powerful antibiotic that can be combined with beta-lactam antibiotics to overcome this resistance. Scientists have known about this antibiotic for decades, but toxicity in human and animal cells prevented it from being used for therapeutic application. Recently, ARS researchers in Peoria, Illinois, chemically modified tunicamycin into less harmful derivatives. The modified tunicamycins did not show any toxicity to human and hamster cells but were still capable of increasing the efficacy of clinical penicillin-based drugs from 32 to 64 times. This significant discovery now allows older type antibiotics to once again be effective; it is an important step towards combating drug resistance and is currently being evaluated by a U.S. drug company.

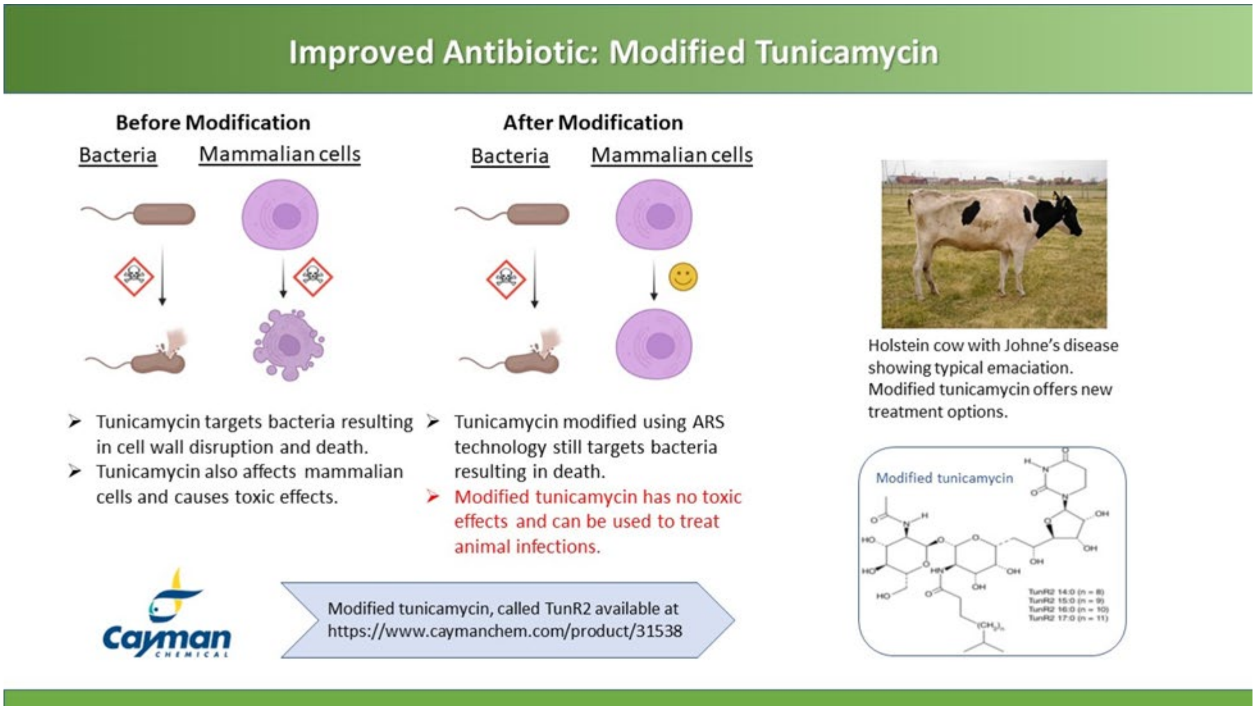


Figure 29. Tunicamycin modified using ARS proprietary technology can be used alone or combined with other antibiotics to target bacteria without toxicity associated with unmodified tunicamycin.

Hering, J., Dunevall, E., Snijder, A., Eriksson, P., Jackson, M.A., Hartman, T.M., Ting, R., Chen, H., Price, N.P., Branden, G., Ek, M. 2020. Exploring the active site of the antibacterial target MraY by modified tunicamycins. ACS Chemical Biology. 15(11):2885-2895. https://doi.org/10.1021/acschembio.0c00423.

Price, N.J.P., Jackson, M.A., Singh, V., Hartman, T.M., Dowd, P.F., Blackburn, J.A. 2019. Synergistic enhancement of beta-lactam antibiotics by modified tunicamycin analogs TunR1 and TunR2. Journal of Antibiotics. 72(11):807-815. https://doi.org/10.1038/s41429-019-0220-x.

Price, N. (US Patent No. 10,513,533 B2) Tunicamycin related compounds with anti-bacterial activity.

Price, N.P.J., Jackson, M.A., Vermillion, K.E., Blackburn, J.A., Li, J., & Yu, B. 2017. Selective catalytic hydrogenation of the N-acyl and uridyl double bonds in the tunicamycin family of protein N-glycosylation inhibitors. Journal of Antibiotics. 70:1122-1128. https://doi.org/10.1038/ja.2017.141.

Price, N.P.J., Hartman, T.M., Li, J., Velpula, K.K., Naumann, T.A., Guda, M.R.,Yu, B., Bischoff, K.M. 2017. Modified tunicamycins with reduced eukaryotic toxicity that enhance the

antibacterial activity of ß-lactams. Journal of Antibiotics. 70(11):1070-1077. https://doi.org/10.1038/ja.2017.101.

Hemp THC concentrations: development and validation of a universal measurement protocol. Total THC concentrations in commercial hemp materials cannot exceed 0.3 percent. Meeting this standard has been a challenge to U.S. hemp producers and requires clear and reproducible analytical methodology. ARS researchers in Peoria, Illinois, developed a rapid 10-minute measuring procedure to determine 20 different cannabinoids and validated a reproducible ethanol extraction method to be used worldwide to analyze for tetrahydrocannabinoid (delta-9 tetrahydrocannabinol, and tetrahydrocannabinolic acid). In collaboration with NIST, researchers participated in an analysis of three uniform samples examined by 130 labs and found that postprocessing methods can generate variable results. Findings were presented in 2022 at several research conferences including Phytochemical Society of North America, Hemp Research Needs, World Congress on Polyphenols Applications, and Cannabis Research Conference. The Global Hemp Innovation Center at Oregon State University currently requires this rapid ARS protocol (ghic_op-3_sops_for_hemp_-_cannabinoid_analyses.pdf (oregonstate.edu)) for measuring the THC in all hemp samples. It should also be noted that the ARS Plant Genetic Resources Unit in Geneva, New York incorporates this ARS protocol into the USDA Hemp Descriptor and Phenotyping Handbook, Version 3, edited by Zachary Stansell, Tyler Gordon, Anthony Barraco, Daniel Meyers, Anthony Rampulla, Tori Ford, Anya Osatuke (Hemp Phenotyping and Descriptors Handbook : USDA ARS).

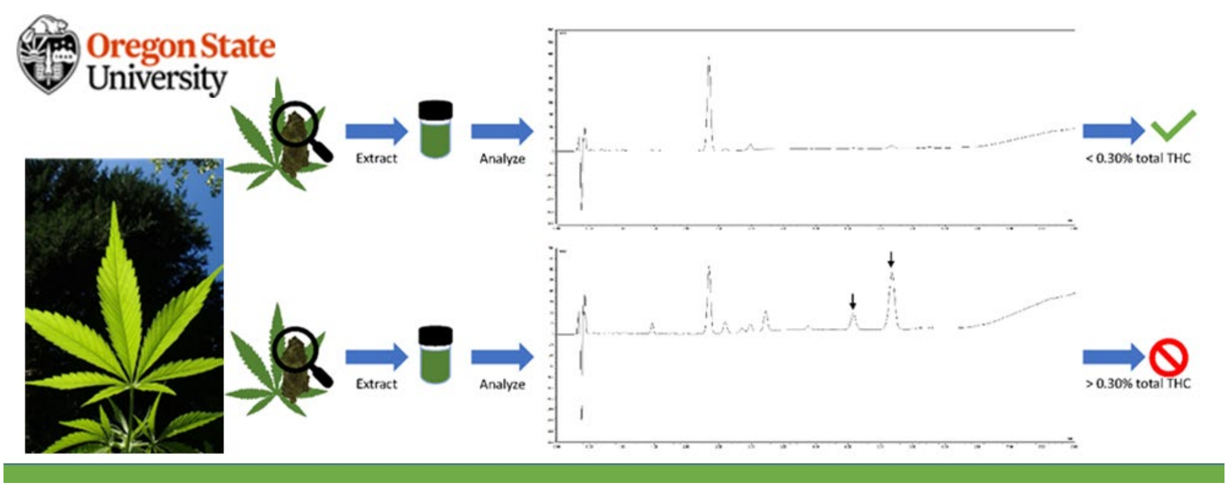


Figure 30. Hemp is grown for its fibers, oils, and supplements. The 2018 Farm Bill states that the total THC in industrial hemp must be less than 0.30 percent. To ensure that industrial hemp is legally compliant a rapid and robust procedure was developed for growers and breeders that was capable of measuring 20 different cannabinoids in 10 minutes to evaluate breeding lines.

Berhow, M., Gude, K., Vermillion, K., Brownstein, K. 2022. Analysis of cannabinoids, flavonoids and anthocyanins in hemp plants. Abstract presented at the Phytochemical Society of North America 2022 Conference, Virginia Tech University, Blacksburg, VA, July 24-28, 2022.

Berhow, M., Brownstein, K., Gude, K., Alonso, M., Kinney, C., Duringer, J. 2022. Evaluation of variation in lab-to-lab measurements of hemp cannabinoids. Abstract presented at the 2022 Cannabis Research Conference, August 8-10, 2022. Virtual Workshop.

Duringer, J., Brownstein, K., Berhow, M. 2022. Methods of quantitative analysis for cannabinoids, terpenes and flavonoids in industrial hemp. Abstract presented at the 15th World Congress on Polyphenols Applications, Valencia, Spain, Sept 28-30, 2022. https://www.polyphenols-site.com

Berhow, M., Brownstein, K. 2022. Measuring the phytochemical composition of hemp products for use as feeds. Abstract presented at the Hemp Feed Workshop, Oct 26-27, 2022, Oregon State University, Corvallis, Oregon.

Berhow, M., Gude, K., Brownstein, K. 2022. Evaluation of accurate measurements of hemp cannabinoids and phenolics. Abstract presented at the Hemp Research Needs (Oregon State University and USDA Workshop). Nov 15, 2022. Virtual Workshop.

Sustainable production of butyric acid. Butyric acid is a short-chain fatty acid that can be used as flavoring agents in feeds and foods. It can also be incorporated into perfumes, pharmaceuticals, plastics, and textile auxiliaries. Historically butyric acid has been produced from petrochemicals, but the renewable feedstock production of butyric acid addresses both sustainability concerns and satisfies consumer preferences when used as food additives or cosmetic products. ARS scientists in Peoria, Illinois, used agricultural residues including wheat straw, corn fiber, and paper mill sludge (PMS) to produce butyric acid via a microbial fermentation route. The pulp and paper making process produces about 300–350 million tons of PMS every year and the majority is disposed of by landfill. The research has led to applications in recycling and reuse of paper mill waste.

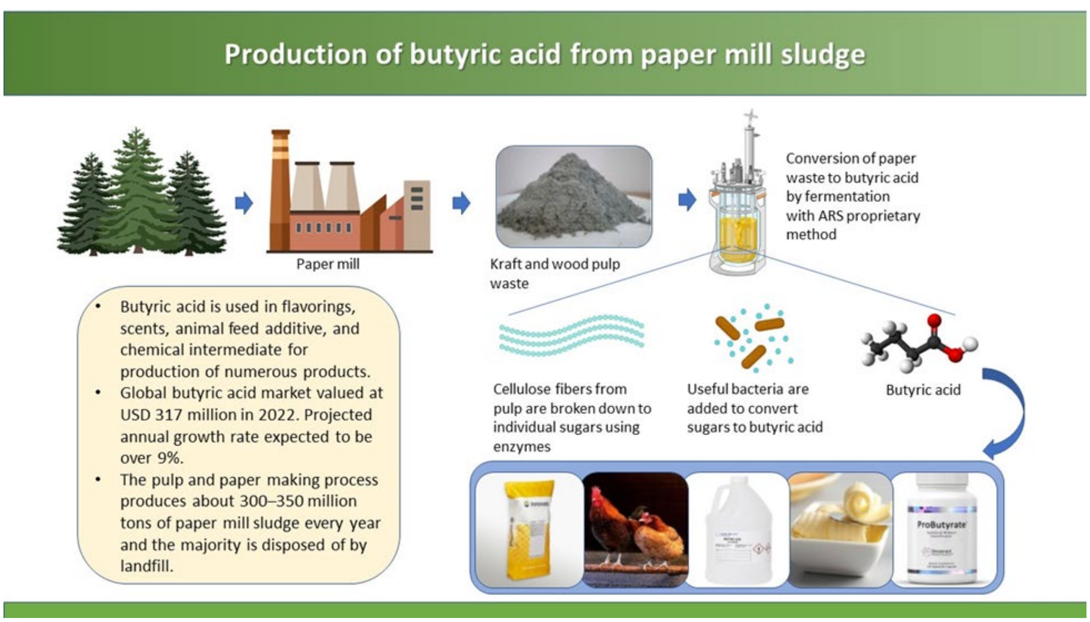


Figure 31. Novel bacterial strain isolated by ARS can be utilized to convert waste product from paper mills to butyric acid, which is used in numerous commercial products.

Qureshi, N., Liu, S., Saha, B.C. 2022. Butyric acid production by fermentation: employing potential of the novel Clostridium tyrobutyricum strain NRRL 67062. Fermentation. 8(10): Article 491. https://doi.org/10.3390/fermentation8100491.

Liu, S., Duncan, S., Qureshi, N., Rich, J.O. 2018. Fermentative production of butyric acid from paper mill sludge hydrolysates using Clostridium tyrobutyricum NRRL B67062/RPT 4213. Biocatalysis and Agricultural Biotechnology. 14:48-51. https://doi.org/10.1016/j.bcab.2018.02.002.

Sensor genes to engineer enhanced cell protection mechanisms in yeast. When renewable plant biomass is processed to yield simple sugars used to create biofuel, the byproducts such as furfural and hydroxymethyl furfural (HMF) are also generated. These byproducts inhibit further microbial conversion of these sugars into fuels or chemicals, greatly reducing the process efficiency and increasing the cost of biofuel production. ARS scientists in Peoria, Illinois, identified a gene in a specific yeast capable of detecting the presence of furfural and HMF and that prompts cell protection mechanisms with improved resistance to inhibitors. Robust industrial yeast strains are vital to low-cost fuels and chemicals from renewable plant biomass and the advancement of U.S. energy independence, a strong rural economy, and preservation of the environment.

