SpringBoard Challenge Statements – 2025

Purpose-driven research, development, and innovation of non-food products and manufacturing solutions derived from soybeans.

Focus Areas: Bioplastics // Lubricants // PFAS Substitutes // Biopolymers // Biofibers

BIOPLASTICS

Background: The majority of traditional plastics are made from nonrenewable fossil fuels. These feedstocks are extracted using processes that contribute significantly to environmental pollution. Plant-based bioplastics, derived from crops such as soy, hemp, or corn, are more sustainable, renewable alternatives, but they present performance and scalability hurdles.

Challenge: *How can soy-derived materials (hull, protein, etc.) be used to create bioplastics that are as effective, cost-efficient, and scalable as traditional petroleum-based plastics?*

Innovation Criteria:

- Develop bioplastics with properties that match or exceed conventional plastics (moldability, durability, water-resistance, etc.); enhanced properties can be achieved by combining biopolymers with other plant-derived natural polymers (lignins, humics, etc.), provided that soy and its derivatives are the main ingredient in such a formulation.
- Ensure the bioplastic synthesis is scalable and cost-effective for downstream processing.
- Improve biodegradability or compostability without compromising performance.

It is known that plant seed oils can be used to produce relatively long-chain dicarboxylic acids, dialcohols, and diamines for the production of a wide variety of polymers such as polyesters, polyamides, polyesteramides, polyimides, polyurethanes, and polyureas, to name a few. For example, oleic acid obtained from seed oils, such as soybean oil, especially high oleic soybean oil, can be oxidized to the nine-carbon dicarboxylic acid, azelaic acid (AA). From AA, the nine-carbon diamine, 1,9-nonanediamine, can be produced using different routes, such as the conversion of the diacid to the diamide with ammonium, dehydration to the nitrile, and hydrogenation to the amine. From AA, 1,9-nonanediol can be produced using hydrogenation. Essentially, any unsaturated fatty acid obtained from a seed oil can be used to produce diacids, diamines, and diols that can subsequently be used to produce a huge number of polymers. Since these monomeric species are not currently produced at high volume, their cost is relatively high, and their use in developing new polymers is largely unexplored.

Since these monomers have relatively long hydrocarbon chains compared to commodity diacids, diols, and diamines, such as adipic acid, ethylene glycol, butylene glycol, and hexamethylene diamine, they absorb less water and are more hydrolytically stable. It has been shown that a wide number of potential polymers can be produced from these seed oil-derived polymers that have properties comparable to or better than properties of commercial plastics. In addition, many possess properties that are unique or differentiated from petroleum-based plastics.[i]

LUBRICANTS

Background: Petroleum-based lubricants are essential in many industries but harmful to the environment. Oils from renewable plant sources like soy, hemp, and canola are often biodegradable and far less toxic to ecosystems, yet their full potential as lubricants remains underutilized because oilseed-based lubricants can cost more and perform less effectively.

Challenge: *How can soy-based oils be engineered to develop lubricants that match or surpass the performance of traditional petroleum-based options while being cost-effective?*

Innovation Criteria:

- Achieve lubrication properties (viscosity, stability, etc.) that meet or exceed industry standards, including under conditions that involve high temperatures and extreme pressure (e.g., automotive, industrial machinery).
- Explore novel formulations that optimize performance without increasing costs.
- Improve biodegradability and reduce toxicity to minimize environmental impact.

Plant seed oils and their derivatives have been heavily investigated for lubrication of metal substrates. However, they have not been so heavily investigated as internal or external lubricants or mold-release agents for plastics. Often, these applications are served by petroleum-based waxes and/or polyolefin oligomers. For example, oxidized, low molecular-weight polyolefins are often added to PVC as an external lubricant for the production of vinyl siding. The polyolefins melt at a relatively low temperature, are compatible but insoluble in PVC, and have lower surface energy than PVC. As a result, the low-viscosity molten polyolefin segregates to the metal/PVC interface during mixing, enabling easier processing of the plastic and smoother surfaces of the extruded siding. Since plant seed oils are easily modified at the ester groups, double bonds, and/or bis-allylic hydrogens, solubility characteristics, viscosity, and melting temperature of hydrogenated derivatives can be tailored to meet performance requirements. The amount of R&D in this area appears to be relatively low. These materials may also be useful for producing mold-release additives for injection moldable plastics.

PFAS SUBSTITUTES

Background: PFAS (per- and polyfluoroalkyl substances) are a group of over 4,000 "forever chemicals" used in a wide variety of products. Many pose significant risks to human health and the environment. It is vital to find safe plant-based substitutes that offer the properties of being non-stick, stain-resistant, fire-retardant, water-repellent, and heat-resistant.

Challenge: *How can soy-based compounds serve as PFAS substitutes in consumer and industrial applications while ensuring similar performance and safety standards?*

Innovation Criteria:

- Identify plant-based compounds (primarily from soy, but one may incorporate hemp, corn, etc., to a much lesser extent as a minor component) that exhibit comparable performance to PFAS (chemically stable, low surface tension, oleophobic, etc.) for use in diverse industries (food packaging, firefighting foams, electrical insulation, etc.).
- Consider biodegradability, compatibility across manufacturers, and degradation.
- Develop scalable and cost-effective cultivation, synthesis, and processing methods.

