



Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-348

Proposal Title: Enhanced Thermophilic Anaerobic Digestion of Swine Manure

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: Develop an innovative thermophilic anaerobic digestion technology for improved methane production from swine manure by mitigating ammonia induced inhibition

Funds Requested: \$609,000

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.

Liquid Swine Manure (LSM) is a valuable resource only if appropriately managed. Taking hog/swine manure as an example, on June 1, 2019, there were 8.7 million hogs/pigs in Minnesota, generating more than 5 million gallons of wastewater each day. Many studies showed that anaerobic digestion is the conventional and efficient technology for utilizing the LSM, converting the available carbon of LSM to bio-methane. The application of bio-methane would contribute to reducing carbon emission from the usage of natural gas. The typical LSM contains abundant ammonia nitrogen, which significantly inhibits the activities of bacteria in anaerobic digestion and therefore resulting in the low bio-methane production. On the other hand, the process of thermophilic anaerobic digestion is vulnerable to the high ammonia content of LSM, impeding the scale-up progress. By removing the ammonia content of LSM, the improvement of total economic opportunity for bio-methane production approach to 50 percent.

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.

This project is designed to evaluate and develop an innovative in-line Intermittent Thermal-Vacuum Stripping assisted Thermophilic Anaerobic Digestion (ITVS-TAD) technology for improving the bio-methane production of Liquid Swine Manure (LSM) by removing ammonia nitrogen content. The project addresses Priority B. Water Resources. Thermal-Vacuum Stripping (TVS) is a promising pretreatment technology to remove the high ammonia nitrogen content of LSM and therefore improve methane production, with very attractive results reported in the literature. To scale up the technology, the application of TVS as pretreatment has to be upgraded to the in-line intermittent design. The modification of in-line design is coming with several challenges, including reactor design, operational conditions optimization, and process control to make the process economically viable. Our preliminary research indicated that ITVS-TAD technology can effectively convert the carbon source of LSM to biomethane by lowering the ammonia nitrogen content of the medium. We also have identified several critical operational parameters of TVS pretreatment assisted thermophilic anaerobic digestion process and system, including pH, C: N ratio, organic loading rate, and salinity, those could promote the production of biomethane yield. We are ready to test the feasibility of modified ITVS-TAD and evaluate its environmental and economic impacts.

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 marketable products, preventing swine wastes from polluting Minnesota lands and waters. 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: Substrate modification and process optimization

Activity Budget: \$150,000

Activity Description:

Substrate composition plays a vital role in bio-methane production as it determines the potential maximum yield through thermophilic anaerobic digestion and therefore co-digestion with the specific substrate is an efficient way to improve the bio-methane potential. Most of the co-digestion studied so far for swine manure is lignocellulose, which will present a unique impact case by case. In this study, we will screen a range of potential co-digested substrate candidates in lab-scale apparatus to evaluate their performance on the in-line Intermittent Thermal-Vacuum Stripping Assisted Thermophilic Anaerobic Digestion of liquid swine manure. The experiment of process optimization will come after the co-digested material selection by adjusting the operational parameters, including pH, organic loading rate, the essential elemental supplement, C:N ratio, mixing rate, and the pattern of intermittent vacuum application.

Activity Milestones:

Description	Completion Date
Screening and performance evaluation of potential co-digested material candidates	2023-03-31
Optimizations of operational parameters and conditions	2023-06-30

Activity 2: Develop a continuous in-line Intermittent Thermal-Vacuum Stripping assisted Thermophilic Anaerobic Digestion (ITVS-TAD) process to generate bio-methane from liquid swine manure

Activity Budget: \$200,000

Activity Description:

A continuous in-line ITVS-TAD process will be implemented in two steps. First, a reactor will be designed for continuous thermophilic anaerobic digestion with in-line thermal-vacuum stripping operation. A stable performance will be our objective to ensure that the application of vacuum will not inhibit the thermophilic anaerobic digestion. Second, an intermittent vacuum treatment scheme will be implemented to the above apparatus with the programmable automatic control including pressure releasing after each period of vacuum application. The processing parameters such as pH, mixing rate, temperature, vacuum gradient will be recorded to guide our further development and investigation of processes. The nutrient compositions, including chemical oxygen demand, total nitrogen, ammonia nitrogen, volatile fatty acids, and solid composition will be monitored during the experiment for the evaluation of the thermophilic anaerobic digestion performance. These planned activities are expected to generate information that will help us understand the relationships between processing variables and product yield and quality, laying the foundation for further R&D to move the technology to commercial sectors.