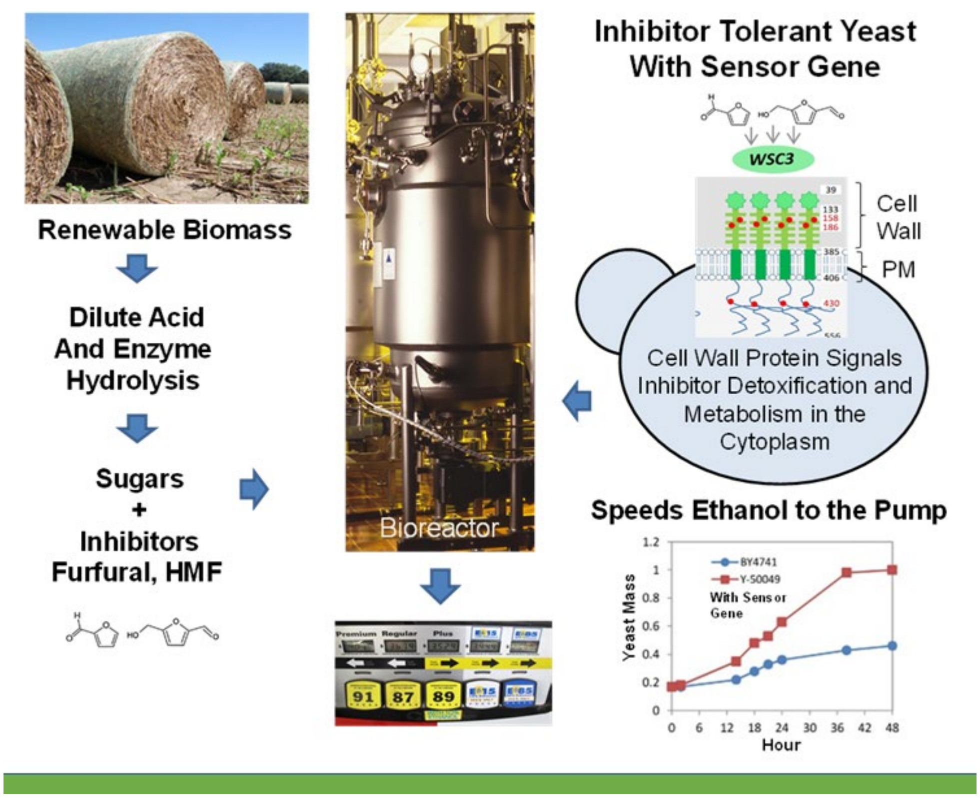


Figure 32. A robust yeast strain Saccharomyces cerevisiae NRRL Y-50049 developed at ARS (Peoria, IL) contains a gene WSC3 that expresses a cell wall protein in response to sensing the inhibitors furfural and HMF. The protein encoded by WSC3 signals enzyme production in the cytoplasm which enables inhibitor detoxification, allowing this yeast to grow and make ethanol more quickly in a bioreactor fed the sugars that are produced during hydrolysis of cellulosic biomass. The cell wall and plasma membrane (PM) are magnified to illustrate the location of the signaling protein which communicates to the cell cytoplasm to prepare for inhibitor detoxification, protect the cell, and allow sugar metabolism. Depicted by red dots, the development of the yeast led to amino acid alterations in the sensor protein that improved cell growth and fermentation.

Liu, Z.L., Wang, X., Weber, S.A. 2018. Tolerant industrial yeast Saccharomyces cerevisiae possesses a more robust cell wall integrity signaling pathway against 2-furaldehyde and 5-(hydroxymethyl)-2-furaldehyde. Journal of Biotechnology. 276-277:15-24. doi: 10.1016/j.jbiotec.2018.04.002.

Liu, Z.L. 2018. Understanding the tolerance of the industrial yeast Saccharomyces cerevisiae against a major class of toxic aldehyde compounds. Applied Microbiology and Biotechnology. 102(13):5369-5390. doi: 10.1007/s00253-018-8993-6.

Improved products using nanocellulose derived from corn stover. Cellulose is the polymer found in plants and is responsible for the plant's strength. If cellulose is reduced to 'nano' scale (one billionth of a meter) it is called nanocellulose (NC). NC produced from corn stover was developed by ARS scientists in Peoria, Illinois. NC has been shown to provide value in many end uses, including polymer blends, medical devices, cosmetics, and for to waste treatment. In all these applications, the NC must flow (be pumped) from one location to the next. For the full value of corn stover NC to be realized, its flow properties must be understood. By using state of the art techniques, the flow properties of NC suspensions were determined allowing for improved NC based products to be produced. Developing a high-value use for excess crop residue typically left on the corn field will provide additional benefits for corn producers and processors.

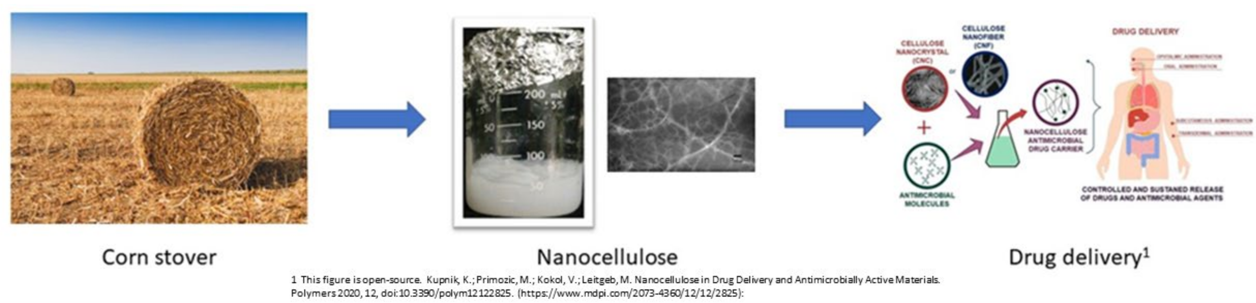


Figure 33. Corn stover nanocellulose suspensions flow properties were identified so the corn stover suspension is an optimized carrier for drug delivery.

Xu, J., Krietemeyer, E.F., Boddu, V.M., Liu, S.X., Liu, W. 2018. Production and characterization of cellulose nanofibril (CNF) from agricultural waste corn stover. Carbohydrate Polymers. 192:202-207. https://doi.org/10.1016/j.carbpol.2018.03.017

Xu, J., Boddu, V.M., Liu, S.X., Liu, W.-C. 2020. A comparative study of microrheology of nanocellulose produced from corn stover using diffusing wave spectroscopy (DWS) and mechanical rheometry. Cellulose Chemistry and Technology. 54(1-2):27-32. https://doi.org/10.35812/CelluloseChemTechnol.2020.54.03.

Xu, J., Liu, W.-C., Boddu, V.M., 2018. Viscoelastic Properties of Microfibrillated Cellulose (MFC) Produced From Corn Stover. Cellulose Chemistry and Technology, 52 (5-6), 337-342.

Problem Statement 3.B: ***Technologies that reduce risks and increase profitability in existing industrial biorefineries.***

Biorefineries and biodiesel facilities are subject to large swings in profitability due to volatility in feedstock cost and selling price. Although modern facilities are efficient, improvements in operational robustness and efficiencies could have significant effects on economic viability. In addition, retooling bioconversion facilities to produce advanced biofuels, biodiesel, and other marketable coproducts, or to increase the value of existing products from feedstocks, will decrease business risk and increase long-term profitability of these biorefineries. The following accomplishments highlight research that focuses on these issues.

Antibiotic alternative for to increase fuel ethanol production. Most fuel ethanol facilities use baker's yeast to ferment sugars from agricultural products to alcohol. Bacterial contamination in large-scale production plants is unavoidable, so efforts usually focus on controlling levels of these bacteria. Contaminating bacteria compete for the same sugars that are used by the yeast and they often synthesize byproducts that inhibit the ability of the yeast to grow. Chronic and acute contamination problems significantly reduce the economic viability of the U.S. fuel ethanol industry. While antibiotics can be used to control the contamination, alternatives are preferred to avoid overuse of antibiotics to combat these infections and eliminate the presence of antibiotic residues in fuel ethanol coproducts. ARS scientists in Peoria, Illinois, developed technology to control contamination using enzymes found in viruses that target contaminating bacteria. Studies have shown that these novel enzymes are able to reduce contamination 1,000-fold in a typical corn mash fermentation and restore ethanol productivity back to normal. These findings will allow ethanol producers to improve the efficiency of their fermentation and reduce the use of antibiotics in their plants.

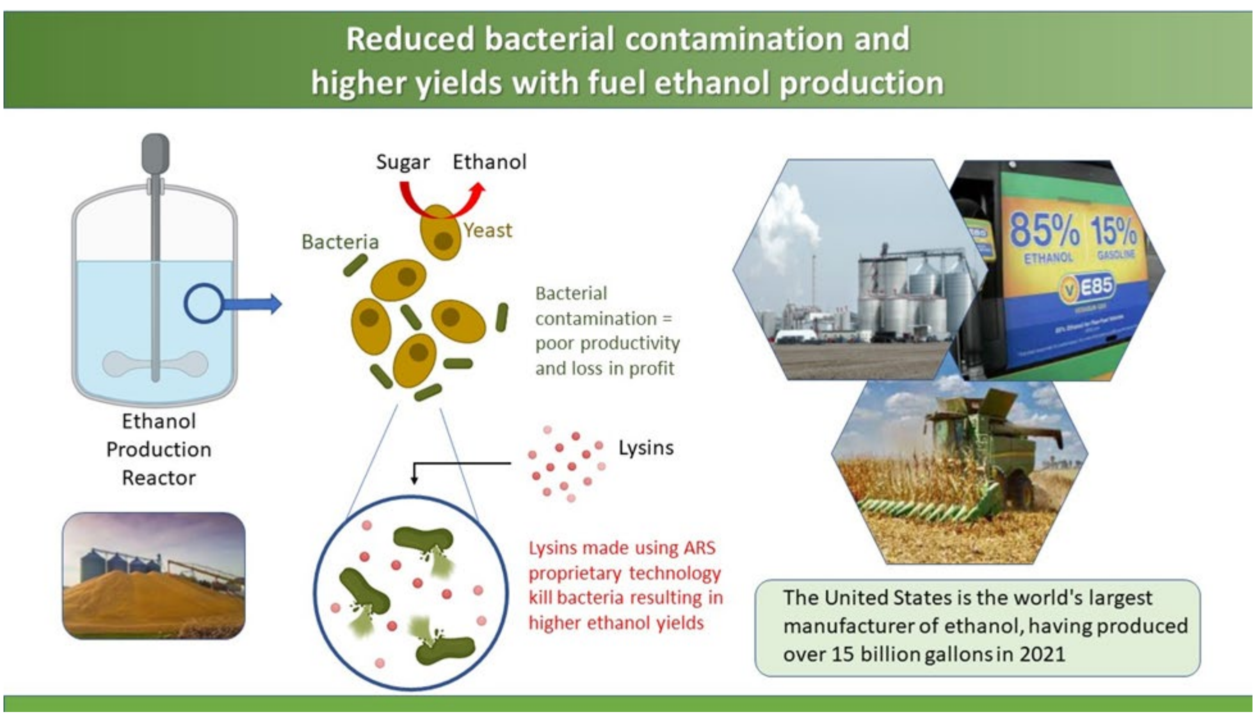


Figure 34. Enzymes that target and kill bacteria contaminating fuel ethanol facilities have been developed by ARS and can be used to improve efficiency for conversion of agricultural sugars to ethanol.

Lu, S.Y., Bischoff, K.M., Rich, J.O., Liu, S., Skory, C.D. 2020. Recombinant bacteriophage LysKB317 endolysin mitigates Lactobacillus infection of corn mash fermentations. Biotechnology for Biofuels. 13. Article 157. https://doi.org/10.1186/s13068-020-01795-9.

Rich, J.O., Anderson, A.M., Leathers, T.D, Bischoff, K.M., Liu, S., and Skory, C.D. 2020. Microbial contamination of commercial corn-based fuel ethanol fermentations. Bioresource Technology. 11:100433. https://doi.org/10.1016/j.biteb.2020.100433.

Rich, J.O., Bischoff, K.M., Leathers, T.D., Anderson, A.M., Liu, S., Skory, C.D. 2018. Resolving bacterial contamination of fuel ethanol fermentations with beneficial bacteria – an alternative to antibiotic treatment. Bioresource Technology. 247:357-362. https://doi.org/10.1016/j.biortech.2017.09.067

Developing yeast as a source of oil for production of green jet fuel or biodiesel. U.S. airlines have committed to reducing carbon dioxide emissions by 50 percent in 2050. This has created pent up demand for renewable jet fuel to replace the fossil-fuel-based 23 billion gallon per year jet fuel market. ARS scientists in Peoria, Illinois, assembled a collection of yeasts from the ARS Yeast culture collection (Peoria, IL) that convert agriculture waste into bio-oil, which is expected to be easily converted into biodiesel or renewable jet fuel. These yeasts include Lipomyces, Yarrowia, and Rhodotorula. One of these yeasts (Rhodotorula toruloides) was used in a pilot demonstration at a commercial development center to convert sugarcane bagasse into bio-oil; the yeast produced 14 gallons of bio-oil per ton of agricultural waste. The oil had a similar composition to vegetable oils currently used for production of green jet fuel and biodiesel. The demonstration was done with partners at the Integrated Bioprocessing Research Laboratory (Urbana) and Center for Advanced Bioenergy and Bioproducts Innovation (Urbana – a Department of Energy Bioenergy Center), and it showed that this exceptional native yeast is robust enough to produce bio-oil using industrially processed biomass. This accomplishment supports the President's mandate to reduce fossil fuels and convert underutilized agricultural residues into a value-added, green biofuels that support rural economies.