PFAS is used in packaging, textile, and film applications because the C-F bonds impart to the materials very low surface tensions, which enables both hydrophobicity and oleophobicity, i.e., omniphobicity. It has been shown that omniphobicity can also be achieved through a physical effect by creating surfaces that possess both micro- and nanoscale surface roughness. Basically, the surface roughness is on a scale that results in nanoscale air pockets that are small enough to overcome capillary forces that typically result in wetting of porous structures by water. It has been shown that porous nanocomposite materials, based on nanomaterials such as cellulose nanofibers/crystals and silica nanoparticles, can be used to create omniphobic surfaces, despite the materials being quite hydrophilic in their nonporous state. The key to creating superhydrophobic or omniphobic coatings with these nanomaterials is creating the surface roughness/porosity characteristics that inhibit the capillary action of water or other liquids. A combination of biobased and/or non-toxic nanomaterials with different size and shape distributions, with or without surface modification, could be used to replace the need for PFAS for packaging, textile, and film applications. The key to this technology is consistently creating the surface roughness requirements using relatively inexpensive and/or low levels of biobased and/or nontoxic nano- and microparticles.

BIOPOLYMERS

Background: Widespread use of petroleum-based polymers contributes to environmental pollution and toxin accumulation. Plant-derived polymers from crops like soy, corn, and wheat offer sustainable, biodegradable alternatives with the potential to reduce ecological impact, but obstacles include limited mechanical properties and production costs.

Challenge: *How can soy-based materials be engineered into polymers that serve as building blocks for bioplastics that may be used across diverse industrial applications?*

Innovation Criteria:

- Develop soy-based biopolymers with essential properties like mechanical strength, water and chemical resistance, durability, and thermal stability. Aesthetic properties (transparency, color stability) and processability (extrusion, molding) are also key.
- Explore environmental impacts: biodegradability, compostability, and recyclability.
- Consider cost-effectiveness and scalability, especially in the production process.

In general, plant-based biopolymers, such as polysaccharides, proteins, and lignin, tend to be quite sensitive to moisture and/or brittle compared to petroleum-based analogs. As is done by nature, these inherent limitations of the pure polymers can be overcome and used to provide synergy between components by creating composite structures with complex morphologies and higher-ordered structures. Due to the limitations of pure plant polymers with respect to their high Tgs/brittle nature and moisture sensitivity, blending them with hydrophobic elastomeric materials such as natural rubber could enable significant utility. For example, different soy components with different levels of soy protein have been used as a reinforcement for natural rubber. Likewise, lignin has been utilized as a biobased reinforcement for natural rubber. Overall, the use of plant polymers and their derivatives in rubber compounds has only received limited attention. Considering the wide range of physical and mechanical properties that can be achieved by derivatizing and combining natural rubber with various polysaccharides, proteins, lignins, and seed oils, more attention should be paid to these multiphase and multifunctional materials. The key to creating value-add materials based on these multicomponent, multiphase materials is utilizing polymer derivatization chemistries to impart compatibility between the different components to enable synergistic interactions and tune properties for a specific application.

BIOFIBERS

Background: Synthetic fibers currently used in the textile industry contribute significantly to pollution and can take hundreds of years to decompose. Fibers, proteins, and starches from natural crops such as soy, corn, and hemp offer sustainable and biodegradable alternatives to petrochemicals. Further research is needed to engineer biofibers that are scalable.

Challenge: *How can soy-based biofibers, developed primarily from soy with potentially other renewable plant sources, be utilized to create scalable textiles that offer strong performance and environmental benefits?*

Innovation Criteria:

- Develop biofibers primarily using soy proteins and starches (and incorporating other plant sources as secondary feedstock as needed) that offer properties needed in the textile industry: strength, durability, softness, breathability, receptiveness to dyeing and finishing treatments, water and chemical resistance, biodegradability, etc.
- Consider eco-conscious synthesis (low-impact water, heat, or chemical processing).
- Explore ways to support local, sustainable fiber production at scale.

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[i] The following articles and patents from Dr. Bret Chisholm illustrate these facts:

A. Kugel, J. He, S. Samanta, J. Bahr, J. L. Lattimer, M. A. Fuqua, C. A. Ulven, and B. J. Chisholm, "Semicrystalline polyamide engineering thermoplastics based on the renewable monomer, 1,9-nonane diamine: Thermal properties and water absorption," *Polymer-Plastics Technology and Engineering*, **51(12)**, 1266-1274 (2012).DOI:10.1080/03602559.2012.699576
B. J. He, S. Samanta, S. Selvakumar, J. L. Lattimer, C. A. Ulven, M. Sibi, J. Bahr, and B. J. Chisholm, "Polyamides based on the renewable monomer, 1,13-tridecane diamine I: Synthesis and characterization of nylon 13,T," *Green Materials*, **1(2)**, 114-124 (2013).DOI:10.1680/gmat.12.00021
C. S. Samanta, J. He, S. Selvakumar, J. L. Lattimer, C. A. Ulven, M. Sibi, J. Bahr, and B. J. Chisholm, "Polyamides based on the renewable monomer, 1,13-tridecane diamine II: Synthesis and characterization of nylon 13,6," *Polymer*, **54**, 1141-1149 (2013).DOI:10.1016/j.polymer.2012.12.034
D. B. J. Chisholm and S. Samanta, "Polyamide copolymers having 2,5-furan dicarboxamide units," U.S. Patent 9,765,186.