Mid-Year Report for FY24 Research Projects

Funded by the North Dakota Soybean Council

Submitted by Iris Feng, 11/29/2024

a. Research Project Title, Principal and Co-Investigators

Title: Anaerobic Digestion of Defatted Soybean Meal for Biogas and Biofertilizer Productions: A Life Cycle Assessment

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b. Research Overview and Objectives

Overview:

Defatted soybean meal (DSM), a by-product of soybean oil production, has garnered attention with the rise in US soybean yields, which hit 4.16 billion bushels in 2023 and are projected to reach 5.30 billion by 2030. This increase suggests a growing surplus of DSM, especially in North Dakota, due to the expansion of soybean crushing plants. Given its limited current uses, there is a pressing need to explore and develop new applications for DSM. Our Year 1 chemical analysis showed DSM is rich in crude protein, cellulose, and hemicellulose, making it a promising candidate for anaerobic digestion (AD). Recent experiments have shown that AD of DSM can produce high biomethane concentrations (50-70%), particularly under mesophilic conditions (95°F) as opposed to thermophilic conditions (131°F), highlighting its significant potential for biomethane production and biofertilizer generation. In light of these findings, the proposed research intends to scale AD trials from 500mL to 2L to better gauge the technology's industrial applicability. Furthermore, conducting a life cycle assessment (LCA) and life cycle cost (LCC) analysis to evaluate the environmental and economic impacts of DSM's new application is essential. These analyses will illuminate benefits of reducing greenhouse gas emissions and generating cost savings, making this innovative use of DSM attractive to soybean growers and the industry at large. This project aims not only to promote sustainable agricultural practices but also to enhance the profitability of soybean farmers through the inventive utilization of by-products, aligning with NDSC's strategic goals.

Objectives:

The specific objectives of this proposal include:

1) expanding the bioreactor capacity for AD from 500 mL to 2L, incorporating the optimized preprocessing technology identified in the Year 1 study to explore enhanced production of methane and biofertilizer.

2) evaluating the potential environmental impacts and economic advantages of new uses for DSM through life cycle assessment and life cycle cost analysis approaches.

c. Completed Work: Deliverables and/or Milestones

The following work has been completed:

1) Collected and analyzed the new batch of soybean meal.
2) Collected two different inoculums from waste water treatment plants in Fargo and Moorhead.
3) Set up a pilot experiment with scaling up reactors (2L).
4) Collected feedstock, digested, and gas samplings during the experiment for further analysis.
5) Developed the LCA structure, and determined the scenarios for the LCA.
6) Developed an inventory data set for LCA approach.

d. Progress of Work and Results to Date

1) Sample Collection and Preparation

A new batch of DSM samples was collected from the Northern Crops Institute, NDSU, Fargo, ND. These samples were analyzed for chemical properties and nutrient content at the NDSU Animal Science and Soil Testing laboratories. The DSM was processed using a blender for grinding and sieved to obtain medium particle sizes ranging from 0.48 to 0.70 mm.

2) Pilot Experiment Setup

Building on Year 1 results, a pilot experiment was conducted under mesophilic conditions at 35°C with a Feedstock to Inoculum (F:I) ratio of 1:2 and DSM particle sizes of 0.48–0.70 mm. The DSM was pretreated with 4% NaOH and co-digested with dairy manure at DSM-to-manure ratios of 2:1 and 4:1. The pilot test included two reactors with a 2:1 DSM-to-manure mixing ratio and one reactor with a 4:1 DSM-to-manure mixing ratio.

Each anaerobic digester had a 2L capacity, scaled up from the 500mL reactors used in Year 1. The AD process was continuously monitored for 40 days.

This setup aimed to test the scale-up process based on initial findings from Year 1.

3) Biogas concentrations of CH4, CO2, and H2S were analyzed twice a week following the standard protocols. An SRI gas chromatograph was used to determine the CH4 and CO2 concentrations while the H2S concentrations was measured by a Jerome meter sulfide analyzer. Before and after the AD process, the pre-digested samples and post-digested slurry were collected for chemical properties and nutrient analysis at NDSU Animal Science and Soil Testing Labs to determine the biofertilizer quality. During the pilot test, only gas concentrations were measured in the laboratory using the gas chromatograph (GC). All other samples were collected and stored at 4°C in a refrigerator for future analysis. Figures 1 and 2 illustrate the accumulated biogas production and daily methane production for the reactor with a 2:1 DSM-to-manure mixing ratio, respectively. Data for the reactor with a 4:1 DSM-to-manure mixing ratio is not included because the respirometer channel became clogged after one week of anaerobic digestion. This issue caused a significant drop in recorded gas production, rendering the data unusable for presenting results. Figure 3 shows the percentage of methane production as in the total biogas.

4) Three LCA scenarios

For conducting the LCA approach, a cradle-to-gate perspective was adopted, concentrating on the biogas production process. The system boundary included the DSM processing stages including feedstock supplementation, pretreatment, AD for biogas production, and digestate management. The functional unit (FU) for this LCA was defined as 1 ton of DSM processed within the system boundary. Figure 4 illustrates the system boundary, and the three scenarios evaluated in this study. The first LCA scenario involves converting DSM into animal feed meals, with the majority of the product transported to neighboring Minnesota, a state with high demand for animal feed (Scenario 1, Figure 4). The second scenario considers anaerobic digestion of defatted soybean meals, with the resulting co-product (digestate) applied to land as a management practice (Scenario 2, Figure 4). The third scenario is similar to the second, except the co-product (digestate) is specifically used as a biofertilizer on the farm for crop production (Scenario 3, Figure 4).

