Action Plan
National Program 306
Quality and Utilization of Agricultural Products
Revised 10/1/2017

The goal of the ARS National Program 306 (NP 306), Quality and Utilization of Agricultural Products, is to enhance economic viability and competitiveness of U.S. agriculture by improving quality and marketability of harvested agricultural commodities to meet consumer needs, develop environmentally friendly, efficient processing concepts, and expand domestic and global market opportunities by developing value-added food and non-food technologies and products, and bioconversion-based products in association with biorefining.

NP 306 addresses postharvest quality and processing of foods, development of value-added non-food biobased products, and biorefining processes. The research described in this Action Plan is expected to increase our knowledge and develop technologies to better measure or enhance the quality of crop and animal food and fiber (including hide) products after harvest and bioconversion. Similarly, the marketability and value of commodities can be increased by ensuring that value-added food products (such as fresh-cut or minimally processed whole produce) retain sensory quality and nutritional value and are free from food safety hazards. The research in this National Program will also generate new information on health-promoting components of foods/new foods, in collaboration with the ARS Human Nutrition National Program (NP 107) and other partners who assess food's effects on important human diseases and obesity.

Food NP 306 research, in addition to postharvest quality and safety, consumers have expressed concerns over rising food prices, which can be attributed to multiple factors. A significant factor in the cost of food production can be attributed to food waste or rot. Estimates indicate that 27 to 43 percent of food, mostly fresh fruits and vegetables, produced in the United States is lost as waste among retailers, food service businesses, and consumers. Additional losses occur during food harvesting, storage, and distribution. The magnitude of the loss is even greater when resources spent on growing food, such as fuel, water, fertilizer, chemicals, land use, and human resources, are considered. NP 306 research will develop technologies that improve quality, extend product shelf life, reduce waste, and decrease costs through innovative processing and packaging.

Non-Food NP 306 research supports postharvest crop fiber, animal hides, and leather and wool quality and processing. Stakeholders who produce fibers and hides constitute an important segment of our rural economy, and these industries have been severely impacted by energy and production costs and have lost market share to foreign competition. Technologies that improve fiber quality, reduce the energy consumption of processing equipment, and develop new products can help the fiber industry compete in a global market.

Biorefining NP 306 research supports bioconversion that enables new, commercially-viable technologies for the refining of agricultural materials into value-added co-products, biobased

products and biofuels. To achieve this goal, this Action Plan was designed to meet the following criteria:

1. Maximize the long-term economic impact of ARS bioconversion research
2. Emphasize ARS' unique capabilities and avoid overlap with research at other institutions
3. Maximize returns to agricultural stakeholders from ARS investment of public funds

By developing commercially viable technologies for the production of biobased industrial products, ARS biorefining research increases the demand for agricultural products and, therefore, benefits both agricultural producers and rural communities.

Relationship of This National Program to the ARS Strategic Plan:

Postharvest Quality outputs of NP 306 research support the "Actionable Strategies" associated with the performance measures shown below from the *ARS Strategic Plan for 2012-2017*:

> **Strategic Goal 1.3**: *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 and non-food technologies and products, except energy and fuels.*
>
> **Performance Measure 1.1.3:** Develop methods and technologies to better define, measure, preserve or enhance quality and improve utilization of food crops, animals and agricultural fibers, as well as non-food, non-fuel biobased products and sustainable technologies/processes**.**
>
> **Target:** 2024 – Cumulatively, 20 new technologies developed by ARS and adopted for uses that provide food crops and products with higher quality and extended shelf life; convenient and acceptable healthy foods; non-food, non-fuel biobased products with cost and performance features comparable or superior to petroleum-based products; and valuable co-products from agricultural residues and processing wastes.

Biorefining outputs of NP 306 research support the "Actionable Strategies" associated with the performance measures shown below from the *ARS Strategic Plan for 2012-2017*:

> **Strategic Goal 2.3**: *Develop Technologies to Enable Sustainable Commercial Production of Biofulels*
>
> **Performance Measure 1.2.3:** Develop technologies to enable sustainable commercial production of bioenergy feedstocks and other biofuels.
>
> **Target:** By 2024 ARS will characterize 10 important feedstock traits, create three enhanced germplasm pools, and establish five significant public-private partnerships for advancing feedstock variety improvement; incorporate six new technologies and introduce three new region-based systems that enable the production of biomass feedstocks to help achieve U.S. goals for meeting legislated mandates for blending biofuels. We will provide 10 science-based practices suitable for developing NRCS conservation plans; and industry will commercialize five biorefining and/or co-products technologies which were enabled by ARS research.

COMPONENT 1: Foods

Problem Statement 1.A: Define, Measure, and Preserve/Enhance/Reduce Attributes that Impact Quality and Marketability.

