



Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-298

Proposal Title: Eco-Friendly Plastics from Cloquet Pulp-Mill Lignin

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

Project Basic Information

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.

Funds Requested: \$196,000

Proposed Project Completion: 2023-06-30

LCCMR Funding Category: Small Projects (H)

Secondary Category: Air Quality, Climate Change, and Renewable Energy (E)

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

Narrative

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.

Activities and Milestones

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

Activity Budget: \$97,000

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 (T_g 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	2021-12-31
Aspen kraft lignin molecular weight distributions and glass-transition temperatures	2022-03-31
Aspen kraft lignin structure and molecular organization	2022-06-30

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

Activity Budget: \$99,000

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 (T_g by DSC) and molecular organization (by X-ray powder diffraction).

Activity Milestones:

Description	Completion Date
Formulations characterized for plastics from unmethylated aspen kraft lignin	2022-12-31
Formulations characterized for plastics from methylated aspen kraft lignin	2023-03-31
Tensile strengths of lignin plastics fall between polyethylene and polystyrene	2023-06-30

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

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.

Project Manager and Organization Qualifications

Project Manager Name: Simo Sarkanen

Job Title: Professor

Provide description of the project manager's qualifications to manage the proposed project.

While a faculty member at the University of Minnesota, Simo Sarkanen has overturned a 60-year-old idea about lignin structure that has blocked progress in some important areas of lignin research. As a result, his group is the only one so far that has created useful plastics containing over 90% levels of lignin. His group has also identified the first functional lignin-degrading enzyme. Consequently, he and his coworkers are uniquely qualified to demonstrate whether their new lignin plastics are biodegradable.

Recent Patents and Publications:

1. Compositions Including Lignin: Chen, Y.-r.; Sarkanen, S.; Wang, Y.-Y. U.S. Patent 2018, No. 10,119,027 issued June 25.
2. Lignin Degrading Methods and Compositions: Chen, Y.-r.; Sarkanen, S.; Wang, Y.-Y. U.S. Patent 2017, No. 9,796,993 issued June 21.
3. Chen, Y.-r.; Sarkanen, S.; Wang, Y.-Y.: Lignin-only polymeric materials based on unmethylated unfractionated kraft and ball-milled lignins surpass polyethylene and polystyrene in tensile strength. *Molecules* 2019, 24, 4611 (15 pages); doi:10.3390/molecules24244611
4. Wang, Y.-Y.; Chen, Y.-r.; Sarkanen, S.: Blend configuration in functional polymeric materials with a high lignin content. *Faraday Discuss.* 2017, 202, 43-59, DOI: 10.1039/c7fd00083a
5. Sarkanen, S.; Chen, Y.-r.; Wang, Y.-Y.: Journey to polymeric materials composed exclusively of simple lignin derivatives. *ACS Sustainable Chem. Eng.* 2016, 4, 5223-5229, DOI: 10.1021/acssuschemeng.6b01700

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

Organization Description:

The resources in the Department of Bioproducts & Biosystems Engineering along with those in the University of Minnesota Characterization Facility are sufficient to carry out the proposed research. The University of Minnesota Sponsored Projects Administration is the entity authorized by the Board of Regents to manage project agreements with LCCMR.

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	maintenance and repair of centrifuges that will be routinely used for the project				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		\$10,000
							Sub Total	\$12,000
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					\$20,000
							Sub Total	\$20,000
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	\$196,000

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
---------------	---------------------	-------------	--

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.

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have patent, royalties, or revenue potential?

Yes,

- Patent, Copyright, or Royalty Potential

Does your project include 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

lignin

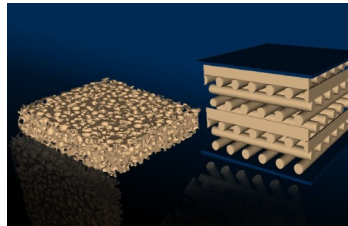
kraft pulp for paper from aspen wood chips

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.foambyemail.com



plastic chair, True Value



computer console, mainlinecomputer.com

Reduced Climate Change, Less Pollution from Plastics Better Environmental Stewardship