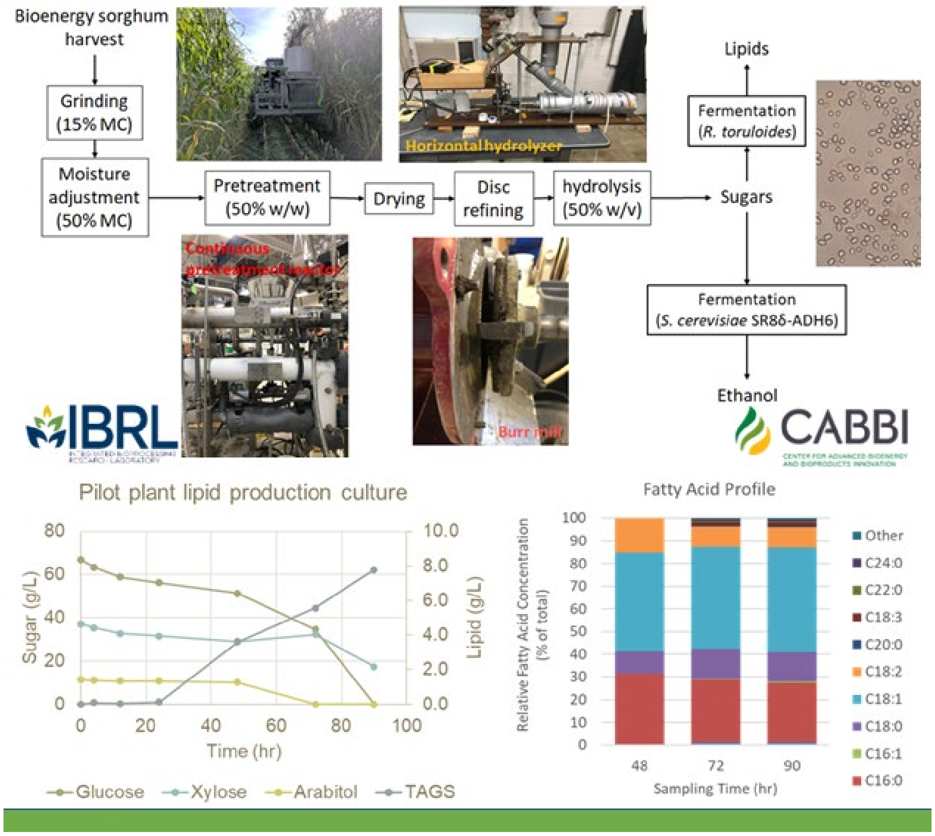


Figure 35. Field grown bioenergy sorghum was harvested at University of Illinois and processed at high solids with cellulases to produce a concentrated sugar syrup. The syrup was fermented to either fuel ethanol or lipids (e.g., oil) using yeast S. cerevisiae and R. toruloides, respectively. Production of yeast lipids from cellulosic sugars (bottom left) prepared in a commercial pilot plant (IBRL, Urbana, IL). The fatty acid profile of the lipids (e.g., oil) makes it favorable for conversion to biodiesel or green jet fuel (bottom right).

Slininger, P.J., Dien, B.S., Quarterman, J.C., Thompson, S.R., Kurtzman, C.P. 2019. Screening for oily yeasts able to convert hydrolyzates from biomass to biofuels while maintaining industrial process relevance. Methods in Molecular Biology. 1995:249-283. https://doi.org/10.1007/978-1-4939-9484-7_16.

Cheng, M., Dien, B.S., Jin, Y.S., Thompson, S., Shin, J., Slininger, P.J., Qureshi, N., Singh, V. 2021. Conversion of high-solids hydrothermally pretreated bioenergy sorghum to lipids and ethanol using yeast cultures. ACS Sustainable Chemistry & Engineering. 9(25):85158525. https://doi.org/10.1021/acssuschemeng.1c01629.

Deshavath, N.N., Dien, B.S., Slininger, P.J., Jin, Y.S., Singh, V. 2022. A chemical-free pretreatment for biosynthesis of bioethanol and lipids from lignocellulosic biomass: an industrially relevant 2G biorefinery approach. Chemical Engineering Journal. 9(1): Article 5. https://doi.org/10.3390/fermentation9010005.

Singh R, Dien BS, Singh V. Response surface methodology guided adsorption and recovery of free fatty acids from oil using resin. Biofuels, Bioproducts and Biorefining. 2021 Sep;15(5):1485-95.

Singh R, Dien BS, Singh V. Solvent-free enzymatic esterification of free fatty acids with glycerol for biodiesel application: Optimized using the Taguchi experimental method. Journal of the American Oil Chemists' Society. 2022 Sep;99(9):781-90.

New renewable, plant-based engine oil additive. There is a great demand in the United States and the world to find new biobased engine additives to help improve lubricant issues found in fossil-fuel based oils. The purpose of an oil is to provide lubrication between two moving metal surfaces. The oil must be of low viscosity (water-like) to penetrate the contact areas yet be viscous enough to provide separation between the moving surfaces at all operating temperatures. But as oils heat up in engines, their viscosities (how thick an oil is) change and they are unable to maintain good separation of the moving parts. ARS scientists in Peoria, Illinois, created and commercialized estolides (made from sunflower, cuphea, pennycress, and soybean oils) to develop a new type of engine oil additive that solves engine lubrication problems. When small amounts of these materials are added to an engine oil, the oil's viscosity remains nearly constant over a broad range of temperatures. These new materials are beneficial to farmers, consumers, and retailers because they are environmentally friendly, improve utilization of soybean and sunflower production, and enhance economic security for rural communities. ARS research helped launch a private company that led to 7.5 million in A-1 funding to produce a sustainable and high performance biobased synthetic motor oil that is commercially available.

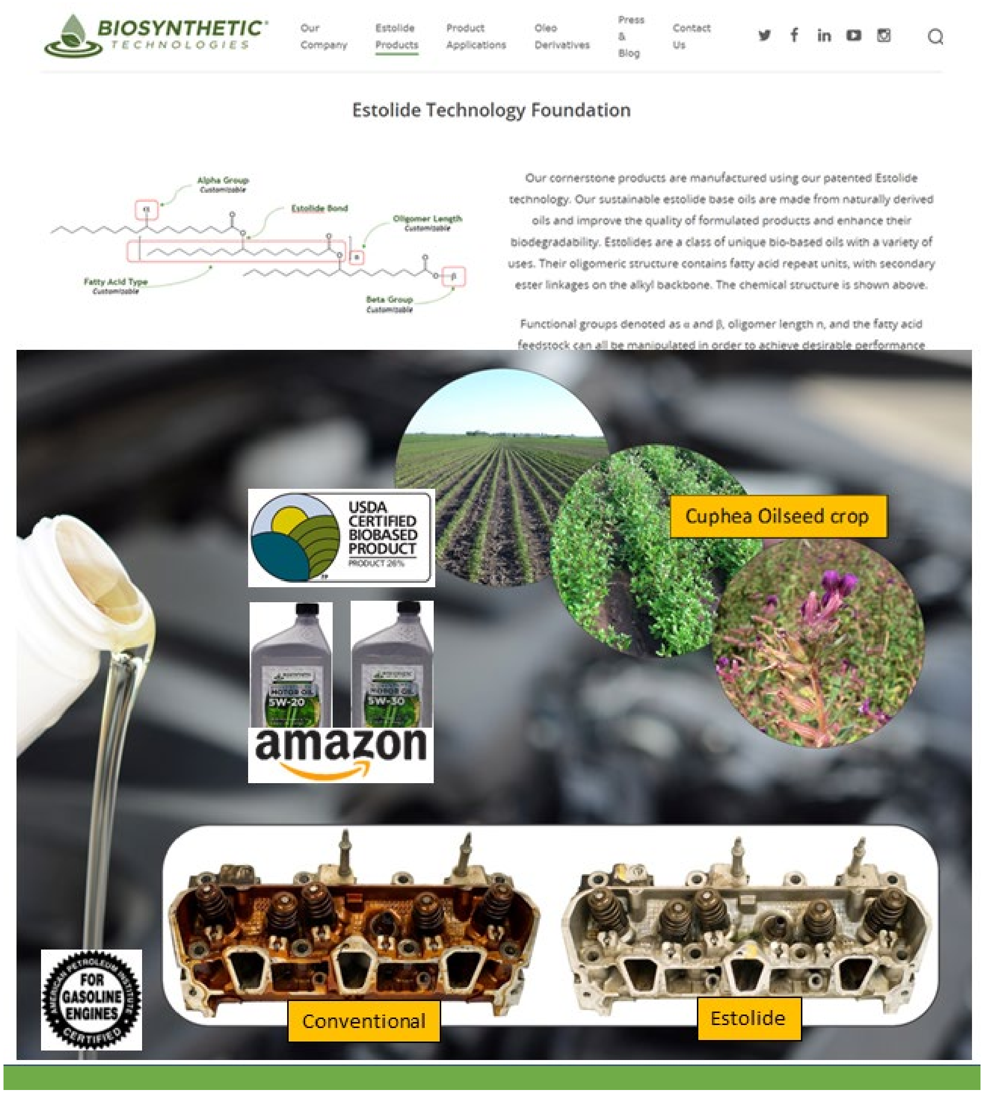


Figure 36. In collaboration with Biosynthetic Technologies, ARS scientists patented a new class of ester molecules that make biobased synthetic motor oils and lubricants a reality. These synthetic oils have proven to make engines run cleaner and last longer, as well as provide better fuel economy. Cylinder head comparison from two engines used in 150,000 mile field trials show the conventional motor oil formulation (left) had typical levels of varnish, while the estolide formulation (right) showed a high degree of overall cleanliness and minimal varnish. These products are mainstream and available at Amazon as passenger car motor oils with American Petroleum Institute (API) certification.

Biosynthetic® Technologies Commercializes Its First in Class High-Performing Biobased Synthetic Motor Oil Using High-Oleic Soybean Oil from Soybeans Grown by U.S. Farmers.

NEWS PROVIDED BY
Biosynthetic Technologies →
25 Oct, 2019, 09:14 ET

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INDIANAPOLIS, Oct. 25, 2019 /PRNewswire/ -- Biosynthetic® Technologies today announced the commercial availability of a high-performing biobased synthetic motor oil using high-oleic soybean oil from soybeans grown by U.S. farmers. The Department of Defense and Washington, D.C. area fleet demonstrations found the product meets or exceeds their performance requirements. Biosynthetic® Technologies' motor oil is also recognized as a United States Department of Agriculture (USDA) Certified Biobased Product meeting the federally mandated purchasing initiative known as the "BioPreferred Program."

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BIOSYNTHETIC® TECHNOLOGIES RAISES $7.5M LED BY HG VENTURES

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Biosynthetic Technologies →
02 Feb, 2022, 09:00 ET

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INDIANAPOLIS, Feb. 2, 2022 /PRNewswire/ -- Biosynthetic® Technologies, LLC today announced that it has raised $7.5 million in a series A-1 funding led by HG Ventures, the corporate venture arm of The Heritage Group, headquartered in

Figure 37. Biosynthetic® Technologies in partnership with ARS scientists commercializes its first-in-class high-performing biobased synthetic motor oil made using high-oleic soybean oil from soybeans grown by U.S. farmers, and raises $7.5M in series A-1 funding led by HG Ventures.

Bantchev, G.B., Cermak, S.C., and Durham, A.L. Estolide molecular weight distribution via gel permeation chromatography. J. Am. Oil Chem. Soc. 96:365-380. 2019 https://doi.org/10.1002/aocs.12165

Isbell, T.A., Lowery, T.A., Vermillion, K., and Cermak, S.C. Synthesis and characterization of polyethylene glycol diesters from estolides containing epoxides and diols. J. Am. Oil Chem. Soc. 97:409-423. 2020. http://dx.doi.org/10.1002/aocs.12336

Isbell, T.A., Lowery, T.A., and Cermak, S.C. Viscometric properties of polyethylene glycol di-esters of estolides. J. Am. Oil Chem. Soc. 97:425-435. 2020. http://dx.doi.org/10.1002/aocs.12334

Chen, Y., Biresaw, G., Cermak, S., Isbell, T., Ngo, H., Chen, L., and Durham, A. Synthesis, properties, and applications of estolides-A review. J. Am. Oil Chem. Soc. 97:232-241. 2020. http://dx.doi.org/10.1002/aocs.12323

Biresaw, G., Chen, Y., Chen, L., Ngo, H., Wagner, K., Vermillion, K.E., and Cermak, S.C. Iso-oleic estolide products with superior cold flow properties, Industrial Crops and Products, 182, 2022, 114857, https://doi.org/10.1016/j.indcrop.2022.114857

Bantchev, G. B. and Cermak, S. C. Correlating viscosity of 2-ethylhexyl oleic estolide esters to their molecular weight. Fuel 309: 122190. 2022. http://dx.doi.org/10.1016/j.fuel.2021.122190

Biresaw, G., Chen, Y., Chen, L., Ngo, H., Wagner, K., Vermillion, K., Cermak, S. Iso-oleic estolide products with superior cold flow properties, Industrial Crops and Products, Volume 182, 2022, 114857, https://doi.org/10.1016/j.indcrop.2022.114857.

Cermak, S.C., Isbell, T.A., and Durham, A.L. Bio-based estolide compositions. (US Patent 10,562,840).

Isbell, T.A., Cermak, S.C. and Lowery, B.A. Polyethylene diester viscosity modifiers. (US

Patent 11,104,859 B2).

Cermak, S.C., Isbell, T.A., and Durham, A.L. Bio-based estolide compositions. (US Patent Application 2019/0092715 A1).

Biresaw, G., Cermak, S.C., and Helen N.L. Bio-based branched estolide compounds. (US Patent Application 2021/0230097 A1).

Isbell, T.A., Cermak, S.C., and Lowery, B.A. Polyethylene diester viscosity modifiers. (US Patent Application 2021/0047580 A1).

Low-cost production of high-value plant-based xylitol. Xylitol is a naturally occurring sweetener that has 40 percent fewer calories than table sugar and has been shown to improve dental health and prevent ear infections. These desirable health-related attributes support the use of xylitol in pharmaceutical and personal-care products, and as an alternative sweetener in gums and mints. Xylitol currently sells for $2.05/lb and has a global market value of $737 million. Xylitol is difficult to extract from natural sources and because the current petroleum-based chemical method of production has high energy and cost demands, a simpler, cheaper, biological route to xylitol processing is preferred. ARS scientists in Peoria, Illinois, determined the effect of several factors on xylitol processing using an inexpensive microbe that makes xylitol from the sugar xylose found in renewable plant biomass. This microbe is resistant to inhibitors of the types encountered in bioprocessing of biomass into fuels and chemicals, and production of xylitol from fibrous biomass is a new use of agricultural-harvesting residues that are typically viewed as low-value or waste material. Working with the biotechnology company zuChem Inc. (Peoria, IL) and the Biotechnology Research and Development Corp. (Peoria, IL), ARS researchers developed a new microbial strain for efficient production of xylitol from agricultural waste. This technology was licensed to the Sweet Appeal food ingredient company and is being marketed globally.