The quality of a food derives from measurable chemical, nutritional, physical, and sensory properties and their complex interactions. Quality is the composite of those attributes of the food and its latent ability to be efficiently milled, malted, baked, cooked, or otherwise processed into appealing, flavorful foods and beverages. Inaccurate or uninformative quality assessment methodologies are detrimental to producers, processors, and ultimately consumers of food products. Quality is assessed and measured at many points from the farm through processing to final packaging and marketing. Quality assessment often requires destructive sampling, expensive equipment, technically advanced protocols and skilled labor, all of which increase final cost to the consumer. NP 306 technologies link crop and animal improvement programs with the food processing industry and consumers. ARS research will develop, evaluate, and implement methods to accurately assess food quality for research, production, and manufacturing programs that lead to improved food quality from farm to consumer.

Consumers intuitively seek food that is at optimal quality and value, bringing to the marketplace quality preferences that influence their choices. Quality that appeals to consumers and is useful for food processors is often transient. As a result of internal biochemical processes and external factors (e.g., insect and microbial activity, storage conditions, and processing practices), desirable quality attributes often change with time after harvest. Uncontrolled sprouting, product moisture content, temperature, relative humidity, concentrations of atmospheric gases, and harvest and handling damage are known to affect the rate of deterioration. In contrast, aging and fermentation of some foods can enhance product quality while extending shelf-life. New information and methods are needed to preserve and enhance the quality and utilization of agricultural products. The research in this Problem Statement will identify processes and compounds that accelerate or inhibit degradation, and will develop novel methods of treating, storing, and processing agricultural commodities and foods to optimize product quality delivered to the consumer.

Research Needs

- Knowledge is lacking about how the underlying chemical and physical properties and processing affect final product quality and sensory characteristics.
- Better understanding of how genetics, production practices, pre- and postharvest environmental conditions, and mechanical handling influence quality.
- New crop cultivars and animal breeds carry with them the potential for altered food quality and these changes need to be quantified and described.
- Measurable chemical, nutritional, and physical properties must be related to sensory perception along with new sensors are required to accurately measure chemical, nutritional, physical, and human sensory properties of agricultural commodities throughout the supply chain.
- New and improved methods to monitor product quality during postharvest handling and storage are necessary, and these technologies will be optimized for accuracy, throughput, and, when necessary, their ability to be nondestructive.

Methods are needed to detect and remove contaminants, defects, and other grade-reducing factors.
- Postharvest biochemical processes need to be correlated to their effects on quality throughout storage and processing.
- Knowledge of internal processes is needed to improve existing management practices and develop innovative techniques to enhance or minimize loss of product quality.
- Instrumentation systems are needed to monitor product quality in storage and modify the storage conditions to minimize deterioration.
- Systems are needed to maintain product identity from the farm to the retail market.

Anticipated Products
- Baseline composition of postharvest food influenced by pre-harvest variation in biotic environmental and management inputs (in cooperation with NP 305, Crop Production).
- Baseline food composition information based on measurable chemical, nutritional, physical, microbiological, and sensory attributes due to effects of storage and postharvest processing; and sampling strategies to accurately measure quality attributes, detect defects, and predict overall quality.
- Sensor/analytical technologies to assess product quality and/or maturity prior to harvest for optimum harvest timing and/or at harvest.
- New laboratory and pilot-scale food processing methods to better replicate commercial processes and improve evaluation of cultivars, harvest methods, storage and processing procedures.
- Identification of plant and animal genes/DNA markers for quality trait loci for flavor, texture, and marketable attributes of food (in cooperation with NP 301, Plant Genetic Resources, Genomics, and Genetic Improvement).
- Efficient, high-throughput and non-destructive technology to grade, sort, and assign value to food based on desired quality/marketability traits after harvest.
- Technology to detect quality lowering attributes or defective products and remove contaminants from the food chain and descriptions of biochemical processes, pre- and post-harvest and metabolites that cause quality deterioration, allergenicity, and cross contamination of allergens postharvest.
- Tools to effectively manage postharvest processing and storage systems and their environments, including instrumentation, control systems, and decision support systems; and innovative storage systems and treatments that maintain/improve product quality and integrity and protect products from pathogens and insects.
- Technology for improvement of packaging, storage containers, and food coatings through management (e.g., humidity, temperature control, atmosphere regulation, and wavelength) to extend the shelf-life of food and preserve flavor, texture, and color.
- Novel methodologies to enhance or predict the quality and utilization of agricultural products.

Potential Benefits (Outcomes)
- Innovative research linking preharvest environmental, biotic, and managerial impact with physical and chemical attributes, genetics, and harvest maturity to sensory and performance traits that produce rapid, inexpensive, product quality assessments.

