



Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-349

Proposal Title: Novel Microalgae Attached Growth for Animal Wastewater Treatment

Project Manager Information

Name: Roger Ruan

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

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Project Basic Information

Project Summary: To develop an attached growth method for fast cultivation and efficient harvesting of microalgae in the anaerobically digested manure for nutrients removal and animal feed production.

Funds Requested: \$760,000

Proposed Project Completion: 2024-06-30

LCCMR Funding Category: Water Resources (B)

Project Location

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

Statewide

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

Statewide

When will the work impact occur?

During the Project and In the Future

Narrative

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

In Minnesota, agriculture is the second-largest industry and produces a large amount of wastewater. The livestock waste (such as dairy and swine manure) contributes a large proportion to this wastewater. For example, the Concentrated Animal Feeding Operations (CAFOs, over 1,000 animal units) produce more manure by weight than 30,000,000 people, which is a severe concern to the environment. Improperly operated feedlots and the manure created there can result in heavily contaminated lakes or rivers that are unhealthy for humans and animals. Meanwhile, livestock wastewater contains large amounts of nutrients which should be reused, recycled and reclaimed (3R).

In recent 20 years, microalgae have been widely used in many areas and attracted significant attention. Among these, coupling algal cultivation and agricultural wastewater treatment is a hotspot in the research and development efforts focused on reuse. Algae generally show effective in wastewater treatment and biomass accumulation, while the downstream process of algal harvest and biomass use still remains a major issue. The main existing methods for algal biomass harvest are adding chemicals (flocculation, coagulation, etc.) or using physical processes (centrifugation, filtration, etc.). These methods may be effective for algal harvest under certain circumstances, but generally bring new burdens to the process, such as chemical residuals, energy waste, running cost, labor increase, process complication, and efficiency reduction, etc. Therefore, finding an easy-to-operated and cost-effective method for the downstream process to achieve the 3R requirement is extremely essential.

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.

In order to solve these issues, we propose to use natural materials which can serve as both algal growth support and animal feed. According to the characteristics and amount of animal wastewater, an integrated technology is expected to build for simultaneous nutrients reduction, biomass recovery and animal feed production.

In this process, anaerobically digested (AD) animal manure wastewater will be used as the media to provide nutrients and water for the algal growth. Plant based materials that can be used as animal feeds directly with little treatment (such as drying) will be selected for algal cells to attach on and grow. Also, searching appropriate high valued algal strains which is easy to attach on the natural materials and have strong tolerance to wastewater. This process can be developed into a centralized and in-situ treatment application co-located with the wastewater source (near the livestock), integrating animal manure anaerobically digested process, algal AD wastewater treatment, algae harvest and animal feed production. This system would both simplify downstream process of algal harvest and biomass reuse, which would improve the economic outlook of the existing process. We expect that the natural material with algal attached on could be a new nutrition source as animal feeds which are fresh, cheap, safe, effective, nutritional and easy to obtain.

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 outcomes of the project will provide the animal production operators a tool to treat animal manures and produce animal feeds. This, if proven cost effective, will make animal wastewater treatment affordable and thus promote greater practice of animal wastewater treatment and reduce environmental impacts and improve economic outlook of animal production operations.

Activities and Milestones

Activity 1: Plant-based growth support material and algae strain selection for the optimal combination

Activity Budget: \$200,000

Activity Description:

Several plant-based materials and algal strains will be selected for fundamental study using artificial culture media. The criteria for support material selection are following desirable properties: suitability for animal feed, adequate resistance to biodegradation (won't disintegrate significantly during cultivation cycle), adequate shape and mechanical strength, suitable surface affinity with algal cells, etc. For algal stains, they should be easy to attach and grow on the support materials and tolerant to high level of salt and other pollutants, and have high yield and adequate nutrients for animals, etc. Experiments will be designed to study the performance of different combinations of support materials and algae strains. The optimized material and algae combination will be selected and used for the next step.