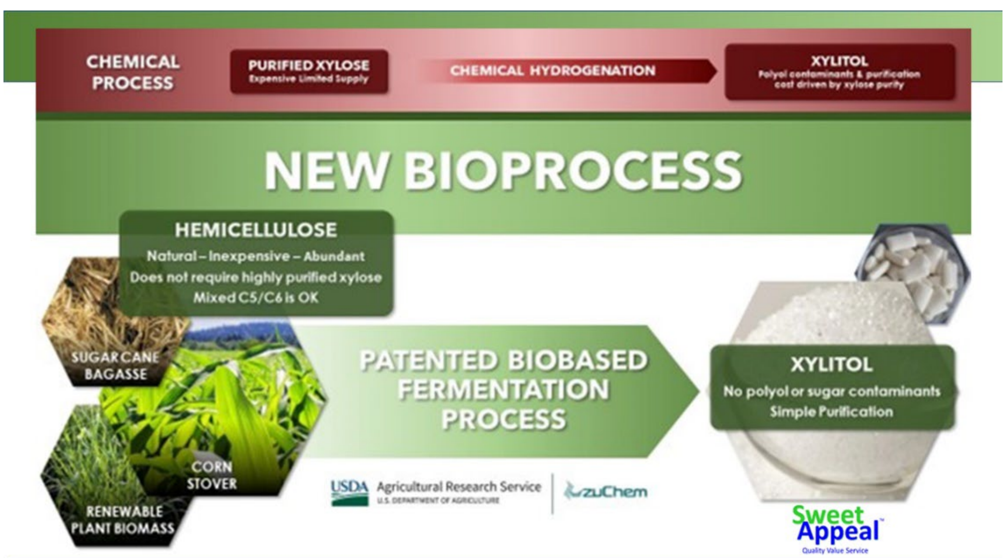

Figure 38. ARS scientists working with zuChem developed a new xylitol bioprocess that is green and uses agricultural crop residues and other biomass. Researchers developed a microbe that allowed for commercial production of xylitol by this greener bioprocess route. In the past, xylitol (alternative sweetener) has been produced in a chemical process which is energy intensive, produces byproducts and requires an expensive starting material. This new bio-based bioprocessed xylitol is sold by Sweet Appeal (Naperville, IL), a joint venture between Harbin Yimei Bioengineering Technology Co., LTD and zuChem.

Saha, B. C., & Kennedy, G. J. (2020). Production of xylitol from mixed sugars of xylose and arabinose without co-producing arabitol. Biocatalysis and Agricultural Biotechnology, 29, 101786.

Saha, B. C., & Kennedy, G. J. (2021). Optimization of xylitol production from xylose by a novel arabitol limited co-producing Barnettozyma populi NRRL Y-12728. Preparative Biochemistry & Biotechnology, 51(8), 761-768.

High purity biophenol from renewable biomass**.** Phenol is a chemical with a $19.4 billion global market. It is made from petroleum and used to make many everyday products, such as plastics, pharmaceutical drugs, and herbicides. U.S. companies produce more than 1 million tons of phenol per year (with increasing demand), and they are under pressure to make it in a way that is environmentally friendly and cost-effective. ARS scientists in Wyndmoor, Pennsylvania, successfully made phenol from non-food biomass. The scientists took switchgrass and used a high temperature process to convert it into bio-oil that is similar to petroleum but contains relatively high levels of phenol. Then they separated out the phenol from the other components using processes similar to processes used in oil refineries, but with novel hardware changes. The result is a method to make phenol without expensive additives and with less complicated processes. The remainder of the oil is used to produce biofuels, and production of phenol as a high value coproduct can reduce the minimum selling price of that fuel. Advancing this technology will reduce the need for both fossil-based fuels and phenol and reduce fossil greenhouse gas emissions. GlaxoSmithKline is interested in a source of renewable phenol and indicated they would be a customer of a company that used this technology to supply it.

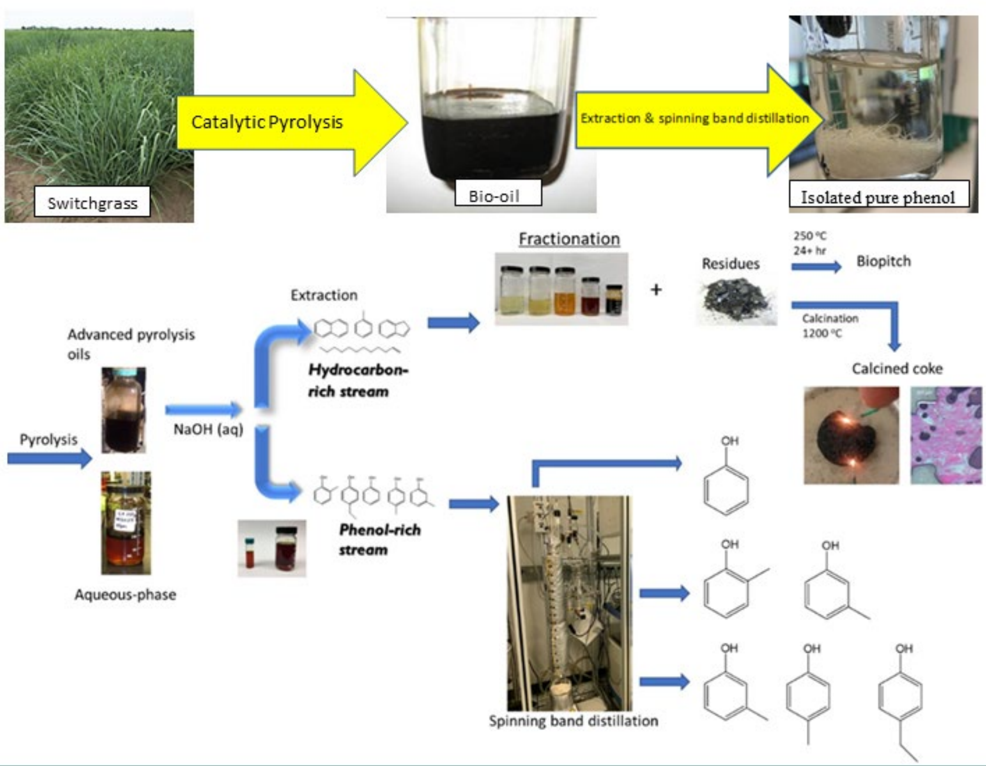

Figure 39. ARS scientists developed a method to produce phenol from switchgrass without expensive additives and complex processes. Overall flow process flow diagram for isolation of biomass pyrolysis oil phenols that uses advanced pyrolysis processes to produce bio-oils (higher quality, lower chemical class diversity, and greater potential for full utilization via refining into both fuels and renewable petrochemical substitutes).

Elkasabi, Y., Jones, K., Mullen, C., Strahan, G., Wyatt, V. 2023. Spinning band distillation of biomass pyrolysis oil phenolics to produce pure phenol. Separation and Purification Technology 314 (2023) 123603. https://doi.org/10.1016/j.seppur.2023.123603

Problem Statement 3.C: ***Accurately estimate the economic value of biochemical, thermolysis conversion technologies.***

The viability and sustainability of a commercial process is a function of its economic competitiveness. In turn, the potential impact of a new biorefining technology is a function of its anticipated effect on the production economics for a commercial biorefinery. By knowing the major cost components for a process technology, ARS researchers can focus their efforts to yield the most impact. Therefore, technoeconomic analyses will be conducted to accurately estimate the expected economic effect of ARS biorefining research. The following accomplishments highlight research that focuses on these issues.

High-performance, ultra-low-viscosity composite base fluids containing biobased oils derived from soy. Composite fluids are obtained by blending petroleum-based polyalphaolefins (PAOs) with base lubricant oils derived from vegetable oils. Blending allows these composite fluids to meet bio-content requirements (e.g., 34 percent for two-cycle engine oil according to the USDA BioPreferred® standard) without compromising cost or performance and meeting API standards. These lubricants consisted of vegetable oil with an additive package to make oils suitable for lower end applications such as chain bar oil, bike chain oils, and basic lubricant type spray oils. Biobased polyester fluids synthesized from soybean oil by ARS scientists in Peoria, Illinois, were investigated for their application as ultra-low-viscosity composite fluids. This occurred in collaboration with scientists at Argonne National Laboratory. Ultra-low-viscosity composite fluids are preferred for engine oil formulations because they generate very low friction when sheared, which translates into higher fuel efficiency, lower fuel consumption, lower tailpipe emissions, and improved air quality. The investigation showed that blending up to 40 percent of biobased polyesters with ultra-low-viscosity PAOs caused a very slight changes in viscosity. In addition, this composite fluid gave lower friction and more than 10-fold lower wear than either pure PAO or vegetable oil polyester. This work indicated that successful commercialization of composite fluids have the potential to generate new markets for soybean and other oilseed crops.

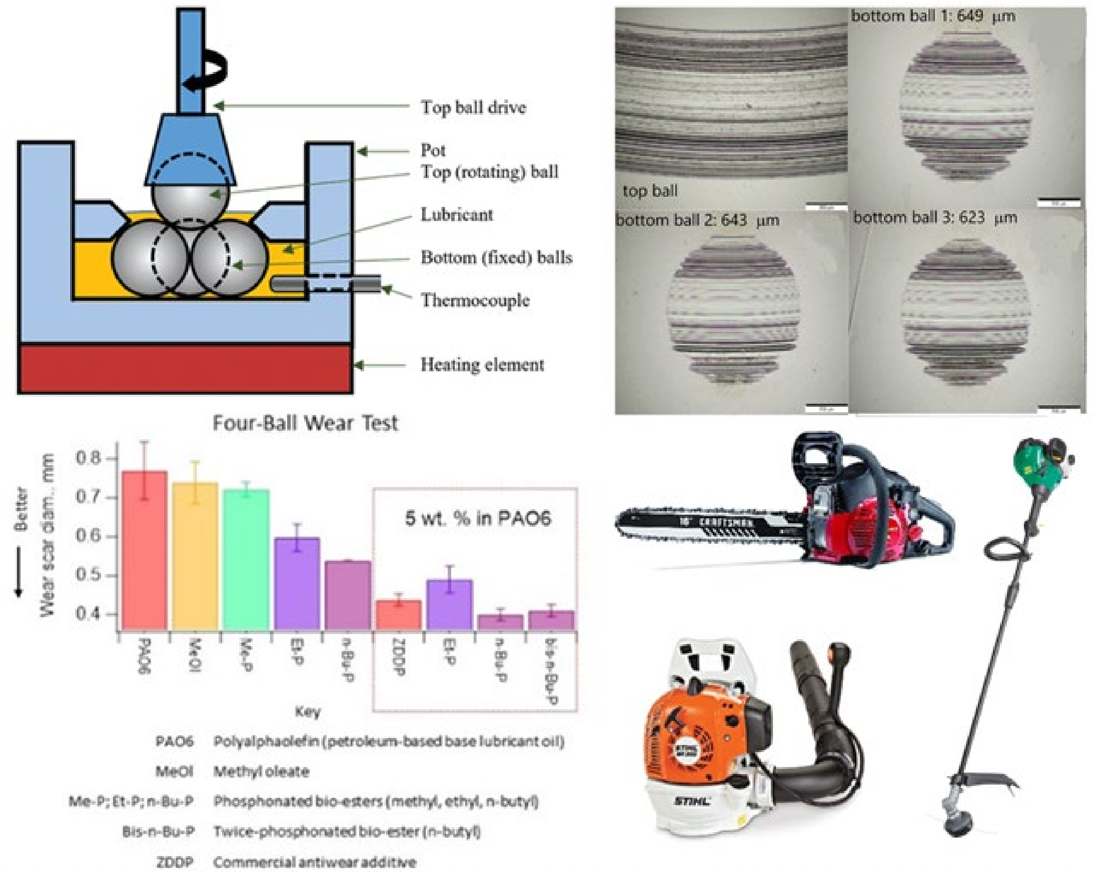

Figure 40. Schematics of the four-ball instrument with wear scars visible on the balls from testing where the upper left is the ring scar of the top ball and balls 1-3 are the bottom ball circular wear scars. This test determines the wear preventive characteristics of a lubricant. Graph summarizes results (less wear scar is better) from the four-ball AW results for phosphonates vs. commercial additives and typical 2-cycle engines that will benefit from these biobased oils.

Lorenzo-Martin, C., Ajayo, O.O., Fenske, G.R., Biresaw, G., Harry O'Kuru, R., Bantchev, G.B. 2018. Tribological performance of ultra-low viscosity composite base fluid with bio-derived fluid. Presentation, 73rd Society of Tribologists and Lubrication Engineers Annual Meeting & Exhibition; May 20-24, 2018; Minneapolis, MN.

Lorenzo-Martin, C., Ajayo, O.O., Fenske, G.R., Biresaw, G., Bantchev, G.B., Harry O'Kuru, R. 2020. Optimization of bio-derived basefluid properties to improve efficiency of hydraulic systems. Presentation, 75th Society of Tribologists and Lubrication Engineers Annual Meeting & Exhibition; May 3-7, 2020; Chicago, IL.

Bantchev, G.B., Biresaw, G., Ajayo, O.O., Lorenzo-Martin, C. 2020. Bio-based phosphonates as lubricants. Presentation, 24th Annual Green Chemistry & Engineering Conference; June 16-18, 2020; Seattle, WA.

Lorenzo-Martin, C., Ajayo, O.O., Fenske, G.R., Biresaw, G., Bantchev, G.B., Harry O'Kuru, R. 2020. Optimization of bio-derived basefluid properties to improve efficiency of hydraulic

systems. Presentation, 75th Society of Tribologists and Lubrication Engineers Annual Meeting & Exhibition; May 3-7, 2020; Chicago, IL.

Bantchev, G.B., Biresaw, G., Ajayo, O.O., Lorenzo-Martin, C. 2020. Bio-based phosphonates as lubricants. Presentation, 24th Annual Green Chemistry & Engineering Conference; June 16-18, 2020; Seattle, WA.

Bantchev, G.B., Lorenzo-Martin, C., Ajayo, O.O. 2021 Phosphonates from Lipids—Synthesis and Tribological Evaluation pp 139-156 In: ACS Symposium Series Vol. 1392 Conversion of Renewable Biomass into Bioproducts Chapter 8. https://pubs.acs.org/doi/10.1021/bk-2021-1392.ch008

A new sustainable diesel fuel additive. Due to the development of ultra-low-sulfur diesel fuel, modern high pressure diesel fuel injection systems must tolerate poor lubrication. To aide in lubrication an additive is required to obtain satisfactory engine performance and extend injector lifetime. Traditional biodiesel is often used for this purpose; however, to be effective, 1 to 2 percent or even more biodiesel is required. ARS scientists in Peoria, Illinois, developed a new lubricating additive based on tung oil, a natural compound obtained from tung trees that are grown in the southern United States. The structure of tung oil allows for it to be chemically modified with a chemical called maleic anhydride; then it is further changed by the addition of methanol or butanol. These new biobased additives were as effective as biodiesel at improving the lubricity of diesel fuel at levels 20 to 40 times lower than what is needed for biodiesel. The new additives were also effective in polyalphaolefins, which are the major components of industrially important motor oils and hydraulic oils. Kraton Chemical LLC has expressed interest in this work, as they are focused on commercializing sustainable biobased chemicals that don't compete with food production.

