Environment and Natural Resources Trust Fund

M.L. 2020 Approved Work Plan

General Information

ID Number: 2020-018

Staff Lead: Corrie Layfield

Date this document submitted to LCCMR: August 13, 2021

Project Title: Eco-Friendly Plastics From Cloquet Pulp-Mill Lignin

Project Budget: $193,000

Project Manager Information

Name: Simo Sarkanen

Organization: U of MN - College of Food, Agricultural and Natural Resource Sciences

Office Telephone: (612) 624-6227

Email: sarka001@umn.edu

Web Address: https://cfans.umn.edu/

Project Reporting

Date Work Plan Approved by LCCMR: August 13, 2021

Reporting Schedule: April 1 / October 1 of each year.

Project Completion: July 31, 2023

Final Report Due Date: September 14, 2023

Legal Information

Legal Citation: M.L. 2021, First Special Session, Chp. 6, Art. 5, Sec. 2, Subd. 07b

Appropriation Language: $193,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to reduce environmental pollution from plastics by creating eco-friendly replacements using lignin from the pulp mill in Cloquet, Minnesota. This appropriation is subject to Minnesota Statutes, section 116P.10.

Appropriation End Date: June 30, 2024

Narrative

Project Summary: We will reduce environmental pollution from plastics by creating eco-friendly replacements using lignin from the pulp mill in Cloquet. The lignin plastics will be similar in strength to polystyrene.

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

Future production of liquid fuels, plastics and chemicals will inevitably shift gradually from oil to renewable plant materials. These raw materials encompass wood (including forest residuals) and crops (including agricultural residues). The structures of tree limbs and trunks, plant stalks and stems, are upheld by cellulose fibrils (like cotton fibers) and a variety of hemicelluloses. The cellulose and hemicelluloses are composed of sugars (like glucose and xylose) that can be converted into fuels, plastics and chemicals. However, production costs are too high for profitability. Fortunately, 12 - 35% of structural plant materials and wood consist of lignins that are quite different from cellulose and hemicelluloses. Traditionally, the value of lignin has been very low: it is used primarily as recovery-boiler fuel in pulp mills. We will remedy this waste by transforming industrial byproduct lignin from the Sappi mill in Cloquet (Minnesota) into eco-friendly plastics. The Cloquet pulp mill employs the kraft process to convert aspen wood chips into cellulosic pulp, with kraft lignin as byproduct. We will demonstrate how surplus aspen kraft lignin, created during increased pulp production, is transformed at 90% levels into valuable biodegradable plastics that are similar in strength to polystyrene.

What is your proposed solution to the problem or opportunity discussed above? i.e. What are you seeking funding to do? You will be asked to expand on this in Activities and Milestones.

(1) We will create eco-friendly plastics from the lignin that makes up 25% of the trunks and limbs of northern Minnesota aspen. The lignin will be the byproduct generated in the Sappi mill, Cloquet (Minnesota), when aspen wood chips are pulped using the “kraft” process to form cellulosic fibers for making paper.
(2) These eco-friendly lignin plastics will contain higher-than-90% levels of aspen kraft lignin. They will be similar in strength to polystyrene, which resists biodegradation and persists in the environment for centuries. On the other hand, lignin plastics will undergo complete biodegradation through a process open to total control (by adding a little sugar).
(3) Lignin plastics will increase the profitability of kraft pulp mills. After cellulosic fibers are formed during kraft pulping, the byproduct lignin is easily isolated. Currently, the value of this kraft lignin is very low because it is burned as fuel.
(4) Aspen kraft lignin will be washed with water and air-dried. For comparison, the effect of simple methylation will be evaluated. Thus, before and after methylation, purified kraft lignin will be cast into plastic test pieces. At 10% levels, commercial blend components will be introduced to enhance the strengths of these new lignin plastics.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state’s natural resources?

The project outcome exemplifies how plant lignocellulose can be completely transformed into biodegradable cellulosic components and lignin plastics. The result will be a model for the use of plant lignocellulose as a renewable raw material with minimal waste. The cellulose and hemicelluloses can be converted into fuels and platform chemicals, while the biodegradable lignin plastics will have production costs below half of the polystyrene selling price. These new lignin plastics can be used in computer consoles, automobile dashboards and a range of attractive consumer articles. The impending vista will promote unprecedented conservation and enhancement of Minnesota’s renewable natural resources.

Project Location

What is the best scale for describing where your work will take place?

Region(s): Metro

What is the best scale to describe the area impacted by your work?

Region(s): Central, NE, NW,

When will the work impact occur?

In the Future

Activities and Milestones

Activity 1: Isolation, purification and characterization of aspen kraft lignin from Cloquet

Activity Budget: $95,000

Activity Description:
Aspen kraft lignin will be isolated by acidifying kraft black liquor from Cloquet. It will be thoroughly washed with water and air-dried. Before and after methylation, the purified aspen kraft lignin will be characterized in regard to its molecular weight distribution (by size-exclusion chromatography), glass-transition temperature by differential scanning calorimetry (Tg by DSC), structure (by nuclear magnetic resonance spectrometry (NMR)), and molecular organization (by X-ray powder diffraction).

Activity Milestones:

Description	Completion Date
Methylated and unmethylated purified aspen kraft lignin for lignin plastics	December 31, 2021
Aspen kraft lignin molecular weight distributions and glass-transition temperatures	March 31, 2022
Aspen kraft lignin structure and molecular organization	June 30, 2022

Activity 2: Formulations for aspen kraft lignin plastics and their strengths

Activity Budget: $98,000

Activity Description:
Methylation of simple lignin derivatives can have a considerable impact on the mechanical properties of polymeric materials with extremely high lignin contents. Methylated and unmethylated aspen kraft lignin will be solution-cast into plastic test pieces on their own and with commercially available blend components at levels below 10%. These plastics will be characterized with respect to tensile strength (Instron), glass-transition temperature by differential scanning calorimetry (Tg by DSC) and molecular organization (by X-ray powder diffraction).

