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United States Department of Agriculture
Project Initiation

Project Data for Accession Number 1031763

Project Title

Converting Agricultural Waste into Biobased, Nontoxic, and Biodegradable Alternatives to Animal and Synthetic Leathers

Project Details

Sponsoring Institution National Institute of Food and Agriculture	**Project Status** COMPLETE
Funding Source NIFA Non Formula	**Grant Year** 2024
Grant No. 2024-33530-41904	**Cumulative Award Amt.** $174,983.00
Proposal No. 2024-00181	**Multistate No.** (N/A)
Project Start Date Jul 01, 2024	**Project End Date** Feb 25, 2026
Program Code [8.8] Biofuels and Biobased Products	

Project Director

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Recipient Organization

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Performing Department

(N/A)

Non Technical Summary

At EcoaTEX, we convert agricultural waste into beautiful biobased synthetic leather materials through a circular and non-hazardous process. We solve a two-fold problem with the agriculture industry and the textile industry, which includes both the fashion and soft furnishings industries. Our technology presents an opportunity to utilize US farmers' limited-value agricultural waste that would otherwise be discarded or burned, thereby generating additional revenue for farmers with added environmental, social, economic, and ethical benefits to the agriculture, textile, fashion, and soft furnishings industries. There is a dire need for material production to start with circularity and a renewable life cycle. This includes the reuse and recycling of waste material, reducing the amount of water, energy, and toxic chemical usage that contaminate our water systems, and creating products that easily biodegrade, all designed from the start to reduce our carbon footprint.Specifically, the fashion industry is the second largest polluter of the

environment after the oil industry and is significantly responsible for the current state of global carbon emissions. In recent decades, the "fast fashion" industry, whose goal is to reduce costs while maximizing profit, has been a dominant contributor to the deterioration of the environment. Animal and synthetic leather production is extremely harmful to the environment and contributes to greenhouse gas emissions and water pollution. Within the animal leather industry, there have been technologies designed to make the toxic tanning process less harmful. Also, technological innovations within the synthetic "leather" sector include new applications to increase the biodegradability of these traditionally unbiodegradable products. Despite these claims, these processes and materials fail to correctly address the issues of water usage, greenhouse gas emissions, biodegradability, and use of toxic chemicals. Today, the most used alternatives to animal leather are polyurethane (PU) and polyvinyl chloride (PVC) "leathers," which both require toxic chemicals. These faux/vegan leather (vinyl) materials will negatively impact the environment and human health for hundreds of years since there is no natural process to break them down.The raw material that we use originates from an abundantly attainable and renewable source, agricultural waste, unlike some of the other newer alternative technologies that require complex processes like fermentation and extended planting and growing durations. Our raw material differs from existing technologies in the source of the raw material itself, as well as speed, production costs, availability, and biodegradability. Additionally, most other biobased alternative leather products are not fully biodegradable and sustainable since they use petroleum-based additives, and only some percentage of their products come from biodegradable raw materials. In addition, our clean manufacturing methods allow us to operate safely and locally to provide a toxic-free work environment. Our bio-"leather" can be easily and economically produced in-house. The product starts by sourcing our proprietary, non-toxic materials, all of which will be made into a finished product/material. In this project, we will conduct a series of experiments and will develop samples with a range of parameters, thicknesses, colors, textures, and finishes. In order to evaluate and improve the quality of our bio-"leather" in comparison with the industry standard, we will conduct various textile testing methods to measure the bio-"leather" properties and collect data. The data will be assessed by conducting a statistical analysis.To reach our target audience, we will first establish partnerships and collaborations with farmers and manufacturers of textiles, apparel, and soft furnishing brands. The affordability of our materials will give us a much wider reach, and we plan to penetrate the market with multiple price points to make our truly green materials accessible to consumers. Our brand messaging communicates the product's core function value and why it matters to the consumer. As consumers increasingly seek out regional products, the eco-friendliness of the product is the most significant predictor for shopping locally. Our product messaging will focus on the circular identity and environmental benefits of our bio-"leather." Notably, since our raw materials will be sourced from local farmers in Georgia, our company's location, we will increase our brand's social awareness with a made-from-local-waste story and plan to implement strategic "Made in USA" and "Georgia Grown" trademarks for example, with our marketing and social profiles.Our bio-based leather-like material innovation introduces a novel, non-hazardous process that enables a circular and traceable value chain. Our mission is to develop biodegradable alternatives to animal and synthetic leathers from agricultural waste that would otherwise be discarded. Our responsible production methods focus on reducing and reusing waste, decreasing the amount of agricultural waste, and providing an environmental benefit for all. The ultimate goal of this project would be to set a precedent to develop a cleaner fashion and textile industry through our circular approach that utilizes agricultural waste.