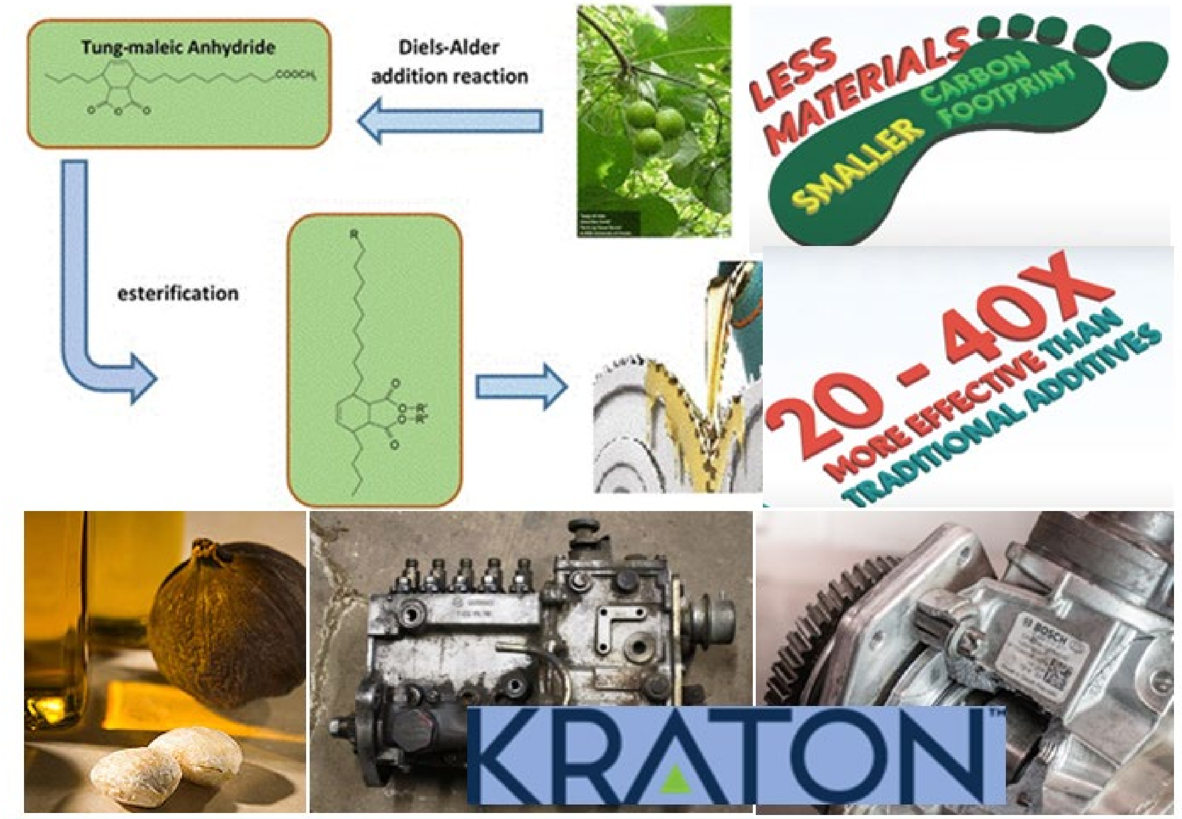

Figure 41. ARS scientists developed more efficient bioadditives using tung oil grown in the United States at lower costs to use in ultralow-sulfur diesel (ULSD) that are 20-40X more effective and reduce diesel engine part failures in fuel injectors and pumps due to ULSD's decreased lubricating properties. Kraton Chemical LLC is interested in these biobased additives as a way to transition to a low-carbon economy.

Liu, Z., Li, J., Knothe, G., Sharma, B.K., Jiang, J. 2019. Improvement of diesel lubricity by chemically modified tung-oil-based fatty acid esters as additives. Energy and Fuels. 33(6):5110-5115. https://doi.org/10.1021/acs.energyfuels.9b00854

APPENDIX 1

National Program 306 – Product Quality and New Uses

Research Projects and Project Scientists

<u>NP 306</u>

2030-21410-022-000D
Domestic Production of Natural Rubber and Resins; Colleen McMahan (P), Q. Chen, Vacant (2.0); Albany, California

2030-41000-067-000D
Bioproducts and Biopolymers from Agricultural Feedstocks; Gregory Glenn (P), W. Hart-Cooper, C. Lee, D. Wood, W. Orts, Vacant; Albany, California

2030-41000-068-000D
Zero Waste Agricultural Processing; William Orts (P), J. McManus, D. Wood, B. Chiou, D. Wong; Albany, California

2030-41000-069-000D
New Sustainable Processes, Preservation Technologies, and Product Concepts for Specialty Crops and Their Co-Products; Jose Berrios (P), Y. Xu; C. Bilbao-Sainz; Albany, California

2030-41430-013-000D
New Technologies and Methodologies for Increasing Quality, Marketability and Value of Food Products and Byproducts; Ronald Haff (P), T. Kahlon, Y. Xu, G. Takeoka; Albany, California

2030-41440-008-000D
Prevention of Obesity Related Metabolic Diseases by Bioactive Components of Food Processing Waste Byproducts and Mitigation of Food Allergies; Wallace Yokoyama (P), Y. Xu, M. Friedman, A. Breksa, Y. Zhang; Albany, California

2034-43000-041-000D
New Approaches to Enhance Fresh Fruit Quality and Control Postharvest Diseases; Chang-Lin Xiao (P), D. Obenland; Parlier, California

2090-43440-008-000D
Characterization of Quality and Marketability of Western U.S. Wheat Genotypes and Phenotypes; Sean Finnie (P) [Pending]; Pullman, Washington

2094-43000-008-000D
Enhancement of Apple, Pear, and Sweet Cherry Quality; David Rudell Jr. (P), L.

Honaas, R. Leisso, Vacant (2.0); Wenatchee, Washington

3020-43440-002-000D
Grain Composition Traits Related to End-Use Quality and Value of Sorghum; Scott Bean (P), F. Aramouni, X. Wu, D. Smolensky, M. Tilley; Manhattan, Kansas

3020-43440-010-000D
Advancing Technologies for Grain Trait Measurement and Storage Preservation; Paul Armstrong (P), L. Pordesimo, J. Campbell, M. Casada, D. Brabec; Manhattan, Kansas

3020-44000-027-000D
Measurement and Improvement of Hard Winter Wheat End-Use Quality Traits; Michael Tilley (P), F. Aramouni, B. Seabourn, X. Wu, S. Bean, Y. Chen; Manhattan, Kansas

3050-41000-010-000D
Improving the Production and Processing of Western and Long-Staple Cotton and Companion Crops to Enhance Quality, Value, and Sustainability; Derek Whitelock (P), J. Tumuluru, C. Armijo, Vacant; Las Cruces, New Mexico

3060-21430-009-000D
Improving Potato Postharvest Quality by Identifying and Manipulating Molecular Processes Regulating Tuber Dormancy and Wound-Healing; Munevver Dogramaci (P), D. Haagenson, Vacant; Fargo, North Dakota

3060-43440-015-000D
Identification and Characterization of Quality Parameters for Enhancement of Marketability of Hard Spring Wheat, Durum, and Oat; Jae-Bom Ohm (P), L. Dykes; Fargo, North Dakota

3060-43440-016-000D
Developing Accurate and Efficient Laboratory Methods for Testing End-use Qualities of Pulse Crops, Identify Factors Associated with End-use Quality, and Develop Processes to Add Value to Pulses; Mike Grusak (P) [Acting], Vacant; Fargo, North Dakota

3096-21410-009-000D
Enhancing the Profitability and Sustainability of Upland Cotton, Cottonseed, and Agricultural Byproducts through Improvements in Pre-Ginning, Ginning, and Post-Ginning Processes; John Wanjura (P), M. Pelletier, G. Holt; Lubbock, Texas

5010-41000-180-000D
New and Improved Co-Products from Specialty Crops; Gordon Selling (P), M. Hojillaevangelist; Peoria, Illinois

5010-41000-181-000D
Improved Utilization of Whole Pulses, Pulse Fractions, and Pulse Byproducts for Health-Promoting Food Ingredients and Biobased Products; Frederick Felker (P), J. Byars, J.

Kenar, S. Liu, M. Singh; Peoria, Illinois

5010-41000-182-000D
Improved Processes and Technologies for Comprehensive Utilization of Specialty Grains in Functional Food Production for Digestive Health and Food Waste Reduction; Sean Liu (P), J. Byars, M. Singh, Vacant (2.0); Peoria, Illinois

5010-41000-183-000D
Development of Enhanced Bio-Based Products from Low Value Agricultural Co-Products and Wastes; Mark Berhow (P), S. Liu, F. Eller, S. Vaughn, Vacant; Peoria, Illinois

5010-41000-184-000D
Technologies for Producing Marketable Bioproducts; David Compton (P), M. Jackson, E. Wegener, K. Evans; Peoria, Illinois

5010-41000-185-000D
Development of New Value-Added Processes and Products from Advancing Oilseed Crops; Steven Cermak (P), R. Evangelista, Vacant (1.9); Peoria, Illinois

5010-41000-186-000D
New High-Value Biobased Materials with Applications Across Industry; Kenneth Doll (P), B. Moser, Z. Liu; Peoria, Illinois

5010-41000-188-000D
Circular Bio-economy via Value-Added Biobased Products; Atanu Biswas (P), Vacant (1.35); Peoria, Illinois

5010-41000-189-000D
New Bioproducts for Advanced Biorefineries; Bruce Dien (P), P. Slininger, B. Saha, M. Bowman, N. Qureshi; Peoria, Illinois

5010-41000-190-000D
Technologies to Improve Conversion of Biomass-Derived Sugars to Bioproducts; Nancy Nichols (P), R. Hector, J. Mertens, Vacant; Peoria, Illinois

5010-41000-191-000D
Antimicrobials for Biorefining and Agricultural Applications; Christopher Skory (P), S. Lu, N. Price, S. Liu, Vacant (2.0); Peoria, Illinois

5010-41000-192-000D
Versatile Biobased Products with Multiple Functions; Robert Dunn (P), G. Bantchev, Vacant; Peoria, Illinois

5010-44000-054-000D
Increasing Food Shelf-Life, Reducing Food Waste, and Lowering Saturated Fats with

Natural Antioxidants and Oleogels; Jill Moser (P), H. Hwang, S. Vaughn, S. Liu; Peoria, Illinois

5010-44000-187-000D
Agricultural-Feedstock Derived Biobased Particles; Steven Peterson (P), S. Kim, J. Xu, Vacant (1.4); Peoria, Illinois

5050-43640-003-000D
Automated Technologies for Harvesting and Quality Evaluation of Fruits and Vegetables; Renfu Lu (P); East Lansing, Michigan

5082-43440-002-000D
Enhancement of Eastern U.S. Wheat Quality, Genetics and Marketability; Byung-Kee Baik (P), B. Penning; Wooster, Ohio

5090-43440-007-000D
Integrated Analysis for Identifying Barley Lines with Superior Malting Quality; Jason Walling (P), C. Henson; Madison, Wisconsin

6034-41000-018-000D
Advancing Value-Adding Technologies for Juice Processing Co-Products; Christina Dorado (P), W. Zhao, J. Manthey, R. Cameron; Fort Pierce, Florida

6034-41430-007-000D
Determination of Flavor and Healthful Benefits of Florida-Grown Fruits and Vegetables and Development of Postharvest Treatments to Optimize Shelf Life and Quality for Their Fresh and Processed Products; Anne Plotto (P), J. Manthey, J. Bai; Fort Pierce, Florida

6040-41440-003-000D
Assessment of Quality Attributes of Poultry Products, Grain, Seed, Nuts, and Feed; Brian Bowker (P), H. Zhuang, S. Trabelsi, S. Yoon, Vacant (2.0); Athens, Georgia

6044-41430-007-000D
Postharvest Management Systems for Processing and Handling Peanuts; Joseph McIntyre (P), M. Lamb, Vacant; Dawson, Georgia

6054-41000-108-000D
Innovative Approaches for Value Added Cotton-Containing Nonwovens; Doug Hinchliffe (P), G. Thyssen, S. Nam, Vacant (1.5); New Orleans, Louisiana

6054-41000-112-000D
Nutritional Benefits of Health-Promoting Rice and Value-Added Foods; Stephen Boue (P), R. Ardoin, B. Smith, Vacant (2.0); New Orleans, Louisiana

6054-41000-113-000D
Development of Novel Cottonseed Products and Processes; Jay Shockey (P), H. Cao,

Z. He, K. Klasson, Vacant (2.0); New Orleans, Louisiana

6054-41000-114-000D
Improved Conversion of Sugar Crops into Food, Biofuels, Biochemicals, and Bioproducts; Kjell Klasson (P), G. Bruni, E. Terrell, I. Lima, S. Uchimiya; New Orleans, Louisiana

6054-41430-009-000D
Enhanced Cotton for Value-Added Applications; Judson Edwards (P), S. Chang, M. Easson, Vacant; New Orleans, Louisiana

6054-43440-051-000D
Improving Evaluation of Catfish Quality and Reducing Fish Waste; Brennan Smith (P), R. Ardoin, Vacant; New Orleans, Louisiana

6054-43440-052-000D
Reducing the Development and Severity of Allergy to Peanuts and Tree Nuts; Soheila Maleki (P), C. Mattison, Vacant; New Orleans, Louisiana

6054-43440-053-000D
Biochemical Approach to Protein Processing, Texturization and Nutritionally Beneficial Plant-based Foods; Brennan Smith (P), R. Ardoin, Vacant; New Orleans, Louisiana

6054-44000-080-000D
Enhancing the Quality and Sustainability of Cotton Fiber and Textiles; Christopher Delhom (P), M. Santiago Cintron, Y. Liu, Vacant (4.0); New Orleans, Louisiana

6060-41000-015-000D
Biobased Pesticide Discovery and Product Optimization and Enhancement from Medicinal and Aromatic Crops; Charles Cantrell (P), M. Wang, P. Tamang, K. Meepagala, University, Mississippi

6066-41440-009-000D
Development and Evaluation of Novel Technologies to Improve Fiber Quality and Increase Profitability in Cotton Processing; Joseph Thomas (P), F. Alege, S. Donohoe, C. Blake; Stoneville, Mississippi

6070-41000-010-000D
Improved Vegetable Processing Methods to Reduce Environmental Impact, Enhance Product Quality and Reduce Food Waste; Suzanne Johanningsmeier (P), M. Qureshi, I. Perez Diaz, F. Breidt; Raleigh, North Carolina

6070-43440-013-000D
Improvement and Maintenance of Peanuts, Peanut Products and Related Peanut Product Flavor, Shelf Life, Functional Characteristics; Lisa Dean (P), M. Qureshi, O. Toomer; Raleigh, North Carolina

8042-43000-016-000D
Integrated Approaches to Improve Fruit and Vegetable Nutritional Quality with Improved Phenolics Contents; Tianbao Yang (P), Vacant; Beltsville, Maryland

8042-43440-006-000D
Reducing Postharvest Loss and Improving Fresh Produce Marketability and Nutritive Values through Technological Innovations and Process Optimization; Yaguang Luo (P), B. Zhou, J. Fonseca, Vacant; Beltsville, Maryland

8072-41000-108-000D
In vitro Human Gut System: Interactions Between Diet, Food Processing, and Microbiota; Lin Liu (P), A. Narrowe, J. Scarino Lemons, J. Firrman, K. Mahalak; Wyndmoor, Pennsylvania

8072-41000-109-000D
New Bioactive Dairy Products for Health-Promoting Functional Foods; Arland Hotchkiss (P), G. Guron, P. Qi; Wyndmoor, Pennsylvania

8072-41000-110-000D
Chemical Conversion of Biomass into High Value Products; Helen Lew (P), M. Yadav, B. Sharma, M. Sarker; Wyndmoor, Pennsylvania

8072-41000-111-000D
Integrated Biological/Chemical Biorefining for Production of Chemicals and Fuels; Ryan Stoklosa (P), V. Garcia-Negron, D. Johnston; Wyndmoor, Pennsylvania

8072-41000-112-000D
Thermo-Catalytic Biorefining; Charles Mullen (P), C. Ellison, V. Wyatt, Y. Elkasabi; Wyndmoor, Pennsylvania

8072-41000-113-000D
Commercial Products from Lipids and Fibers; Richard Ashby (P), J. Msanne, Vacant; Wyndmoor, Pennsylvania

8072-41000-114-000D
Reclaiming Value from Coproducts of Dairy Food Manufacture; Margaret Tomasula (P), R. Garcia, A. Miller, B. Plumier, J. Renye Jr., M. McAnulty, Vacant; Wyndmoor, Pennsylvania

APPENDIX 2

National Program 306 – Product Quality and New Uses

Publications by Research Project
October 2018 – September 2022

NP 306

2030-21410-021-000D
DOMESTIC PRODUCTION OF NATURAL RUBBER AND INDUSTRIAL SEED OILS;
Colleen McMahan (P), Q. Chen, T. McKeon, Vacant; Albany, California.