- Faster delivery of improved crop cultivars through development and implementation of improved definitions of quality and methods to accurately assess cultivar quality
- Improved measurement of quality will allow producers and processors to reduce costs and improve product consistency through segregation of raw materials according to desired quality characteristics.
- Food processing and production management decisions based on quality assessments will result in improved yield and product quality while minimizing product loss from spoilage, infestation, contamination, and poor quality.
- Sensors, quality definitions, and accurate measurements of quality attributes will provide the means to measure the effects of various additives/supplements. The improved measurements (instruments and methods) should measure differences in product quality and relate them to consumer perceptions and expectations.
- Technology to detect and remove contaminants or defective products from food streams will minimize product loss and provide higher quality food to consumers.
- Reduction of loss caused by inadequate post-harvest storage.
- Innovative storage systems will be developed to maintain product quality and identity.
- Low-cost storage systems that can be used for temporary short-term storage at harvest and for emergency food shortages during domestic and international crises.
- Improved utilization of products through quality enhancement techniques.
- Globally competitive, high-quality products with extended shelf life.

Problem Statement 1.B: New Bioactive Ingredients and Health-promoting Foods.

Foods not only provide essential nutrients for sustaining life, but also can impart healthy physiological responses for both humans and animals. Health-promoting foods contain bioactive food ingredients that influence health beyond basic nutritional value (calories, basic metabolic requirements). Health-promoting foods can be from plant, animal or microbial sources and bioactive ingredients, including naturally occurring or induced nutrients from plants, probiotic bacteria, and prebiotic oligosaccharides. The public health promise of the nascent health-promoting foods industry necessitates a multi-pronged research approach to identify biologically active compounds in agricultural materials and health-promoting foods, characterize their structures and physiological functions, and examine the interplay between biologically active constituents and nutritional components. Identification of these constituents, in turn, facilitates agronomic practices and breeding of crop cultivars, livestock, or microbial strains with enhanced bioactive qualities.

Research Needs

- New discoveries are needed to reach the full potential of bioactive ingredients in foods which includes the roles of bioactive ingredients in health-promotion benefits and the effects of environment and processing on health-promoting potentials of foods.
- Broad development of health-promoting foods also will require various food delivery systems with improved understanding of the role of the environment in preserving/enhancing the activity of bioactive ingredients under extended shelf-life conditions.
- Common structural motifs responsible for activity are present in many bioactive ingredients; yet these motifs are poorly characterized and understood. Synergistic and antagonistic relationships between bioactive food ingredients and nutritional components in food matrices exist but are insufficiently characterized at this time.
- New sources of novel bioactive ingredients, should be identified, isolated, and characterized using innovative instrumental and bioassay techniques.
- Expansion of knowledge is needed for probiotic bacteria and their role in promoting health, as well as prebiotic oligosaccharides that stimulate the growth of probiotic bacteria.
- New information on bioactive ingredients should be related to metabolic pathways, regulatory genes, population subgroups, the development of probes (simple colorimetric assays, high-throughput analytical techniques, gene specific molecular markers, etc.) and simulated human intestinal microbiome assays for rapid evaluation of new sources of high-valued compounds to aid in predicting which population subgroups will respond positively to the bioactive compounds.

Anticipated Products

- Health-promoting foods with enhanced levels and activities of bioactive compounds (e.g., fiber, proteins, oils, phytonutrients, etc.) with established efficacy, bioavailability, and safety that represent cost-effective dietary interventions for reducing the risk of chronic disease.
- Identification of new bioactive ingredients and methods to standardize their minimum concentration in foods; develop proteomic, metabolomic, and nutrigenomic tools for evaluation and characterization of food bioactive ingredients; and improve biomarkers to predict success of full-scale human clinical trials and alleviate the need for animal testing.
- Innovative and improved delivery systems for functional food bioactive ingredients (i.e., novel encapsulation, nanoemulsion, controlled release, protein-based “natural”, probiotic bacteria, and synbiotics).
- New and improved crop varieties, animal, and microbial strains as sources of bioactive ingredients (in cooperation with other ARS National Programs and partners).
- Development of new health-promoting foods.

Potential Benefits (Outcomes)

- New food products that potentially stave off health problems caused by aging, and infectious or chronic diseases, thus reducing health care costs in the United States.
- Enhanced competitiveness of the U.S. food industry in the global marketplace.
- Increased values of crops, livestock, or microbial strains used as health-promoting foods or raw materials for functional foods as a benefit to the U.S. rural economy.
- Improved understanding of mechanisms of action of bioactive food ingredients and their role in human health and reducing risk of diseases.

Problem Statement 1.C: New and Improved Food Processing and Packaging Technologies.