Animal Health Component

Animal Health Component: 0%

Research Effort Categories

Basic	20%
Applied	30%
Developmental	50%

United States Department of Agriculture
Project Initiation

Classification

Knowledge Area (KA)	Subject of Investigation (SOI)	Field of Science (FOS)	Percent
511	1899	2000	10%
402	7299	2000	10%
901	7310	2090	10%
511	1830	1000	15%
511	1211	1000	15%
511	1820	2000	10%
511	1730	2000	10%
511	5120	1000	10%
511	0650	1000	10%

Knowledge Area

[511] New and Improved Non-Food Products and Processes

[402] Engineering Systems and Equipment

[901] Program and Project Design, and Statistics

Subject Of Investigation

[1899] Oilseed and oil crops, general/other

[7299] Research equipment and methods, general/other

[7310] Experimental design and statistical methods

[1830] Peanut

[1211] Pecan

[1820] Soybean

[1730] Hemp

[5120] Textiles

[0650] Wood and wood products

Field Of Science

[2000] Chemistry

[2090] Statistics, econometrics, and biometrics

[1000] Biochemistry and biophysics

Keywords

sustainability, circularity, Agricultural waste, biodegradable biobased leather alternative

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Goals / Objectives

The top goal of this project is to boost the USA's economic competitiveness in the sustainability-focused global market by introducing new eco-friendly products that reduce the US agriculture and textile industries' environmental impact. We solve a two-fold problem with the agriculture industry and the textile industry, which includes both the fashion and soft furnishings industries. Our technology presents an opportunity to utilize US farmers' limited-value agricultural waste that would otherwise be discarded or burned, thereby generating additional revenue for farmers with added environmental, social, economic, and ethical benefits to agriculture, textile, fashion, and soft furnishings industries. Specifically, the fashion industry is the second largest polluter of the environment after the oil industry and is significantly responsible for the current state of global carbon emissions. Synthetic textiles, animal, and faux/vegan leathers like vinyl will negatively impact the environment and human health for hundreds of years since their production requires toxic chemicals, and there is no natural process to break them down. There is a dire need for material production to start with circularity and a renewable life cycle from the start. This includes the reuse and recycling of waste material, reducing the amount of water, energy, and toxic chemical usage that contaminate our water systems, and creating products that easily biodegrade, all designed from the start to reduce our carbon footprint. Synthetic and animal leather production is extremely harmful to the environment and contributes to greenhouse gas emissions and water pollution. Perfluorinated or "forever chemicals" used in leather production and functional and performance clothing have damaged the environment and harmed human health for hundreds of years since there is no natural process to break them down. While some vegan "leathers" offer an alternative to animal leather, many are often made from petroleum-based plastics, contain hazardous chemicals, are not biodegradable, produce enormous amounts of waste, and release microplastics and toxic fumes into the environment. According to the Higg Materials Sustainability Index, leather made from cow's skin contributes more to global warming, water pollution, water depletion, and greenhouse gas emissions than synthetic or plant-based vegan "leather." In addition, the tanning of animal leather uses toxic chemicals like chrome, acids, and ammonium salts and exposes workers to arsenic, which can increase the risk of developing cancer by as much as 50%. Synthetic petroleum-based leather (PU and PVC) may generate less emissions than animal leather production, but it still retains a significant carbon footprint. The production of current synthetic leather has a carbon cost of 15.8 kg per square meter. These materials do not biodegrade, contribute to microplastic production, and release toxic chemicals during manufacturing. While these "leathers" do not use animals and are cheap and durable, they are not an answer to the environmental concerns of leather production. We offer a circular system that includes sustainable and biodegradable leather-like materials with comparable performance capabilities to other materials currently available. In line with the Sustainable Development Goals of the United Nations, our proprietary lignocellulosic raw material offers a zero-waste solution as it is derived from agricultural waste by-products (agro-waste) that would otherwise be discarded. By implementing this process, we address and solve the major problems concerning water, energy, and chemical use in manufacturing by eliminating toxic chemicals, using less water and energy, and reducing water pollution normally created in textile and, animal, and synthetic leather production.The major objectives of this project:Objective 1. Demonstrate the process using a range of raw materials and parameters.We seek to demonstrate the process using different raw materials, including pecans, peanuts, and a combination, nanofibrillated cellulose (NFC), nanocrystalline cellulose (NCC), and a combination, three different fibers, different chemicals as plasticizers, and temperature. Differences in pecan and peanut shells/hulls' properties will potentially lead to distinct differences in physical and mechanical properties. Thickness, tensile strength, tear resistance, water vapor permeability, melting temperature, decomposition temperature, density, flex resistance, abrasion resistance, and colorfastness will be comparatively assessed according to ASTM and AATCC standards. Success Metrics: Biobased leather alternatives developed using our technology achieve statistically comparable or better physical and mechanical performance as compared to synthetic and animal leather.Note that even for comparable performance, the elimination of toxic substances and biodegradability offered by our technology is a critical advantage.Objective 2. Develop various thicknesses, aesthetic coloration, and textures.In order tooffer comparable products to synthetic and animal leather, we intend todevelop various thicknesses from about 0.5 mm to about 6 mm for different applications and different surface textures by using heating and embossing techniques to create different designs and patterns. Additionally, we will use different pigments from plant, lake, and earth sources.