Chen, G.Q., Johnson, K., Morales, E., Ibanez, A.M., Lin, J.T. 2017. A high-oil castor cultivar developed through recurrent selection. Industrial Crops and Products. 111:8-10. https://doi.org/10.1016/j.indcrop.2017.09.064.

Lin, J.T., Hou, C.T., Dulay, R.M., Ray, K.J., Chen, G.Q. 2017. Structures of hydroxy fatty acids as the constituents of triacylglycerols in Philippine wild edible mushroom, Ganoderma lucidum. Biocatalysis and Agricultural Biotechnology. 12/148-151. https://doi.org/10.1016/j.bcab.2017.09.010.

Zhu, Y., Xie, L., Chen, G.Q., Lee, M., Loque, D., Scheller, H.V. 2018. A transgene design for enhancing oil content in Arabidopsis and Camelina seeds. Biotechnology for Biofuels. 11:46. https://doi.org/10.1186/s13068-018-1049-4.

Ponciano, G.P., Dong, N., Chen, G.Q., McMahan, C.M. 2018. A bicistronic transgene system for genetic modification of Parthenium argentatum. Plant Biotechnology Reports. 12(2):149-155. https://doi.org/10.1007/s11816-018-0478-7.

Hathwaik, U.I., Lin, J.T., McMahan, C.M. 2018. Molecular species of triacylglycerols in the rubber particles of Parthenium argentatum and Hevea brasiliensis. Biocatalysis and Agricultural Biotechnology. 16:107-114. https://doi.org/10.1016/j.bcab.2018.07.019.

Ramirez-Cadavid, D., Cornish, K., Hathwaik, U.I., Kozak, R., McMahan, C.M., Michel, F. 2019. Development of novel processes for aqueous extraction of natural rubber from Taraxacum kok-saghyz (TK). Journal of Chemical Technology & Biotechnology. 94(8):2452-2464. https://doi.org/10.1002/jctb.6027.

Lee, K., Kim, E., Jeon, I., Lee, Y., Chen, G.Q., Kim, H. 2019. Lesquerella FAD3-1 gene is responsible for the biosynthesis of trienoic acid and dienoic hydroxy fatty acids in seed oil. Industrial Crops and Products. 134:257264. https://doi.org/10.1016/j.indcrop.2019.04.008.

Placido, D.F., Dong, N., Dong, C., Cruz, V., Dierg, D., Cahoon, R.E., Kang, B., Huynh, T.T., Whalen, M.C., Ponciano, G.P., McMahan, C.M. 2019. Downregulation of a CYP74 rubber particle protein increases natural rubber production in Parthenium argentatum . Frontiers in Plant Science. 10:760. https://doi.org/10.3389/fpls.2019.00760.

Kim, H., Lee, K., Jeon, I., Jung, H., Heo, J., Kim, T., Chen, G.Q. 2019. Fatty acid composition and oil content of seeds from perilla germplasm of Republic of Korea. Genetic Resources and Crop Evolution. 66(7):1615-1624. https://doi.org/10.1007/s10722-019-00803-8.

Nelson, A.D., Ponciano, G.P., McMahan, C.M., Ilut, D.C., Pugh, N.A., Elshikha, D.E., Hunsaker, D.J., Pauli, D. 2019. Transcriptomic and evolutionary analysis of the mechanisms by which P. argentatum, a rubber producing perennial, responds to drought. Biomed Central (BMC) Plant Biology. 19:494. https://doi.org/10.1186/s12870-019-2106-2.

Kim, H., Park, M., Lee, K., Suh, M., Chen, G.Q. 2020. Variant castor lysophosphatidic acid acyltransferases acylate ricinoleic acid in seed oil. Industrial Crops and Products. 150:112245. https://doi.org/10.1016/j.indcrop.2020.112245.

Chen, G.Q., Lin, J.T., Van Erp, H., Johnson, K., Lu, C. 2020. Regiobiochemical analysis reveals the role of castor LPAT2 in the accumulation of hydroxy fatty acids in transgenic lesquerella seeds. Biocatalysis and Biotransformation. 25:10167. https://doi.org/10.1016/j.bcab.2020.101617.

Placido, D.F., Dierig, D.A., Cruz, Von, M.V., Ponciano, G.P., Dong, C., Dong, N., Huynh, T.T., Williams, T.G., Cahoon, R.E., Wall, G.W., Wood, D.F., Mcmahan, C.M. 2020. Downregulation of an allene oxide synthase gene improves photosynthetic rate and alters phytohormone homeostasis in field-grown guayule. Industrial Crops and Products. 153:112341. https://doi.org/10.1016/j.indcrop.2020.112341.

2030-21410-022-000D
DOMESTIC PRODUCTION OF NATURAL RUBBER AND RESINS; Colleen McMahan (P), Q. Chen, Vacant (2.0); Albany, California.

Cornish, K., Dacosta, B., McMahan, C.M. 2020. Temporal analysis of natural rubber transferases reveals intrinsic distinctions for in vitro synthesis in two rubber-producing species. Current Topics in Biochemical Research. 21:45-58.

Chen, G.Q., Kim, W., Johnson, K., Park, M., Lee, K., Kim, H. 2021. Transcriptome analysis and identification of lipid genes in Physaria lindheimeri, a genetic resource for hydroxy fatty acids in seed oil. International Journal of Molecular Sciences. 22(2). Article 514. https://doi.org/10.3390/ijms22020514.

Torres, L.F., McCaffrey, Z., Washington, W., Williams, T.G., Wood, D.F., Orts, W.J., McMahan, C.M. 2021. Torrefied agro-industrial residue as filler in natural rubber compounds. Journal of Applied Polymer Science. 138(28). Article e50684. https://doi.org/10.1002/app.50684.

Chen, G.Q., Johnson, K., Nazarenus, T.J., Ponciano, G.P., Morales, E., Cahoon, E.B. 2021. Genetic engineering of lesquerella with increased ricinoleic acid content in seed oil. Plants. 10(6). Article 1093. https://doi.org/10.3390/plants10061093.

Placido, D.F., Heinitz, C.C., McMahan, C.M., Banuelos, G.S. 2021. Guayule is an industrial crop that can be grown for its natural rubber production and phytoremediation capability in the Western San Joaquin Valley, California. Current Plant Biology. 28. Article 100223. https://doi.org/10.1016/j.cpb.2021.100223.

Dong, C., Ponciano, G.P., Huo, N., Gu, Y.Q., Ilut, D., McMahan, C.M. 2021. RNASeq analysis of drought-stressed guayule reveals the role of gene transcription for modulating rubber, resin, and carbohydrate synthesis. Scientific Reports. 11. Article 21610. https://doi.org/10.1038/s41598-021-01026-7.

Ramirez Cavidad, D., Hathwaik, U.I., Cornish, K., McMahan, C.M., Michel Jr., F. 2022. Alkaline pretreatment of Taraxacum kok-saghyz (TK) roots for the extraction of natural rubber (NR). Biochemical Engineering Journal. 181. Article 108376. https://doi.org/10.1016/j.bej.2022.108376.

Santim, R., Sanchez, A., da Silva, M., McMahan, C.M., Malmonge, J. 2022. Electrically conductive nanocomposites produced by in situ polymerization of pyrrole in a natural rubber latex medium. Polymer Composites. 43(5):2972-2979. https://doi.org/10.1002/pc.26591.

Placido, D., Dong, N., Amer, B., Dong, C., Ponciano, G.P., Kahlon, T.S., Whalen, M., Baidoo, E., McMahan, C.M. 2022. Downregulation of squalene synthase broadly impacts isoprenoid biosynthesis in guayule. Metabolites. 12(4). Article 303. https://doi.org/10.3390/metabo12040303.

Park, M., Lee, K., Chen, G.Q., Kim, H. 2022. Enhanced production of hydroxy fatty acids in arabidopsis seed through modification of multiple gene expression. Biotechnology for Biofuels. 15. Article 66. https://doi.org/10.1186/s13068-022-02167-1.

Placido, D., McMahan, C.M., Lee, C.C. 2022. Wounding and cold stress increase resin and rubber production of Parthenium argentatum cultivar G711. Industrial Crops and Products.

Torres, L.F., McCaffrey, Z., Williams, T.G., Wood, D.F., Orts, W.J., McMahan, C.M. 2023. Evidence of silane coupling in torrefied agro-industrial residue filled SBR compounds. Journal of Applied Polymer Science. 140:12.

Chen, G.Q., Ponciano, G.P., Dong, C., Dong, N., Johnson, K., Bolton, T.T., Williams, T.G., Wood, D.F., Placido, D.F., Mcmahan, C.M., Dyer, J.M. 2023. Overexpressing an Arabidopsis SEIPIN1 reduces rubber production in guayule. Industrial Crops and Products. https://doi.org/10.1016/j.indcrop.2023.116410.

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2030-41000-054-000D
TECHNOLOGIES FOR IMPROVING INDUSTRIAL BIOREFINERIES THAT PRODUCE MARKETABLE BIOBASED PRODUCTS; William Orts (P), W. Hart-Cooper, K. Wagschal, C. Lee, D. Wong; Albany, California.

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PREVENTION OF OBESITY RELATED METABOLIC DISEASES BY BIOACTIVE COMPONENTS OF FOOD PROCESSING WASTE BYPRODUCTS AND MITIGATION OF FOOD ALLERGIES; Wallace Yokoyama (P), Y. Xu, M. Friedman, A. Breksa, Y. Zhang; Albany, California.

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INTEGRATE PRE-AND POSTHARVEST APPROACHES TO ENHANCE FRESH FRUIT QUALITY AND CONTROL POSTHARVEST DISEASES; Chang-Lin Xiao (P), D. Obenland; Albany, California.

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NEW APPROACHES TO ENHANCE FRESH FRUIT QUALITY AND CONTROL POSTHARVEST DISEASES; Chang-Lin Xiao (P), D. Obenland; Parlier, California.

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MEASUREMENT AND IMPROVEMENT OF HARD WINTER WHEAT END-USE QUALITY TRAITS; Michael Tilley (P), F. Aramouni, B. Seabourn, X. Wu, S. Bean, Y. Chen; Manhattan, Kansas.

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ENHANCING THE QUALITY, UTILITY, SUSTAINABILITY AND ENVIRONMENTAL IMPACT OF WESTERN AND LONG-STAPLE COTTON THROUGH IMPROVEMENTS IN HARVESTING, PROCESSING, AND UTILIZATION; Derek Whitelock (P), C. Armijo, P. Funk, Vacant; Las Cruces, New Mexico.

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IMPROVING POTATO NUTRITIONAL AND MARKET QUALITY BY IDENTIFYING AND MANIPULATING PHYSIOLOGICAL AND MOLECULAR PROCESSES CONTROLLING TUBER WOUND-HEALING AND SPROUT GROWTH; Vacant (P), D. Haagenson, Vacant (2.0); Fargo, North Dakota.

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IDENTIFICATION AND CHARACTERIZATION OF QUALITY PARAMETERS FOR ENHANCEMENT OF MARKETABILITY OF HARD SPRING WHEAT, DURUM, AND OAT; Jae-Bom (P), L. Dykes; Fargo, North Dakota.

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NEW BIOBASED PRODUCTS AND IMPROVED BIOCHEMICAL PROCESSES FOR THE BIOREFINING INDUSTRY; Christopher Skory (P), Vacant (3.3), S. Liu; Peoria, Illinois.

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VEGETABLE OIL-BASED FUELS, ADDITIVES AND COPRODUCTS; Gerhard Knothe (P), B. Moser, R. Dunn, R. Murray; Peoria, Illinois.

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EVALUATION OF THE CHEMICAL AND PHYSICAL PROPERTIES OF LOW-VALUE AGRICULTURAL CROPS AND PRODUCTS TO ENHANCE THEIR USE AND VALUE; Mark Berhow (P), F. Eller, B. Tisserat, S. Vaughn, S. Liu; Peoria, Illinois.

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IMPROVED UTILIZATION OF LOW-VALUE OILSEED PRESS CAKES AND PULSES FOR HEALTH-PROMOTING FOOD INGREDIENTS AND BIOBASED PRODUCTS;
Frederick Felker (P), J. Kenar, J. Byars, M. Singh, S Liu; Peoria, Illinois.

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INNOVATIVE PROCESSING TECHNOLOGIES FOR CREATING FUNCTIONAL FOOD INGREDIENTS WITH HEALTH BENEFITS FROM FOOD GRAINS, THEIR PROCESSING PRODUCTS, AND BY-PRODUCTS; Sean Liu (P), J. Byars, M. Singh, Vacant; Peoria, Illinois.

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INDUSTRIAL MONOMERS AND POLYMERS FROM PLANT OILS; Kenneth Doll (P), B. Moser, Z. Liu; Peoria, Illinois.

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REPLACEMENT OF PETROLEUM PRODUCTS UTILIZING OFF-SEASON ROTATIONAL CROPS; Steven Cermak (P), T. Isbell, R. Evangelista, R. Harry; Peoria, Illinois.