Food processing and packaging should make safe, nutritious, and convenient food readily available throughout the year and in every American community. Challenges to assure the food supply in the 21st century have grown complex through a matrix of rising energy costs, environmental imperatives, the capacity for unsafe food to be rapidly and widely distributed, and increasing world demand for nutritious high-quality foods. Major opportunities exist along with these challenges. Recovery of valuable bioactive food ingredients from processing operations can increase the economic value of foods, while reducing environmental impact. New concepts for preservation, increased understanding of sensory mechanisms, and new structure-function relationship insights for food ingredients may make it possible to create new nutritious foods with excellent sensory properties. The United States needs expanded food processing and packaging research both to realize the opportunities and to successfully meet the challenges required to ensure an affordable, high-quality food supply.

Research Needs

- Improved non-thermal preservation techniques to ensure product stability and safety should enhance retention and bioavailability of nutrients and beneficial bioactive food ingredients while retaining desirable sensory characteristics.
- New processes and technologies are needed for protecting, stabilizing, or maintaining the activity of sensitive food components (vitamins, probiotics, bioactive peptides, and fatty acids), throughout processing, storage, and component delivery.
- Large-scale processes with minimal environmental impact are needed to replace aging technologies associated with high energy demand, high water usage, and/or high wastewater load. Also, processes are required to convert food byproducts (hulls, fruit peels, pulp, pomace, and oil seed meal) to commercial products through capture of fiber and bioactive ingredients.
- New food processing technology should be developed to create food structures and matrices at the molecular level with specified function that can boost the quality and nutrition of processed and snack foods for health and wellness.
- Economical small scale technologies are needed for value-added processing of locally produced commodities on or near the farm for local direct marketing of high-quality products.
- Continued improvement is needed in techniques to control the growth of spoilage microorganisms and human pathogens.

- Processes are needed that can convert off-size and off-appearance raw products or by-products into highly functional, high-nutrition food ingredients or non-food products.
- New packaging and coating technologies are needed to protect or enhance the properties of foods, reduce or control the incidence of decay and enteric bacteria, and to extend their useful life through shelf-stable packaging systems.

Anticipated Products

- More efficient (sustainable) food processing (including organically compliant) techniques that reduce energy use, water use, and waste generation per unit of food delivered to consumers.
- New processes (separation, concentration, extraction, and fractionation) to convert low-value commodities or by-products into higher value food ingredients or non-food products.
- Food technologies yielding foods with enhanced nutritional benefits.
- Safer products and/or products with longer shelf-life from new processes that control growth of spoilage microorganisms and human pathogens (in cooperation with National Program 108, Food Safety, and other partners).
- New technologies for production of shelf-stable, frozen, and extended shelf-life food products, including cost-effective systems that preserve bioactive ingredients, enhance food security, or food tailored to meet nutritional requirements for the School Lunch Program, Food for Peace, 'Ready to Eat', and similar programs (in cooperation with National Program 107, Human Nutrition, and other partners).
- Food processing protein-based food ingredients ranging from native to modified proteins, for fortification of foods and beverages.
- New protective films and coatings for foods made from proteins, carbohydrates, lipids, and other food components to enhance the appearance, improve quality, and contribute to the function of shelf-based packaging system.

Potential Benefits (Outcomes)

- Continued availability of adequate, healthy, and affordable food supply for the U.S. population.
- Improved ability to optimize the nutritional, functional, textural, and sensory properties of foods.
- Increased ability for farmers and processors to deliver foods that have proven health benefits to people.
- Increased value to crops and livestock with improved or new higher value-added co-products development from processing waste streams.
- Maintained or higher quality produce will assist U.S. food processors to remain economically competitive in the global market place. Reduction of the environmental impact (e.g. petroleum-based energy use, water use, air pollution, and greenhouse gas emissions) required to safely produce and deliver food to consumers.

Component 1 Resources
The following ARS locations have research projects addressing the Problem Statements identified under Component 1: Albany, CA; Athens, GA; Beltsville, MD; Dawson, GA; East Lansing, MI; Fargo, ND; Ft. Pierce, FL; Madison, WI; Manhattan, KS; New Orleans, LA; Oxford, MS; Parlier, CA; Peoria, IL; Pullman, WA; Raleigh, NC; Wenatchee, WA; Wooster, OH; and Wyndmoor, PA.

COMPONENT 2: Non-Food (fibers including hides)

By far, the highest-volume agricultural commodity used in the manufacture of non-food products is cotton, and U.S. farmers plant 10-15 million acres of cotton each year. Due to cotton's importance, ARS has been a long-time leader in post-harvest cotton research, which is considered one of the Agency's most important non-food research areas.