Activity Milestones:

Description	Completion Date
Formulations characterized for plastics from unmethylated aspen kraft lignin	December 31, 2022
Formulations characterized for plastics from methylated aspen kraft lignin	March 31, 2023
Tensile strengths of lignin plastics fall between polyethylene and polystyrene	June 30, 2023

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Tom Radovich	Sappi North America (in Cloquet)	Mr. Radovich will supply aspen black liquor from which aspen kraft lignin will be isolated. Aspen kraft lignin is the starting material for producing eco-friendly plastics.	No

Dissemination

Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.
The results will be disseminated through peer-reviewed journals such as Green Chemistry, ACS Sustainable Chemistry and Engineering, etc. Presentations at regional, national and international conferences also provide excellent opportunities to disseminate project results with respect to related scientific communities. Discussions with colleagues at other institutions can provide useful insights into future research directions.
The College of Food Agricultural and Natural Resource Sciences (CFANS) and the Department of Bioproducts and Biosystems Engineering (BBE) at the University of Minnesota have well established education and outreach programs which are in place and provide valuable opportunities to engage with members of the general public.
The ultimate target audience encompasses technical personnel in pulp mills and emerging biorefineries that seek to produce commodity organic chemicals (including liquid fuels) from lignocellulose in agricultural crop residues and forest residuals.
The Minnesota Environment and Natural Resources Trust Fund (ENRTF) will be acknowledged through use of the trust fund logo or attribution language on project print and electronic media, publications, signage, and other communications per the ENRTF Acknowledgement Guidelines.

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this be funded?
As our LCCMR project nears completion, funds will be sought for an injection-molding apparatus that can produce test pieces under conditions more closely allied to industrial practice. Adequate funding will be requested from DOE and/or USDA. Otherwise, when our work becomes sufficiently far advanced, companies and/or entrepreneurs will be approached for bringing lignin plastics to the market place. Articles can take many forms, ranging from automobile dashboards through stackable auditorium chairs to garden furniture, etc.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
postdoctoral researcher		development of functional lignin-based plastics from aspen kraft lignin			26.7%	1.5		$164,000
							Sub Total	**$164,000**
Contracts and Services								
Arrow Laboratory Specialists	Professional or Technical Service Contract	The entity will provide maintenance and repair of centrifuges that will be routinely used throughout the project in preparing the unmethylated and methylated lignin preparations for making biodegradable plastics.		X		0		$2,000
Characterization Facility and NMR Center at the University of Minnesota	Internal services or fees (uncommon)	Equipment/facility usage fees for characterizing aspen kraft lignin structure and molecular organization; these studies are essential for aspen kraft lignin-based plastics blend composition optimization purposes				0		$8,000
							Sub Total	**$10,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	laboratory supplies: chemical reagents, nitrogen, solvents & laboratory consumables, etc.	producing and subsequent mechanical testing aspen kraft lignin-based plastics					$19,000
							Sub Total	**$19,000**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**

Travel In Minnesota								
							Sub Total	**-**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$193,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Contracts and Services - Arrow Laboratory Specialists	Professional or Technical Service Contract	The entity will provide maintenance and repair of centrifuges that will be routinely used throughout the project in preparing the unmethylated and methylated lignin preparations for making biodegradable plastics.	Arrow Laboratory Specialists, the provider, is the only local company capable of maintaining and repairing our centrifuges; they have been doing so for approximately 20 years. **This is a single source contract.**

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
			Non State Sub Total	**-**
			Funds Total	**-**

Attachments

Required Attachments

Visual Component

File: 15211286-bee.pdf

Alternate Text for Visual Component

Eco-friendly lignin plastics from Minnesota pulp mill will increase profitability of making paper by replacing polystyrene and other plastics from petrochemical sources....

Optional Attachments

Support Letter or Other

Title	File
Background Check Certification Form	c7461ec9-48c.pdf

Difference between Proposal and Work Plan

Describe changes from Proposal to Work Plan Stage

No changes have been made to the workplan.

Additional Acknowledgements and Conditions:

The following are acknowledgements and conditions beyond those already included in the above workplan:

Do you understand and acknowledge the ENRTF repayment requirements if the use of capital equipment changes?

N/A

Do you agree travel expenses must follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?

N/A

Does your project have potential for royalties, copyrights, patents, or sale of products and assets?

Yes

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

Yes

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

No

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

Eco-friendly lignin plastics from Minnesota pulp mill will increase profitability of making paper as they replace plastics from petrochemicals

Aspen often grows in nearly pure stands. Photo © University of Minnesota Extension

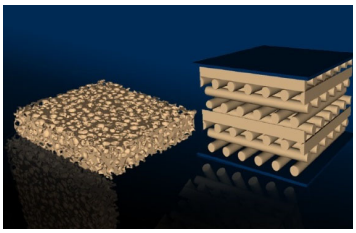
www.sappi.com

kraft pulp for paper from aspen wood chips

Lignin Plastics

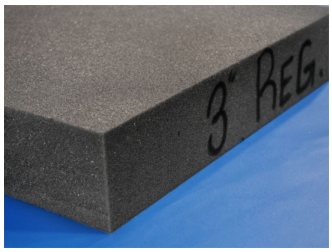
Broad Range of Lignin Plastic Products

automobile dashboard; http://kinlane.com



3-D printed foam; doi:10.1038/srep24871

CD jewel case



insulation foam; www.foambymail.com

plastic chair, True Value

computer console, mainlinecomputer.com

Reduced Climate Change, Less Pollution from Plastics
Better Environmental Stewardship