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CONVERSION OF POLYSACCHARIDES AND OTHER BIO-BASED MATERIALS TO HIGH-VALUE, COMMERCIAL PRODUCTS; Atanu Biswas (P), V. Finkenstadt, V. Boddu; Peoria, Illinois.

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VALUE-ADDED BIO-OIL PRODUCTS AND PROCESSES; Girma Biresaw (P), G. Bantchev, R. Dunn; Peoria, Illinois.

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TECHNOLOGIES FOR IMPROVING PROCESS EFFICIENCES IN BIOMASS REFINERIES; Bruce Dien (P), J. Mertens, M. Bowman, N. Nichols; Peoria, Illinois.

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BIOCHEMICAL TECHNOLOGIES TO ENABLE THE COMMERCIAL PRODUCTION OF BIOFUELS FROM LIGNOCELLULOSIC BIOMASS; Patricia Slininger (P), B. Dien, Z. Liu; Peoria, Illinois.

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IMPROVED UTILIZATION OF WHOLE PULSES, PULSE FRACTIONS, AND PULSE BYPRODUCTS FOR HEALTH-PROMOTING FOOD INGREDIENTS AND BIOBASED PRODUCTS; Sean Liu (P), Vacant (2.0), J. Byars, M. Singh; Peoria, Illinois.

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CIRCULAR BIO-ECONOMY VIA VALUE-ADDED BIOBASED PRODUCTS; Atanu Biswas (P), Vacant (1.35); Peoria, Illinois.

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GENETIC AND BIOCHEMICAL BASIS OF SOFT WINTER WHEAT END-USE QUALITY; Byung-Kee Baik (P), B. Penning; Wooster, Ohio.

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IDENTIFYING THE NEXT GENERATION OF MALTING BARLEY THROUGH IMPROVED SELECTION CRITERIA AND QUALITY ANALYSIS OF BREEDING LINES; Jason Walling (P), C. Henson; Madison, Wisconsin.

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QUALITY, SHELF-LIFE AND HEALTH BENEFITS FOR FRESH, FRESH-CUT AND PROCESSED PRODUCTS FOR CITRUS AND OTHER TROPICAL/SUBTROPICAL-GROWN FRUITS AND VEGETABLES; Anne Plotto (P), J. Bai, E. Baldwin, R. Cameron, Vacant; Ft. Pierce, Florida.

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NUTRITIONAL AND SENSORY PROPERTIES OF RICE AND RICE VALUE-ADDED PRODUCTS; Stephen Boue (P), J. Beaulieu, C. Grimm, Vacant; New Orleans, Louisanna.

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INNOVATIVE APPROACHES FOR VALUE ADDED COTTON-CONTAINING NONWOVENS; Doug Hinchliffe (P), G. Thyssen, S. Nam, Vacant (1.5); New Orleans, Louisiana.

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DEVELOPING TECHNOLOGIES THAT ENABLE GROWTH AND PROFITABILITY IN THE COMMERCIAL CONVERSION OF SUGARCANE, SWEET SORGHUM, AND ENERGY BEETS INTO SUGAR, ADVANCED BIOFUELS, AND BIOPRODUCTS; Kjell Klasson (P), M. Wright, I. Lima, S. Uchimiya, Vacant (2.0); New Orleans, Louisiana.

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DEVELOPING TECHNOLOGIES THAT ENABLE GROWTH AND PROFITABILITY IN THE COMMERCIAL CONVERSION OF SUGARCANE, SWEET SORGHUM, AND ENERGY BEETS INTO SUGAR, ADVANCED BIOFUELS, AND BIOPRODUCTS-

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NUTRITIONAL BENEFITS OF HEALTH-PROMOTING RICE AND VALUE-ADDED FOODS; Stephen Boue (P), R. Ardoin, B. Smith, Vacant (2.0); New Orleans, Louisiana.

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DEVELOPMENT OF NOVEL COTTONSEED PRODUCTS AND PROCESSES; Jay Shockey (P), H. Cao, Z. He, K. Klasson, Vacant (2.0); New Orleans, Louisiana.

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IMPROVED CONVERSION OF SUGAR CROPS INTO FOOD, BIOFUELS, BOICHEMICALS, AND BIOPRODUCTS; Kjell Klasson (P), G. Bruni, E. Terrell, I. Lima, S. Uchimiya; New Orleans, Louisiana.

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HEALTH-PROMOTING BIOACTIVES AND BIOBASED PESTICIDES FROM MEDICINAL AND HERBAL CROPS; Charles Cantrell (P), K. Meepagala, Vacant (2.0); University, Mississippi.

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BIOBASED PESTICIDE DISCOVERY AND PRODUCT OPTIMIZATION AND ENHANCEMENT FROM MEDICINAL AND AROMATIC CROPS; Charles Cantrell (P), M. Wang, P. Tamang, K. Meepagala; University, Mississippi.

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COTTON GINNING RESEARCH TO IMPROVE PRCOESSING EFFICIENCY AND PRODUCT QUALITY IN THE SAW-GINNING OF PICKER-HARVESTED COTTON; Ruixiu Sui (P), Vacant (4.0); Stoneville, Mississippi.

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IMPROVED PROCESSES FOR THE PRESERVATION AND UTILIZATION OF VEGETABLES, INCLUDING CUCUMBER, SWEETPOTATO, CABBAGE, AND PEPPERS TO PRODUCE SAFE, HIGH QUALITY PRODUCTS WITH REDUCED ENERGY USE AND WASTE; Frederick Breidt (P), I. Perez Diaz, S. Johanningsmeier; Raleigh, North Carolina.

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IMPROVED VEGETABLE PROCESSING METHODS TO REDUCE ENVIRONMENTAL IMPACT, ENHANCE PRODUCT QUALITY AND REDUCE FOOD WASTE; Suzanne Johanningsmeier (P), M. Qureshi, I. Perez Diaz, F. Breidt; Raleigh, North Carolina.

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IMPROVEMENT AND MAINTENANCE OF FLAVOR, SHELF LIFE, FUNCTIONAL CAHRACTERISTICS, AND BIOCHEMICAL/BIOACTIVE COMPONENTS IN PEANUTS, PEANUT PRODUCTS AND RELATED COMMODOTIES THROUGH IMPROVED HANDLING; Lisa Dean (P), O. Toomer, Vacant; Raleigh, North Carolina.

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IMPROVEMENT AND MAINTENANCE OF PEANUTS, PEANUT PRODUCTS AND RELATED PEANUT PRODUCT FLAVOR, SHELF LIFE, FUNCTIONAL CHARACTERISTICS; Lisa Dean (P), M. Qureshi, O. Toomer; Raleigh, North Carolina.

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ENHANCING FRUIT AND VEGETABLE NUTRITIONAL QUALITY WITH IMPROVED PHENOLICS CONTENTS; Tianbao Yang (P), Vacant (1.4); Beltsville, Maryland.

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EVALUATION AND MAINTENANCE OF FLAVOR, NUTRITIONAL AND OTHER QUALITY ATTRIBUTES OF FRESH AND FRESH-CUT PRODUCE; Yaguang Luo (P), J. Fonseca, Vacant; Beltsville, Maryland.

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REDUCING POSTHARVEST LOSS AND IMPROVING FRESH PRODUCE MARKETABILITY AND NUTRITIVE VALUES THROUGH TECHNOLOGICAL INNOVATIONS AND PROCESS OPTIMIZATION; Yaguang Luo (P), B. Zhou, J. Fonseca, Vacant; Beltsville, Maryland.

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IN VITRO HUMAN INTESTINAL MICROBIAL ECOSYSTEM: Effects of Diet; Lin Liu (P), Vacant (3.0), J. Firrman; Wyndmoor, Pennsylvania.

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ENABLE NEW MARKETABLE, VALUE-ADDED COPRODUCTS TO IMPROVE BIOREFINING PROFITABILITY; Helen Lew (P), M. Yadav, M. Sarker, Vacant; Wyndmoor, Pennsylvania.

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SORGHUM BIOREFINING: INTEGRATED PROCESSES FOR CONVERTING ALL SORGHUM FEEDSTOCK COMPONENTS TO FUELS AND CO-PRODUCTS; Ryan Stoklosa (P), D. Johnston, Vacant; Wyndmoor, Pennsylvania.

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IMPROVING THE SUSTAINABILITY AND QUALITY OF FOOD AND DAIRY PRODUCTS FROM MANUFACTURING TO CONSUMPTION VIA PROCESS MODELING AND EDIBLE PACKAGING; Margaret Tomasula (P), R. Garcia, B. Plumier, J. Renye Jr., M. McNaulty, Vacant (2.0); Wyndmoor, Pennsylvania.

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IN VITRO HUMAN GUT SYSTEM: ITERACTIONS BETWEEN DIET, FOOD PROCESSING, AND MICROBIOTA; L. Liu (P), A. Narrowe, J. Scarino Lemons, J. Firrman, K. Mahalak; Wyndmoor, Pennsylvania.

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NEW BIOACTIVE DAIRY PRODUCTS FOR HEALTH-PROMOTING FUNCTIONAL FOODS; Arland Hotchkiss (P), G. Guron, P. Qi; Wyndmoor, Pennsylvania.

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CHEMICAL CONVERSION OF BIOMASS INTO HIGH VALUE PRODUCTS; Helen Lew (P), M. Yadav, B. Sharma, M. Sarker; Wyndmoor, Pennsylvania.

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THERMO-CATALYTIC BIOREFINING; Charles Mullen (P), C. Ellison, V. Wyatt, Y. Elkasabi; Wyndmoor, Pennsylvania.

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IMPROVING THE QUALITY OF ANIMAL HIDES, REDUCING ENVIRONMENTAL IMPACTS OF HIDE PRODUCTION, AND DEVELOPING VALUE-ADDED PRODUCTS FROM WOOL; Cheng Kung Liu (P), M. Sarker, Vacant; Wyndmoor, Pennsylvania.

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APPENDIX 3

National Program 306 – Product Quality and New Uses

Patents and Licenses 2016 –2022

PATENTS:
There were 38 patents, 8 of which were licensed, and 4 in the list below are patent applications that were licensed (*), but not yet patented from 2016-2022; listed by title, lead inventor. All cases here were filed between 2018-2022.

2022
- FABRIC COMPOSITIONS COMPRISING ATTACHED ASCORBIC ACID; Judson Edwards.

2021
- MOISTURE RESISTANT CELLULOSE FOAMS; Gregory Glenn.
- CELLULOSIC FIBERS COMPRISING INTERNALLY DISPERSED CUPROUS OXIDE NANOPARTICLES; Matthew Hillyer. *

2020
- GERMINATION/SPROUTING AND FRUIT RIPENING REGULATORS; Tianbao Yang. (Patent Application Serial No. 17/702,885)
- GERMINATION/SPROUTING AND FRUIT RIPENING REGULATORS; Tianbao Yang. (Patent Application Serial No. 17/702,180)
- ADHESIVES GENERATED FROM SOYBEAN MEAL AND DISTILLER'S DRIED GRAINS WITH SOLUBLES; Brent Tisserat.
- ISOCHORIC IMPREGNATION OF SOLID FOODS AT SUBFREEZING TEMPERATURES; Tara McHugh.
- ABSORBENT MATERIAL; Steven Vaughn.
- REVERSIBLE IMINE UV-ABSORBERS; William Hart-Cooper.
- SYNTHETIC ENZYME COMPLEXES FOR IN VITRO RUBBER PRODUCTION; Grisel Ponciano.
- ADHESIVE COMPOSITIONS AND METHODS OF ADHERING ARTICLES TOGETHER; Brent Tisserat.
- MOISTURE/OIL-RESISTANT FIBER/STARCH COMPOSITE MATERIALS; Gregory Glenn.X-RAY INSECT IRRADIATOR; Ronald Haff.
- HYDROXY FATTY ACID SYNTHESIS; Steven Cermak.
- SYSTEM AND METHOD FOR HARVESTING FRUIT; Renfu Lu.
- C-GLYCOSIDE AMINE DERIVATIVES AND METHODS OF MAKING; Michael Jackson.

PATENTS [CONTINUED] All cases here were filed between 2018-2022.:

2019

- BIOBASED SUPERABSORBENT HYDROGELS; Veera Boddu.
- ANTIMICROBIAL PHENOLIC FATTY ACID-BASED EPOXY CURING AGENTS FOR EPOXIES; Kun Huang.
- NATURAL PACKAGING COMPOSITION; William Hart-Cooper. *
- BROAD-SPECTRUM SYNERGISTIC ANTIMICROBIAL COMPOSITIONS; William Hart-Cooper. *
- PROCESS FOR THE DECARBOXYLATION, ISOMERIZATION, HYDROGENATION, DEHYDROGENATION, AND CYCLIZATION/AROMATIZATION OF FATTY ACIDS YIELDING PRODUCTS WITH SIGNIFICANT AROMATIC CONTENT; Kenneth Doll.
- CELLULOSIC FIBERS COMPRISING EMBEDDED SILVER NANOPARTICLES AND USES THEROF; Sunghyun Nam. *
- THERMOCHEMICAL BIOMASS COMPOUNDER; Zachariah McCaffrey.
- POLYETHYLENE DIESTER VISCOSITY MODIFIERS; Terry Isbell.

2018

- METHODS FOR EXTRACTING AND PURIFYING CAPSINOIDS SUCH AS CAPSIATE AND DIHYDROCAPSIATE FROM CAPSICUM SP. FRUIT; Charles Cantrell.
- METHOD AND SYSTEM FOR CHROMOGENIC ARRAY-BASED FOOD TESTING; Yaguang Luo.
- COMPOSITIONS CONTAINING DIESEL AND FATTY ACID METHYL ESTER/MALEIC ANHYDRIDE/ESTERS (FAME/MA/ESTERS) AND THE USE OF FAME/MA/ESTERS TO IMPROVE THE LUBRICITY OF DIESEL; Zengshe Liu.
- COMPOSITIONS AND PROCESSES FOR RENEWABLE RIGID FOAM; Gregory Glenn.
- CRISP AND HARD WHOLE OAT KERNEL SNACK; Tara McHugh.

2017

- INTERMITTENT INFRARED DRYING FOR BREWERY-SPENT GRAIN; Roberto Avena Bustillos.
- COMPOSITIONS CONTAINING MICROENCAPSULATED ORGANIC COMPOUNDS; Sanghoon Kim.
- FATTY AMMONIUM SALT STARCH COMPLEXES AS ANTIMICROBIALS, PLANT WOUND, AND WOOD PROTECTANTS; William Hay.
- METHODS FOR PREPARING OILS CONTAINING AT LEAST 2% ALKYL-BRANCHING ON THE HYDROCARBIN CHAIN; Helen Lew.
- COMPOSITIONS AND METHODS FOR FOOD PACKAGING; Gregory Glenn.
- IMAGING SYSTEM FOR SORTING POULTRY MEAT WITH WOODEN BREAST MYOPATHY; Seung Yoon.