Activity Milestones:

Description	Completion Date
Plant based growth support materials are collected and characterized	2021-12-31
Algae strains are selected and their growth performance on selected support materials are evaluated	2022-12-31
Combination of support material and algae strain is optimized	2022-12-31

Activity 2: : Test the algae-material combinations in AD wastewater and evaluate the feasibility of feed application of the harvested biomass

Activity Budget: \$200,000

Activity Description:

The optimized algae-material combinations will be tested in the AD swine manure in lab-scale. The removal of nutrients (TN, TP and COD reduction, etc.), biomass accumulation under different cultivation condition (temperature, pH, etc.) will be evaluated. Then harvested biomass (support material and algae cells attached on the support materials) will be analyzed for nutrients (DHA, fatty acid, etc.) and safety parameters (heavy metal, bacterial, etc.) to evaluate for the potentials as animal feeds.

Activity Milestones:

Description	Completion Date
AD wastewater treatment effects and biomass accumulation will be evaluated	2023-06-30
Cultivation condition will be tested and combinations will be further optimized	2023-09-30
Components valuation and safety of harvested biomass will be analyzed	2023-09-30

Activity 3: Design, fabricate, and test pilot-scale system on farm

Activity Budget: \$360,000

Activity Description:

With the process optimized, a small pilot-scale systems will be designed according to the actual local livestock's real wastewater qualities, operation conditions, etc. The pilot-scale systems will be operated on an animal farm for 6-8 week. The data obtained from the pilot operation will be analyzed to improve this technology.

Activity Milestones:

Description	Completion Date
Scale up parameters will be developed	2023-09-30
Pilot-scale system will be designed, built, and adjusted	2024-03-31
Operation data will be analyzed and technology improvement and demonstration will be completed	2024-06-30

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Yanling Cheng	University of Minnesota	co-PI	No
Paul Chen	University of Minnesota	co-PI	Yes

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?

The proposed technology would be an in situ integrated processing system for the CAFOs wastewater treatment which will reuse and recycle the nutrients on farm. This system will be a cost-effective and energy-saving way for nutrients reduction, biomass collection, and animal foods production. In the long-term, we will cooperate with CAFOs to build the manure treatment system using this technology. Findings from this project will be used to obtain additional funds from USDA.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Demonstrating Innovative Technologies to Fully Utilize Wastewater Resources	M.L. 2014, Chp. 226, Sec. 2, Subd. 08c	\$1,000,000
Development of Innovative Sensor Technologies for Water Monitoring	M.L. 2016, Chp. 186, Sec. 2, Subd. 04j	\$509,000

Project Manager and Organization Qualifications

Project Manager Name: Roger Ruan

Job Title: Professor and Director

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

Dr. Roger Ruan, Professor and Director, Center for Biorefining and Department of Bioproducts and Biosystems Engineering, University of Minnesota, Fellow of ASABE and Fellow of IFT, is the project manager of the proposed project. Dr. Ruan's research focuses on renewable energy technologies, solid and liquid waste treatment and utilization, and environmental engineering. Specifically, he has conducted research and published his findings in the areas of municipal, agricultural, and industrial wastewater treatment and utilization through novel anaerobic digestion, microalgae cultivation, and hydroponic cultivation, biomass and solid wastes (including plastics) gasification and pyrolysis, airborne pathogen disinfection, catalysis, non-thermal plasma, ammonia synthesis, etc. He is a top-cited author in the area of agricultural and biological sciences with an h-index of 63, i10-index of 255, and over 15,400 citations, and has received over 180 projects totaling over \$45 million in various funding for research, including major funding from USDA, DOE, DOT, DOD, LCCMR, and industries. He was the project manager of several earlier LCCMR funded projects which resulted in the issuance of a US patent and licensing of a technology. Therefore he has the technical expertise and project management experience to ensure the execution of proposed projects.