Success Metrics: achieve aesthetically comparable or better physical appearance, as compared to synthetic and animal leather.This effort will culminate in the production of a variety of biobased leather samples composed primarily of sustainable materials. This foundational work will establish the platform technology as a facile and scalable approach.Objective 3. Experiment with different inherent and applied functional finishes. Initial experiments have confirmed that our biobased "leather" alternative has inherent antimicrobial properties. We will test the performance of our nanocellulose hydrogel to deliver functionalities to our biobased "leather."In this project, we will investigate and improve the biobased "leather" antimicrobial properties, further justifying future testing with a wider range of functional properties. Successful entrapment of functional molecules into the nanocellulose host will require testing different systems containing NFC and NCC with a functional agent.Success Metrics: Demonstrate the efficacy of nanocellulose hydrogels to deliver functional properties to the biobased "leather."Objective 4. Evaluate platform capabilities as a leather alternative.We will test the physical and mechanical performance of our biobased "leather" according to ASTM and AATCC test methods in comparison to synthetic and animal leathers. Several standardized test methods need to be conducted on our leather-like materials to evaluate their performances for textile applications. We will evaluate and measure appearance, touch and feel, thickness, tensile strength, tear resistance, water vapor permeability, melting temperature, decomposition temperature, density, flex resistance, abrasion resistance, and colorfastness. We will then evaluate the performance by conducting a statistical analysis.