Cotton-fabric manufacturing in China, India, and Pakistan has grown to the point where the great bulk of U.S. cotton is exported to these countries. Because of global competition, the quality of exported U.S. cotton is critical for the continued economic viability of U.S. cotton producers. This situation is exacerbated by the fact that much of the cotton produced overseas is hand-picked by low-cost labor, thereby posing significant challenges to U.S. machine-harvested cotton with respect to fiber quality.

In addition, the lack of growth in world-wide cotton production has led to a consolidation in manufacturers of equipment to harvest and process cotton. Consequently, the remaining equipment manufacturer conducts little or no research to improve its equipment; and ARS has become the only institution performing important post-harvest cotton research needed by the U.S. cotton industry. As a reflection of strong industry support, ARS post-harvest cotton researchers received almost $3.8 million in grants between 2008 and 2013 from Cotton Inc., a check-off program that funds research of benefit to U.S. cotton producers. ARS post-harvest cotton research focuses generally on technologies that ensure the cost and quality competitiveness of U.S. cotton exports and that create new markets for cotton.

Two other agricultural products—wool and hides—support large, long-standing non-food/non-feed markets. However, as for cotton, finished products based on leather and wool have lost substantial market share to synthetic materials; and most of the finished goods manufacturers utilizing these products are now overseas. ARS is the only institution performing important post-harvest research both needed by U.S. exporters of hides and leather and that enable new applications for wool.

Problem Statement 2.A: In collaboration with industrial partners, develop new post-harvest technologies…

i. **To increase or protect the market demand for [or increase the value of] existing U.S.-produced non-food biobased products derived from agricultural products and byproducts, and**

ii. To enhance product quality, improve process efficiencies, and reduce processing risks for existing U.S. producers of non-food biobased products derived from agricultural products and byproducts.

Research targeting this Problem Statement focuses on technologies that will impact existing markets and value-added chains [between harvest and product export or U.S-based product manufacturing] for non-food biobased products. Technologies enabled under this Problem Statement can either (a) provide defensive protection to existing market share for U.S. stakeholders; (b) help U.S. stakeholders increase market share in existing markets, or (3) both.

To ensure that ARS research targeting this Problem Statement will benefit industry, collaborations with existing manufacturers and users are necessary. However, it is important that research addressing this Problem Statement is pre-competitive to the extent possible and enables commercially desirable technologies that the private sector cannot develop on its own within a time frame limited by existing market opportunities and threats. It is also important that intellectual property generated by this research be managed so that it is broadly available to U.S. stakeholders.

Most of the ARS research targeting this Problem Statement serves stakeholders in the cotton, hides, and wool industries. These industries are increasingly competitive on a global scale and demand continued innovation within their entire supply chains.

The term 'non-food biobased products' in this Problem Statement is broadly defined and includes animal feed. Also, the term 'agricultural products and byproducts' is broadly defined and includes cotton, hides, leather, wool, on-purpose plant feedstocks, crop residues, food-processing byproducts, biorefinery co-products, and livestock manures. In addition, the term 'post-harvest technologies' includes technologies for harvesting/collecting agricultural materials to be converted into non-food biobased products.

Research Needs

- Develop criteria, methods, and instrumentation that allows industry to rapidly and accurately assess raw or in-process material quality.
- Develop tools to predict processing efficiencies and product quality/performance from raw material physical composition and structure.
- Identify methods to help industry to preserve raw or in-process material quality during handling, storage, or transportation.
- Develop new or modified processes and equipment to increase labor, energy, and capital productivity; decrease ecological footprints; and increase product value.

Anticipated Products

- Criteria, methods, and instrumentation to assess raw or in-process material quality.
- Tools to predict processing efficiencies and product quality/performance from raw material composition and structure.
- Methods that preserve raw or in-process material quality during handling, storage, or transportation.

- Processes or equipment to increase labor, energy and capital productivity; decrease ecological footprints; and increase product value.

Potential Benefits (Outcomes)

- Greater economic returns to U.S. agricultural producers, processors of non-food biobased products, and rural communities in the United States.

Problem Statement 2.B: Enable technologies for (1) expanding market applications of existing biobased products, and (2) producing new marketable non-food biobased products derived from agricultural products and byproducts and estimate the potential economic value of the new products.

Both industrial and end-use consumers increasingly demand sustainable, renewable products manufactured from domestically sourced raw materials and with relatively low life-cycle ecological footprints. Consequently, biobased products could take market share from fossilized-carbon-based products, which are neither renewable, sustainable nor ecologically friendly, and/or which often must be imported. Biobased products that replace petroleum-based products are particularly competitive due to higher oil prices, a trend which should continue as petroleum reserves are depleted. In addition, many biobased products are biodegradeable—a feature that results in especially low life-cycle ecological footprints.