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

Organization Description:

The Center for Biorefining is a University of Minnesota research center and help coordinate the University efforts and resources to conduct exploratory fundamental and applied research; provide education on bioenergy, biochemicals and biomaterials; stimulate collaboration among the University researchers, other public sector investigators, and private investigators involved in biobased production technology development; promote technology transfer to industries; and foster economic development in rural areas. The Center's research programs are funded by DOE, USDA, DOT, DOD, LCCMR, IREE, Xcel Energy, and other federal and state agencies, NGOs, and private companies. The Center is equipped with state of the arts analytical instruments, and processing facilities ranging from bench to pilot scale.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	\$ Amount
Personnel								
Paul Chen		Co-Principal Investigator			36.5%	0.48		\$64,621
Post Doc		Researcher			25.4%	3		\$193,799
Roger Ruan		Principal Investigator			36.5%	0.12		\$24,328
Graduate Research Assistant		Research Assistant			45%	1.5		\$150,933
Graduate Research Assistant		Research Assistant			45%	1.5		\$150,933
							Sub Total	\$584,614
Contracts and Services								
							Sub Total	-
Equipment, Tools, and Supplies								
	Tools and Supplies	Materials and lab supplies including chemicals for analysis, growth support materials, consumable supplies for analytical instruments, algae strains, fertilizers, filtering materials, glassware, etc.	For running experiments and operating the systems.					\$19,386
	Equipment	Components for fabrication of experimental apparatus and demonstration system, including bench scale reactors, multi-level reactors, light source, pumps and flow control, pipes, liquid-solid separators, biomass harvest unit, filtration units	To fabricate experimental apparatus and small system for running experiments, conducting performance analysis, and demonstration					\$150,000
							Sub Total	\$169,386
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								
		Repairs & Maintenance	Repairs & Maintenance of analytical instruments					\$6,000
							Sub Total	\$6,000
							Grand Total	\$760,000

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
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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: [a02a17f6-5d6.pdf](#)

Alternate Text for Visual Component

The visual shows a process flow diagram, pictures of attached growth lab apparatus and growth characteristics, and nutrient removal data.

Optional Attachments

Support Letter or Other

Title	File
UMN authorization letter	c5dd9a42-7b8.pdf
UMN financial audit report	6a064b5a-097.pdf

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?

No

Novel microalgae attached growth for animal wastewater treatment

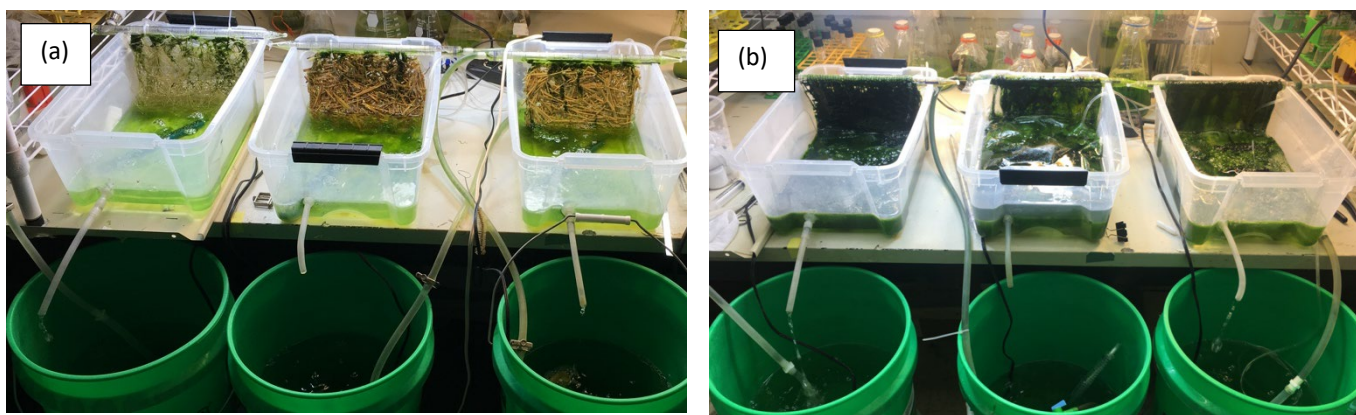
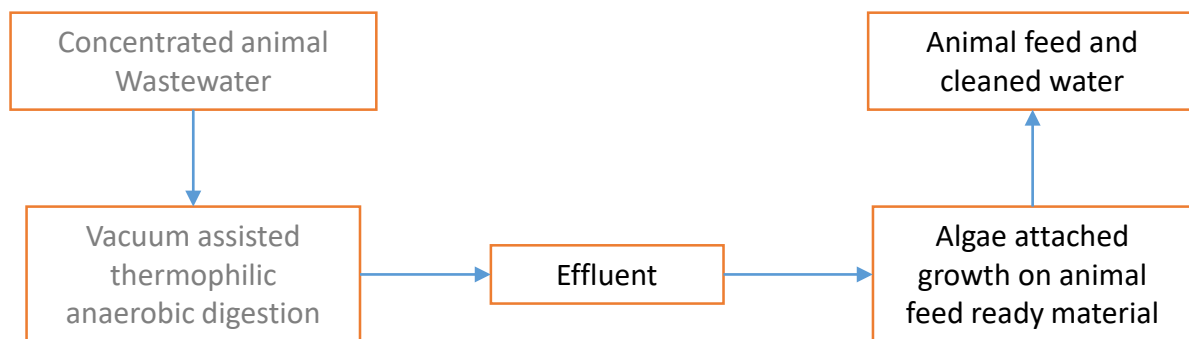