PATENTS [CONTINUED] All cases here were filed between 2018-2022.:

- HEALTHCARE TEXTILES; Judson Edwards.

2016

- SELF-ASSEMBLED ACTIVE AGENTS; William Hart-Cooper.
- HIGH YIELDS OF ISOMELEZITOSE FROM SUCROSE BY ENGINEERED GLUCANSUCRASES; Gregory Cote.

National Program
306
Product Quality and New Uses
2023 ONP Accomplishments

FY 2023 Accomplishments
NP 306 (Product Quality and New Uses)

Compostable food-safe adhesive for fruit and vegetable stickers. U.S. agricultural exports worth millions of dollars are at risk because several countries/regions, including France, Flanders, and New Zealand, enacted legislation that will require all price look up labels on produce to be certified for home composting. At the request of the Foreign Agricultural Service, ARS researchers in Albany, California, and industry collaborators developed a food-safe, compostable adhesive formulation that solved a key coating issue of uneven spreading on the back of the labels. This formulation was tested on a variety of produce and met the requisite standards. The additive that was identified to solve the coating issue will be submitted in an invention disclosure. Research results will help U.S. fruit and vegetable exporters meet the more stringent international standards. (NP 306, C1, PSC, Project No. 2030-41000-068-000D)

Novel freezing technology yields safer quality juice products. Processes for conserving natural juices need new systems that maintain sensory and nutritional quality and prolong shelf life with reduced microbial loads. ARS researchers in Albany, California, discovered that isochoric freezing, a new preservation technology, reduced native microbial loads below detection limits in pomegranate and carrot juice, extended the shelf life of both products, and resulted in better overall juice quality. Isochoric freezing is a promising alternative to conventional pasteurization for addressing key consumer and food safety factors for juice products. (NP 306, C1, PSA, Project No. 2030-41000-069-000D)

New technology proves walnut dust not explosive. Fires and/or explosions at agricultural facilities have been an issue across the world. Walnut dust is designated as combustible by the U.S. Occupational Safety and Health Administration and some local governments and insurance companies have attempted to apply that designation to dust at walnut huller and sheller facilities. Facilities that generate potentially combustible dusts must abide by National Fire Protection Association standards that require expensive sprinkler systems; however, approved dust control systems can cost from $100,000 to more than $1 million and it can be difficult for facilities to obtain approval for building permits and insurance coverage. At the request of the Western Agricultural Processors Association, ARS researchers in Las Cruces, New Mexico, conducted tests to determine the combustibility of dust from walnut hulling and shelling facilities. These tests showed that walnut dusts were not combustible and therefore not an explosion hazard. These results should enable the industry to keep walnut huller and sheller dusts from being classed as combustible, help clear the way for construction of new walnut processing plants, and save the industry many thousands of dollars for needless fire and explosion suppression hardware and practices. (NP 306, C1, PSA, Project No. 3050-41000-010-000D)

First control of blueberry fruit rot. Postharvest fruit rots are a key factor limiting the storage and shelf life of fresh blueberries. Controlling postharvest fruit rot diseases is important to the domestic and international marketing of fresh blueberries, but no products have been registered in the United States specifically for controlling postharvest fruit rots. ARS researchers in Parlier, California, evaluated natamycin, a biofungicide and food-safe additive already used in the food industry, as a postharvest dipping or spraying treatment for controlling postharvest blueberry rot. They found that it is an effective postharvest control for reducing fruit rot and maintaining fruit quality of fresh blueberries. Data is being used to support a pending registration of natamycin for postharvest use on blueberries. (NP 306, C1, PSA, Project No. 2034-43000-041-000D)

First plant-based potato sprout inhibitor. Postharvest potato sprouting can lead to alterations in weight, texture, nutritional value, softening, shrinkage, and the formation of toxic alkaloids, so controlling sprouting is critical during potato storage. The most efficient and cost-effective sprout-inhibiting chemical is Chlorpropham (CIPC); however, its degradation products are hazardous for consumer health and the environment, so it has been banned in the European Union, and some export markets have implemented zero CIPC residue levels. ARS researchers in Oxford, Mississippi, determined that *Melissa officinalis L.* essential oil compounds suppressed sprouting on three potato cultivars (Ranger Russet, Terra Rosa, and Dakota TrailBlazer). This is the first report on using *Melissa officinalis L.* essential oils to inhibit sprouting and these findings indicate that the essential oils can be utilized to develop new commercial products for sprout control of potatoes. Such products would reduce toxic chemical residues in potatoes and contribute to improved human and environmental health. (NP 306, C1, PSB, Project No. 6060-41000-015-000D)

Olive extracts on melons are superior to chlorine for food safety. Melons are a diverse group of desert fruits that include orange or green flesh cantaloupe, honeydew, and mixed hybrid varieties, and they are all difficult to effectively wash, clean and sanitize. The outer rinds of melons are easily contaminated by *Salmonella, Listeria*, and *Escherichia coli (E. coli)* while they are growing and these foodborne pathogens can be transferred to the edible portions during postharvest cutting and dividing. ARS researchers in Albany, California, applied olive extracts, which contain many bioactive compounds, to melon surfaces and found the extracts were effective for controlling *Salmonella, L. monocytogenes* and *E. coli*: The antimicrobial activity of olive extract exceeded the current industry standard of 50 parts per million (ppm) that is achieved with chlorine treatment. These results indicate that compounds from olive byproducts can be used to inactivate foodborne pathogens on melons. (NP 306, C1, PSA, Project No. 2030-41440-008-000D)

AI identifies grain insect pests. Monitoring stored product insect pests is a common practice in managing stored grain and ensuring postharvest grain quality. Current manual sampling and monitoring methods used in large grain storage and food production facilities are time-consuming, labor-intensive, and require expertise for accurate species identification, all of which incur significant expenses for the facility. ARS scientists in Manhattan, Kansas, used deep learning methods and artificial intelligence (AI) to develop image-based identification for five common stored grain insect species: lesser grain borer, rusty grain beetle, red flour beetle, rice weevil, and saw-toothed grain beetle. The system they developed identified all species with an accuracy level of at least 96 percent; the new system also bypassed previous bottlenecks, which led to more rapid response times for implementing pest controls and ultimately reduced damage and economic losses. This work is part of a broader effort to develop camera-based systems for automated pest monitoring in warehouses, flour mills, and general food storage facilities that will improve pest identification and control. Discussions have started with a company producing image-based insect monitoring devices to co-develop insect identification using AI technology, which could showcase how AI can improve pest management. (NP 306, C1, PSA, Project No. 3020-43440-010-000D)

Postharvest treatment improves sweet potato chips. Sweet potato chips are an increasingly popular snack, but more information is needed about how cell wall polymers impact chip textures and fat contents. U.S. sweet potato varieties were not bred for chipping, which leads to issues such as undesirably soft to hard textures and higher oil contents. ARS researchers in Raleigh, North Carolina, investigated how sweet potato cell wall polymers affect sweet potato chip texture and oil uptake to identify important sweet potato characteristics to enhance with breeding or modify with postharvest treatments for desirable chip attributes. Slices treated with a pectin-strengthening enzyme resulted in firmer chips, and chips treated with an enzyme that degrades proteins or an enzyme blend that weakens the cell wall structure were softer. Oil contents were also lower in chips treated with the enzyme blend. This demonstrated chip texture and oil contents are dependent on cell wall polymers and can be modified using postharvest processing treatments such as food-grade enzymes. This research was spotlighted in an article in the Institute of Food Technologists' Food Technology trade magazine and researchers were invited to present their findings at an Institute for the Advancement of Food and Nutrition Sciences' Innovation Showcase. The research will lead to the development of new varieties and postharvest processes for sweet potato chips, which use ~11.2 million kg of sweet potatoes yearly. (NP 306, C1, PSA, Project No. 6070-41000-010-000D)

Producing biodiesel from citrus seed byproducts. The global citrus industry generates around 50-60 million tons of excess biomass when producing juices such as orange juice. This underutilized biomass causes environmental issues when discarded, so finding uses for this material reduces food industry waste while potentially generating new revenue streams. ARS researchers in Peoria, Illinois, converted vegetable oil from waste citrus seeds into biodiesel using a well-known process referred to as transesterification. The fuel properties of the biodiesel produced from waste citrus seed oil were within the specifications of the U.S. biodiesel standard. Using a waste oil as a feedstock for biodiesel production is economically advantageous because feedstock acquisition can approach 80 percent of the cost to produce biodiesel when refined commodity lipids are utilized as feedstocks. These results are beneficial to the citrus and renewable fuels industries and to the public, since using an agricultural waste material to produce an alternative fuel facilitates the societal transition away from petroleum and its consequent environmental and climatic effects. (NP306, C3, PSA, Project No. 5010-41000-186-000D)

3D-printing technology creates superior textured artificial meats. Dysphagia is a medical condition associated with difficulty swallowing food and affects one in six adults in the United States. Currently, dysphagia patients are limited to foods that include purees, minced or small bite-size forms, or liquids. Often, these foods are visually and texturally unappetizing and nutritionally deficient. ARS scientists in Albany, California, used temperature-controlled 3D cryoprinting (TCC) to provide texture, which is a major factor in the sensory evaluation of meat quality, to 3D-printed ground meat. TCC incorporates freezing to the conventional 3D printing technology which then generates structures that confer texture to the 3D printed ground meat. The technology can be used to provide texture to ground meat or meat analogues and provides visually and texturally appealing nutritious foods to people who have difficulties swallowing. (NP306, C1, PSA, Project No. 2030-41000-069-000D)

Novel production of acetaldehyde via renewable energy. Acetaldehyde has many uses in the production of resins, disinfectants, pharmaceuticals, dyes, and solvents, and is typically obtained from petroleum sources. The global market for acetaldehyde was valued at $1.6 billion in 2022 and is expected to expand 3.3 percent annually to a market value of $2 billion by 2029. Efficient acetaldehyde production is possible from bioethanol for a variety of useful products, but reaction efficiencies are typically insufficient for large-scale production. ARS researchers in Peoria, Illinois, developed an improved method that utilizes electrical energy to facilitate the production of acetaldehyde from ethanol. This electrochemical process is an attractive approach because it can rely on renewable energy and provides new markets for ethanol produced from corn. This work will benefit growers and companies in the green chemicals industry. (NP 306, C2, PSB, Project No. 5010-41000-184-000D)

Domestic pectin production from Florida oranges. The global pectin market is currently valued at $967 million and is expected to grow to a value of $1.2 billion by 2028. Most pectin is obtained from apple pomace and citrus peel byproducts from juicing. Florida is a major citrus juice producer but there are currently no pectin production facilities in Florida or even in the United States, and establishing a pectin production facility would support generating a domestic source of pectin and increase the production value of Florida citrus. ARS scientists in Fort Pierce, Florida, identified the optimum pilot scale conditions for pectin production from Florida sweet oranges; their work included support for the design, engineering, and commercialization efforts of a citrus juice co-product manufacturing facility in the state of Florida. The researchers are still engaged with and provide support to the collaborator in establishing this facility, which would be a first of its kind in the United States and would increase the value of a major fruit crop in the state of Florida. (NP 306, C1, PSA, Project No. 6034-41000-018-000D)

Sorghum bran nanoparticles for biomedical uses. Sorghum bran, which is the outer layers of the grain, is a byproduct of sorghum milling and its use in nanoparticle production would benefit the sorghum industry by providing high value use for a byproduct. ARS researchers in Manhattan, Kansas, successfully made nanoparticles from sorghum bran that were high in phenolic content. Phenolic compounds are increasingly recognized as important for human health, so the sorghum bran nanoparticles could have application in the biomedical field for uses such as nanomedicine for disease treatment. Using bran is also an environmentally friendly source of material for nanoparticle production, which would benefit companies interested in nanoparticle production. (NP 306, C2, PSB, Project No. 3020-43440-002-000D)

Synthesizing 2-ethylhexanol from agricultural biomass. The chemical 2-ethylhexanol, which is currently produced from petroleum, has a global market value of approximately $6 billion and is widely used in manufacturing plastics and personal care products. ARS researchers in Peoria, Illinois, developed an improved method to convert biobutanol, an alcohol produced by fermenting agricultural feedstocks, into industrially important 2-ethylhexanol. This new technology has the potential to produce 2-ethylhexanol at lower costs compared to other biobutanol conversion methods because of its higher yields and easier product recovery. Synthesizing chemicals from agricultural resources to replace those typically derived from petroleum opens new market opportunities to producers and will help support the growing bioeconomy. (NP 306, C2, PSB, Project No. 5010-41000-184-000D)

Biobased nanofiber/soybean polymer biocomposites with polypropylene strengths. Conventional polymers have excellent durability and mechanical strength for high-performance applications, so they have become ubiquitous in modern society. However, these materials are nonrenewable, are not biodegradable, and in some cases are toxic. Sustainable and biodegradable polymers made with renewable resources are attractive alternatives, but often suffer from performance deficiencies relative to conventional polymers. ARS researchers in

Peoria, Illinois, developed a biobased composite polymer made from a mixture of cellulose nanofibers and polymerized soybean oil. Composites are advantageous because they are stronger and more functional than the individual components. The resulting renewable composites had mechanical strengths that were comparable to nonrenewable conventional plastics like polypropylene and can be used for packaging, textiles, fibers, and rigid plastic applications that are often unsuitable for non-composites. These findings are beneficial to the agricultural and polymer industries because they represent a new source of polymer produced from agricultural materials that can potentially replace existing materials derived from petroleum. This will provide U.S. farmers with an additional high-value outlet for soybean oil and residual crop waste (cellulose). (NP 306, C2, PSB, Project No. 5010-41000-186-000D)

Plant composites for sustainable biopackaging. Plastic foam is used extensively as internal packing/cushioning material in many of the 21 billion packages shipped throughout the United States each year. The large majority of packaging foams end up in landfills, but significant amounts escape as litter in the landscape and ocean environments. Composite foam panels are of growing interest as a part of the circular economy where renewable, biodegradable, compostable materials replace nonrenewable, nondegradable plastic products. ARS researchers in Albany, California, demonstrated how to use starch and paperboard to make composite foam panels. Starch is an abundant and low-cost commodity that has been explored as a replacement for petroleum-based plastics, and paperboard reinforcing elements improve the strength of the fiber composite foam. The foam composites were lightweight, insulative, biodegradable, and were similar in strength to polystyrene packaging foam. Composite foam panels can be prepared with a large range of physical and mechanical properties that would meet numerous applications. The results of this research show that plant-based materials could be used as a sustainable, renewable, and environmentally friendly alternative to single-use plastic foam packaging. (NP 306, C1, PSC, Project No. 2030-41000-067-000D)