To maximize the likelihood that ARS research will generate economic impact, ARS researchers will estimate the potential economic impact of technologies that their research could enable. By knowing the major cost components for a process technology, ARS researchers can focus on efforts that yield the most impact. As the research proceeds, efforts that are unlikely to generate economic impact will be redirected.

ARS research targeting new nonfood biobased products focuses on (1) near- and mid-term opportunities for generating economic returns and (2) on enabling technologies with applications in existing markets. Technologies that create drop-in substitutes for existing commercial products are easier to assess than those for new-to-the-market chemicals or materials – products which require extensive and expensive customer qualification testing. Prior to patenting, ARS will work with industry partners to evaluate the commercial potential of inventions.

Collaborations with existing manufacturers and users are critical to ensure that ARS conducts research that benefits industry. However, it is important that research addressing this Problem Statement is pre-competitive to the extent possible and enables commercially desirable technologies that the private sector cannot develop on its own within a time-frame limited by existing market opportunities and threats.

In Problem Statement 2.B, the term ‘non-food biobased products’ is broadly defined and for example includes chemicals, polymers, elastomers, composites, agrichemicals, and animal feed. Also, the term ‘agricultural products and byproducts’ is broadly defined and includes cotton, hides, leather, wool, on-purpose plant feedstocks, crop residues, food-processing byproducts, biorefinery co-products, and livestock manures.

Research Needs

- Develop technologies that enable new market applications for existing biobased products.
- Develop technologies that enable new commercially viable biobased products.
- Estimate the potential market that a new biobased product could capture.

Anticipated Product

- Technologies to enable new market applications of existing biobased products.
- Technologies to enable new commercially viable biobased products.
- Process cost estimates and models for production of new biobased products and for new market applications of biobased products.

Potential Benefits (Outcomes)

- Greater economic returns to U.S. agricultural producers and rural communities.
- Increased impact of ARS research for new applications of biobased products and for new biobased products.

Problem Statement 2.C: Collaborate with breeders and production researchers in the development of both new cultivars/hybrids and new production practices/systems that optimize the quality and production traits of crop-derived products and byproducts for conversion into non-food biobased products.

This Problem Statement recognizes the influence of genetics and production systems on both manufacturing cost and quality/value of intermediate and finished biobased products. New crop varieties can be bred to optimize (1) quality traits of benefit to post-harvest processing, (2) cropping productivity/profitability, or (3) both.

This NP 306 research will assist specialists in crop variety development and/or crop production systems to assess how new varieties and cropping practices, such as crop rotations and double cropping, affect the economic viability and life-cycle ecological footprints of the resulting products.

In this Problem Statement, the term ‘agricultural products and byproducts’ is broadly defined and includes cotton, on-purpose plant feedstocks, crop residues, food-processing byproducts, and biorefinery co-products. Also, the term ‘non-food biobased products’ is broadly defined and includes animal feed.

Research Needs

- Identify inherent genetic properties, production environment/practices, and harvesting practices that maximize the composite returns to value-added chains for non-food biobased products.

Anticipated Products

- Crop varieties and production/harvesting practices that maximize profitability of cropping systems for non-food biobased products and the value of crops converted into non-food biobased products.

Potential Benefits (Outcomes)

- Increased competitiveness of U.S. produced non-food biobased products.
- Greater economic returns to U.S. agricultural producers and rural communities.

Component 2 Resources

The following ARS locations have research projects addressing the problem statements identified under Component 3: Albany, CA; Beltsville, MD; Mesilla Park, NM; Lubbock, TX; New Orleans, LA; Oxford, MS; Peoria, IL; Stoneville, MS; Ft. Pierce, FL; and Wyndmoor, PA.

COMPONENT 3. Biorefining

As a low-cost agricultural producer, the United States has the necessary raw-material base (feedstocks) to support a healthy, domestic bioconversion products industry. Further, if U.S. bioconversion i.e. biobased products manufacturers can be first to market and learn to maximize customer value and manufacturing productivity, U.S. manufacturing will enjoy an edge in the emerging world-wide biorefining. Even if production of finished biobased products is done overseas U.S. agricultural producers and processors need technologies to ensure their products meet the quality and cost requirements of industrial customers in these competitive global markets.

This Component for non-food biobased products is designed to maximize the long-term economic impact of ARS non-food biobased products research, and to emphasize ARS' unique capabilities and avoid overlap with research at other institutions.