Activity Milestones:

Description	Completion Date
ITVS-TAD process and reactor design	2021-12-31
Fabricate lab-scale ITVS-TAD system	2022-06-30
Collection of the data in the continuous operation of ITVS-TAD	2022-12-31
Evaluation of the process stability	2022-12-31

Activity 3: Demonstrate the ITVS-TAD process and evaluate the potential economic, environmental and ecological impacts of the proposed technology

Activity Budget: \$259,000

Activity Description:

For this project, we plan to establish a pilot-scale ITVS-TAD based on the above studies. We plan to provide big pictures of the potential economic, environmental and ecological impacts of the swine manure to bio-methane technology. Additional data on mass balance will be collected.

Activity Milestones:

Description	Completion Date
Establish a pilot-scale ITVS-TAD process	2023-12-31
Continuously operate the pilot-scale process for 2 months	2024-06-30
Collect nutrient composition, product yield, and energy consumption data with different operational parameters	2024-06-30

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Paul Chen	University of Minnesota	co-PI	Yes
Yanling Cheng	University of Minnesota	co-PI	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?

New scientific knowledge and experience on thermal-vacuum assisted thermophilic anaerobic digestion of liquid swine manure will be acquired through research. The potential economic, environmental and ecological impacts will be presented to the stakeholders to raise their awareness and attract their support. We will seek industry partners and private, state, and federal funding to further develop and eventually commercialize the technology.

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								
Roger Ruan		Principal Investigator			36.5%	0.12		\$24,328
Paul Chen		Co-Principal Investigator			36.5%	0.48		\$64,621
Graduate Research Assistant		Research Assistant			45%	1.5		\$150,933
Post Doc		Researcher			25.4%	3		\$193,799
							Sub Total	\$433,681
Contracts and Services								
							Sub Total	-
Equipment, Tools, and Supplies								
	Equipment	Components for fabrication of experimental apparatus and demonstration unit, including AD reactors, heating and temperature control units, ammonia stripping reactor, vacuum pump and control unit, mixer, temperature sensors, pressure sensors, etc.	To fabricate experimental apparatus and small system for running experiments, conducting performance analysis, and demonstration					\$150,000
	Tools and Supplies	Materials and lab supplies including chemicals for analysis, reagents, bacteria strains, trace fertilizers, pH testing and control, consumable supplies for analytical instruments, glassware, etc.	For running experiments and operating the systems.					\$19,319
							Sub Total	\$169,319
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	\$609,000

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: [86e4a000-979.pdf](#)

Alternate Text for Visual Component

- 1) issues with current manure management practice
- 2) our approach and preliminary data
- 3) our lab equipment and facilities
- 4) key parameters to be studied
- 5) expected outcomes

Optional Attachments

Support Letter or Other

Title	File
UMN authorization letter	3a0949bd-298.pdf
UMN financial audit report	bdf28e66-d5a.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

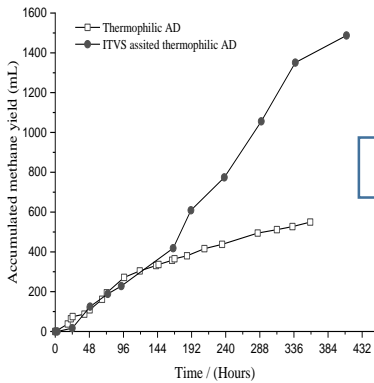


- Risk of water pollution
- Nutrients Partially utilized by crops



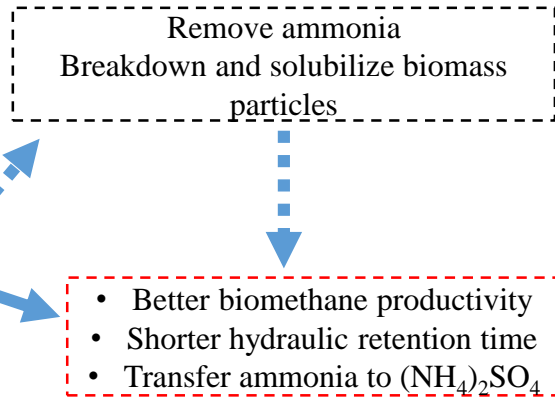
- Process inhibited by high ammonia of liquid swine manure
- Long hydraulic retention time

A new strategy



Input: mixture of liquid swine manure + biomass

ITVS-thermophilic AD



Lab scale in-line Intermittent Thermal-Vacuum Stripping (ITVS) assisted thermophilic Anaerobic Digestion (AD) process and system



Key processing parameters

- The pattern of intermittent stripping
- Salinity
- Ammonia
- C: N ratio
- Organic Loading rate
- Volatile Fatty Acids
- Biogas composition

Outcome of the Project

- Processes will be developed and investigated for conversion of liquid swine manure and biomass to biogas and N fertilizer
- Potential economic, environmental and ecological impacts of the proposed strategy will be evaluated
- Stakeholders will be presented with the research findings and recommendations for further actions
- The research findings will be used for seeking industrial partnerships and external funds for further R & D efforts