Fig. 1. Algae attached growth on blankets of various materials on the first (a) and 12th (b) day of cultivation.

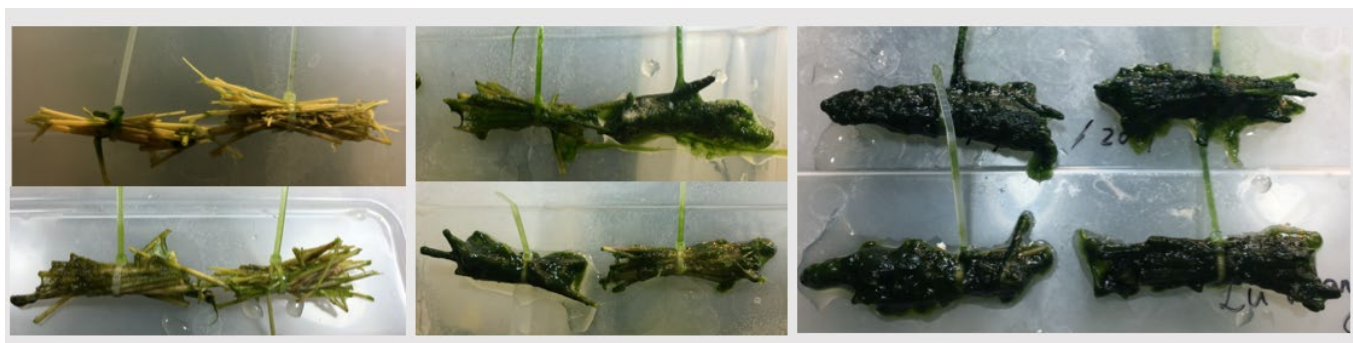


Fig. 2. Algae attached growth on natural material rolls during 12-days cultivation.

Nutrient removal effects of AD swine manure through selected algae cultivation in lab-scale system.

Parameter	Pre-treated ADSW	Algal treatment	Removal rate (%)
COD (mg/L)	12600 ± 66	2790 ± 125	77.79
TN (mg/L)	310 ± 7	74.8 ± 3.7	75.81
TP (mg/L)	30.6 ± 0.8	5.3 ± 0.1	82.70
NH4-N (mg/L)	194 ± 5	0.88 ± 0.1	99.55