ARS non-food biobased products research targets near- and mid-term opportunities for economic returns and focuses on enabling technologies with applications in existing markets. It is important that ARS non-food biobased products research be pre-competitive and develop commercially desirable technologies that the private sector cannot develop on its own within a time frame limited by existing market opportunities and threats. Collaborations with existing manufacturers and users are critical to ensure that ARS conducts pre-competitive research that benefits industry; and in support of this need, ARS has internal resources to efficiently and rapidly capture intellectual property and transfer enabling technologies to industry for commercial development and deployment. In addition, because of both (1) ARS' uniquely broad, geographically-diverse, multi-disciplinary research capacities for agricultural research, including world-class collections of plant germplasm and microorganisms, and (2) ARS' lack of internal barriers to the exchange of ideas (intellectual property), ARS can quickly and efficiently identify and conduct research that will maximize impact. Additionally, ARS non-food biobased research that involves collaboration with feedstock development or production researchers is of high priority.

An important resource available to non-food biobased products researchers at ARS is the USDA Regional Biomass Research Centers. These regional networks of ARS laboratories focus resources associated with several ARS National Programs and catalyze public and/or private research and technical partnerships to enable complete regionally appropriate feedstock supply chains for non-food biobased products.

ARS research enables commercially viable technologies for non-food biobased products and helps to increase both the demand for agricultural products and the number of manufacturing jobs in rural communities.

Under Component 3, ARS will conduct research of potential benefit to biorefiners that utilize biochemical conversion technologies.

Processes for the biochemical conversion of agricultural materials typically involve the following process steps:

- Feedstock fractionation;
- Production of fermentable sugars;
- Biocatalytic, chemical and or thermolysis i.e. anaerobic digestion, enzymatic (catalytic and non-catalytic), hydrolysis, metal catalysis, microbial (bacterial, fungi and yeast), and pyrolysis and torrefaction; and
- Recovery and purification of advanced biofuels, biobased chemicals, and/or co-products.

Problem Statement 3.A: Technologies for producing advanced biofuels (including biodiesel), 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, sweet sorghum, sugar cane, or sugar beets) or plant-derived fiber (such as grain fiber, stover, straw, or bagasse) into biofuels- or diesel-compatible that supplement fossil-based fuels or other marketable products. These feedstocks may include food-processing wastes or agricultural residues, as well as energy crops.

The current biofuels industry is dominated by corn ethanol. But current limits on both the amount of ethanol that can be practically blended with gasoline and the amounts that can be economically produced from corn are significant barriers to further growth in the Nation's biofuels industry. The forecasted decrease in demand for gasoline, coupled with the overbuilding of grain ethanol production capacity, has muted the need for research to increase production of fuel ethanol.

In contrast, there is a strong need for marketable biofuels that can suppliment fossil-derived liquid transportation fuels such as biodiesel and biojet. Such advanced biofuels, as well as other products and/or co-products from the biorefineries that produce them, will help maintain the economic viability of existing biorefineries and enable growth of the biorefining industry. Examples of high-value products and co-products include chemicals (>C2 alcohols, ketones, aldehydes, carboxylic acids, and aromatics), proteins and peptides, sugar alcohols (xylitol, sorbitol and mannitol), biopolymers (dextran, alternan, pullulan, schizophyllan, polymalic acid, functional hemicellulose and cellulose derivatives), and livestock feeds. Technical challenges to commercialization of these products include:

- Identification and demonstration of viable routes to new products
- Low efficiency of existing pretreatment and hydrolysis (enzyme) technologies
- Limited number of microorganisms that fully utilize all sugars/proteins for the fermentative conversion of agricultural materials to advanced biofuels and chemicals

Biorefineries that process a variety of feedstocks enjoy a significant competitive advantage. However, most biocatalytic-based biorefineries are relatively inflexible regarding feedstock choice. Consequently, research to help make biocatalytic-based biorefining processes more feedstock-flexible could generate significant impact.

Further, to increase the likelihood that industry will adopt technologies enabled by ARS research addressing Problem Statement 1, close coordination is required between ARS researchers and product/co-product users. ARS research to develop products or co-products for animal feed

applications will also likely require collaboration with ARS animal nutrition laboratories and may also benefit from collaboration with ARS feedstock development researchers.

ARS research addressing Problem Statement 3 will not focus on biogas (i.e., methane).

Biodiesel has been approved by the U.S. Environmental Protection Agency as an advanced biofuel under the Renewable Fuels Standard (RFS2), its market is anticipated to grow to 4 billion gallons, more than 10 percent of the on-road diesel pool, by 2022. In the face of this growing demand, new biodiesel feedstock will need to be developed, and more demanding expectations for diesel engine performance (e.g., higher engine temperatures/pressures, greater fuel economy, and lower emissions) will require higher-quality fuels.