Project Methods

Milestones and work plan to be completed during the project:1. Demonstrate the process using a range of raw materials.Task 1.1 - Develop samples of biobased "leather" using a range of parameters. In this project, the chemical composition and interactions of the biobased "leather" components will be investigated to mimic the properties of animal leather and synthetic polyurethane (PU) leathers using non-toxic and biodegradable materials. The basis of our biobased "leather" is agro-waste derived from nutshells/hulls, and because of its composition, our material has a color and structure similar to animal leather. The formulation of the organic biobased "leather" combines biodegradable ingredients to reinforce the material while still preserving its flexibility. The nutshells/hulls we use are less water-soluble, more resistant to bacterial attack, provide the biobased "leather" with higher mechanical properties, and increase the bond interactions of the biobased "leather" framework. The material is combined with other chemicals to enhance its gel-forming abilities and is cross-linked primarily with calcium ions. Our biobased "leather" material will consist of a resin topcoat and an organic layer with natural fibers embedded in the layer. The organic layer consists of nutshells/hulls, non-toxic chemicals, and nanocellulose hydrogels. The resin functions by starting with a fatty acid component such as lauric, capric, or palmitic, which increases the water barrier properties of the material due to its hydrophobic nature. Then, we use a plasticizer using epoxidized plant oil such as epoxidized soybean oil. This reaction is initiated by heat and a chemical initiator such as benzoyl peroxide. The cross-linker is used to introduce amine groups for further stabilization, resulting in flexible yet durable bonds. In this project, samples will be made by using a range of raw materials, chemicals, and drying temperatures.Task 1.2 - Test biobased "leather" performance. We will perform a series of characterization tests according to ASTM and AATCC test methods on the samples created during Task 1. Optical and scanning electron microscope (SEM) imaging will be used to assess the morphology and surface roughness of the samples. Tensile strength will be measured using an Instron Tensile Tester to determine the force in Newtons required to break the specimen. Tear strength will be determined using a Digital Elmendorf Tear Tester to determine the torsion force required to tear a specimen. The average thickness will be calculated using a digital thickness gauge. Water vapor permeability will be determined by calculating the rate at which water vapor passes through a test specimen after being exposed to moist air on one side and dry air on the other. Thermogravimetric analysis (TGA) will be conducted on the specimens to determine their thermal stability and decomposition behavior. To obtain a temperature range for the decomposition of the samples, differential scanning calorimetry (DSC) analysis will be performed to determine how the biobased "leather" heat capacity is changed by temperature. Flex resistance will be measured by using the flexometer to evaluate the resistance of the samples to cracking when flexing creases. Finally, abrasion resistance will be estimated using the rotary platform-double-head tester.2. Develop various thicknesses, aesthetic coloration, and textures.Task 2.1 - Develop various colored biobased "leathers."Due to the nature of our raw materials, natural pigmentation is similar to animal leather. To expand the color

range, natural pigments will be added to the organic layer to add aesthetic coloration to the biobased "leather."Task 2.2 - Develop embossed and textured biobased "leathers."We will develop samples with various textures and surface designs by using a heating and embossing technique to have a comparable appearance to synthetic and animal leathers.Task 2.3 - Test colorfastness, touch and feel, and evaluate appearance. We will assess the appearance of the samples using qualitative measures by evaluating the softness of materials via the touch-and-feel method. Additionally, the color strength and colorfastness of the colored samples will be assessed according to AATCC test methods. Color strength (K/S) is defined as the ratio of absorbed (K) and scattered (S) light by the colored material, and colorfastness is the resistance to color fading, bleeding, or staining when actions such as rubbing (dry and wet crockfastness) are performed on colored textiles.3. Experiment with different inherent and applied functional finishes. Our nanocellulose hydrogels can be used to host various functional molecules and transfer them to the biobased "leather."For Phase I, we will investigate improving the inherent antimicrobial properties of the biobased "leather" by using a finishing agent since results from this investigation will inform future efforts to further expand platform capabilities to include flame-resistant, UV-protective, and many other functional molecules.Task 3.1 - Functionalization of hydrogels. We will investigate the use of antimicrobial functionalized nanocellulose hydrogels to add antimicrobial properties to our biobased "leather."Functionalized hydrogels applied to the organic layer will be pretreated as needed. Effective functionalization is predominately dependent on encapsulation stability and gel-to-functional particle ratio. Regarding encapsulation stability, we will leverage relevant molecular interactions to promote attachment.Task 3.2 - Test functional performance. Antimicrobial properties will be tested using standard methods published by the Clinical Laboratory Standards Institute. The bactericidal performance of the functionally treated samples versus the samples treated with unfunctionalized hydrogels as controls will be used to measure antimicrobial functionality and determine the minimum inhibitory concentration (MIC).4. Evaluate platform capabilities as a leather alternative.Task 4.1. Conduct statistical analysis. We will conduct a full factorial design experiment, which consists of the entire range of parameters affecting the quality of the biobased leather alternative to obtain the best combination of these parameters to create the leather alternative with comparable properties to animal leather. We have five different variables: nutshells/hulls, nanocellulose hydrogels, fibers, plasticized fatty acid, and temperature. We will measure the response variables. Finally, we will conduct an Analysis of Variance (ANOVA) using R for Statistical Analysis.