Thermolysis or thermochemical conversion i.e. pyrolysis and torrefaction of biomass comprises 1) heating in the absence of oxygen; 2) gasification, heating under partial oxygen conditions; and 3) combustion, heating under excess oxygen. The advantages of thermochemical-based biorefinining include the ability to process a wide range of feedstocks (e.g., agricultural residues, crop residues, energy crops, manure, and even agricultural plastics) and a relatively high throughput rate for a biorefining process. Pyrolysis offers a unique potential to directly produce hydrocarbon fuel intermediates (i.e., refinery fuel blendstocks) that can potentially enter existing petroleum refinery flow streams without creating a whole new refinery system. In fact, the only commercial biorefineries that produce drop-in hydrocarbon fuels are pyrolysis-based (KiOR and Diamond Green Diesel). Among the thermochemical conversion routes, pyrolysis is the only one that has the full potential to provide small footprint technologies that can accommodate at- or near-farm production of liquid fuel intermediates and chemicals from biomass. Distributed, village-scale pyrolysis has been suggested by industry groups, finance communities, and some philanthropists as a viable tool for strengthening rural economies. Near- or on-farm pyrolysis has the potential to play a major role in helping the United States meet renewable fuel standard (RSF2) goals. Research is needed at both fundamental and applied levels to establish pyrolysis as a viable process for the conversion of biomass to hydrocarbon fuels and chemicals at farm scale.

Research Needs

- New commercially viable technologies for fractionating agricultural materials and/or food-process wastes into products for direct sale or for further processing into marketable products. New commercially viable processes for depolymerizing cellulose and hemicellulose to fermentable sugars
- New commercially viable biocatalytic-based processes for the production of advanced biofuels and/or biobased chemicals
- Commercially viable hybrid (biocatalytic and/or chemical) processes to convert sugars, oligosaccharides, non-food proteins, and/or lignin to advanced fuels and/or biobased chemicals
- Commercially viable processes to modify fatty acid alkyl ester structures in biodiesel to improve its low temperature operability
- New commercially viable technologies to significantly lower the crystallization temperature of biodiesel by reducing the levels of contaminants (e.g., sterol glucoside) and/or persistent intermediates (e.g., saturated monoglycerides)

- Commercially viable process systems, feedstock or co-reactants, feedstock collection/storage practices, feedstock preprocessing methodologies (e.g., chopping, drying, densifying, torrefying, charring), or catalysts that enable the commercial viable near- or on-farm conversion systems for the production of partially-deoxygenated bio-oils, and marketable co-products

Anticipated Product

- Biocatalytic, chemical or hybrid (biocatalytic and chemical) and thermolysis technologies that are used by industry for the production of advanced biofuels, biobased products, and/or co-products.
- Recommendations adopted by biorefiners, feedstock producers or plant breeders regarding desirable feedstock traits and feedstock handling/preprocessing/blending practices that enhance biocoversion performance

Potential Benefits (Outcomes)

- Expanded markets for biofuels (including biodiesel) and biobased products
- Increased demand for agricultural products

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

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

Efforts addressing Problem Statement 3.B must involve collaborations with industrial biorefiners or biodiesel faculties or receive external funding support as early as possible in the research.

Research Needs

- Commercially viable technologies for increasing process efficiencies or reduce the incidence of operating disruptions in existing biorefineries
- Commercially viable technologies that enhance the feedstock-flexibility of existing biorefineries/ biodiesel facilities
- Commercially viable technologies for the production of biofuels and other marketable products from food processing wastes
- Commercially viable technologies that increase the number of marketable products produced in existing biorefineries/ biodiesel facilities
- Commercially viable technologies for converting ethanol into advanced biofuels or biobased chemicals
- Commercially viable technologies that enhance the value of existing byproduct streams

Anticipated Products

- New ARS-enabled technologies that are used by existing biorefiners/ biodiesel producers to reduce their business risks and increase profitability
- New ARS-enabled technologies that are used by industrial buyers of co-products from existing biorefiners/ biodiesel facilities
- Technologies deployed by industry to significantly improve cold-flow performance of biodiesel fuels

Potential Benefits (Outcomes)

- An economically healthy biorefining industry
- Stable demand for agricultural products to supply feedstocks for the ethanol production industry

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 competiveness. 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 so as to yield the most impact. Therefore, technoeconomic analyses will be conducted to accurately estimate the expected economic impact of ARS biorefining research.

Research Need

- Accurate estimates of the effect of new technologies on capital and operational costs in commercial biochemical conversion facilities

Anticipated Products

- Capital and operating cost models for new biocatalytic- and hybrid-based biorefining and thermolysis technologies
- Research that maximizes the impact of public funding is identified for biochemical conversion and thermolysis technologies

Potential Benefits (Outcomes)

- Increased commercial deployment of new biorefining/biodiesel technologies.

Component 3 Resources

The following ARS locations have research projects addressing the Problem Statements identified under Component 3: Albany, CA; New Orleans, LA; Peoria, IL; and Wyndmoor, PA.