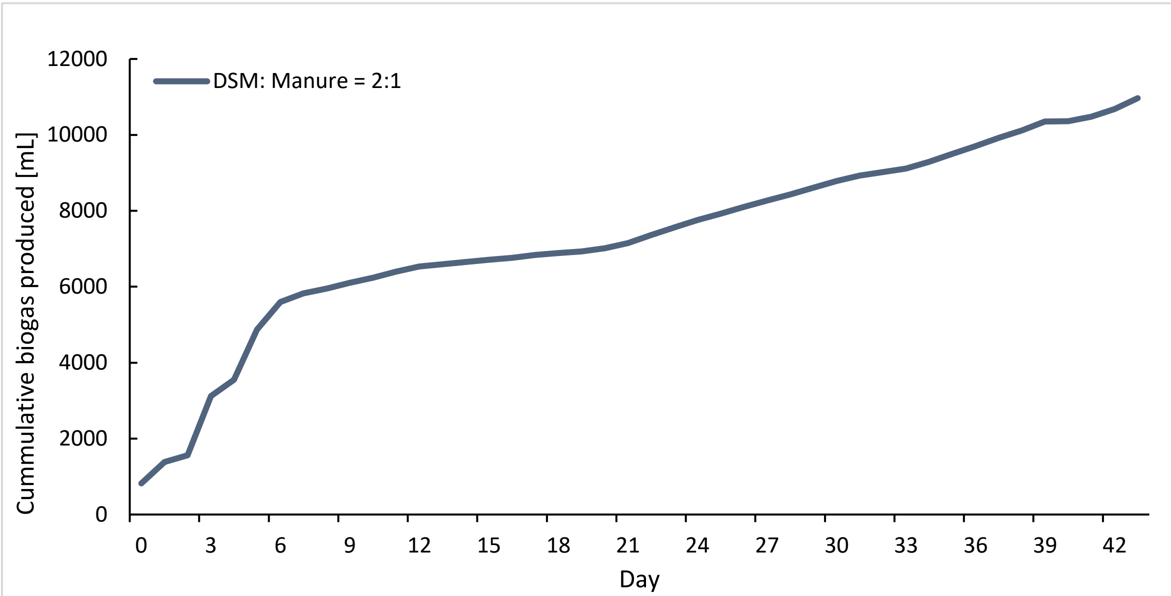

Figure 1. Accumulated biogas production of reactor 2:1 DSM-to-manure mixing ratio.

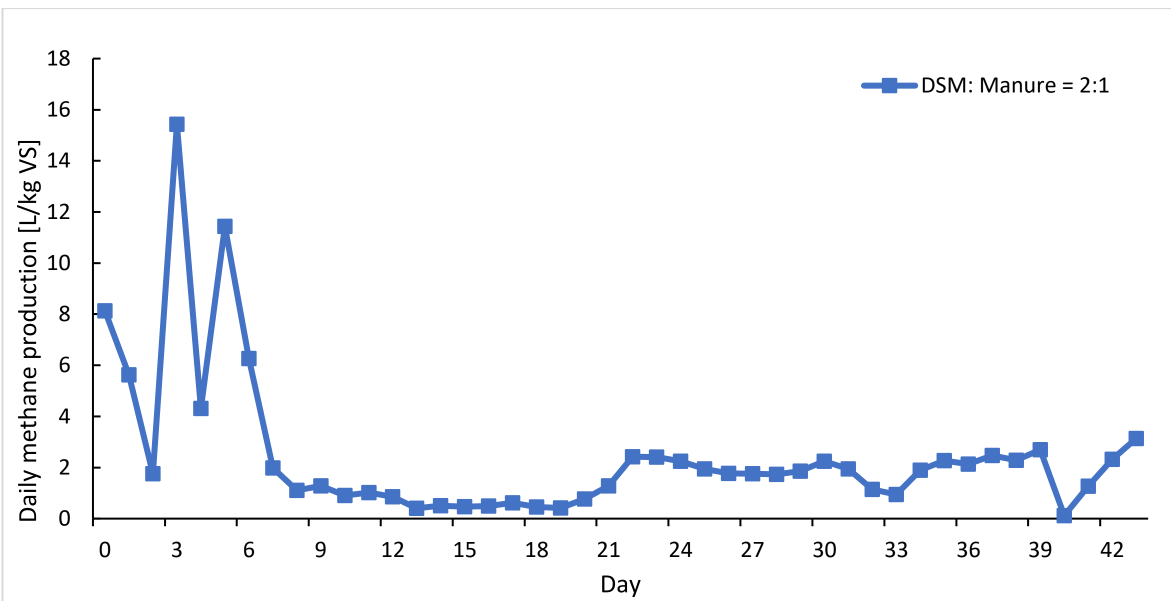

Figure 2. Daily methane production of reactor 2:1 DSM-to-manure mixing ratio.

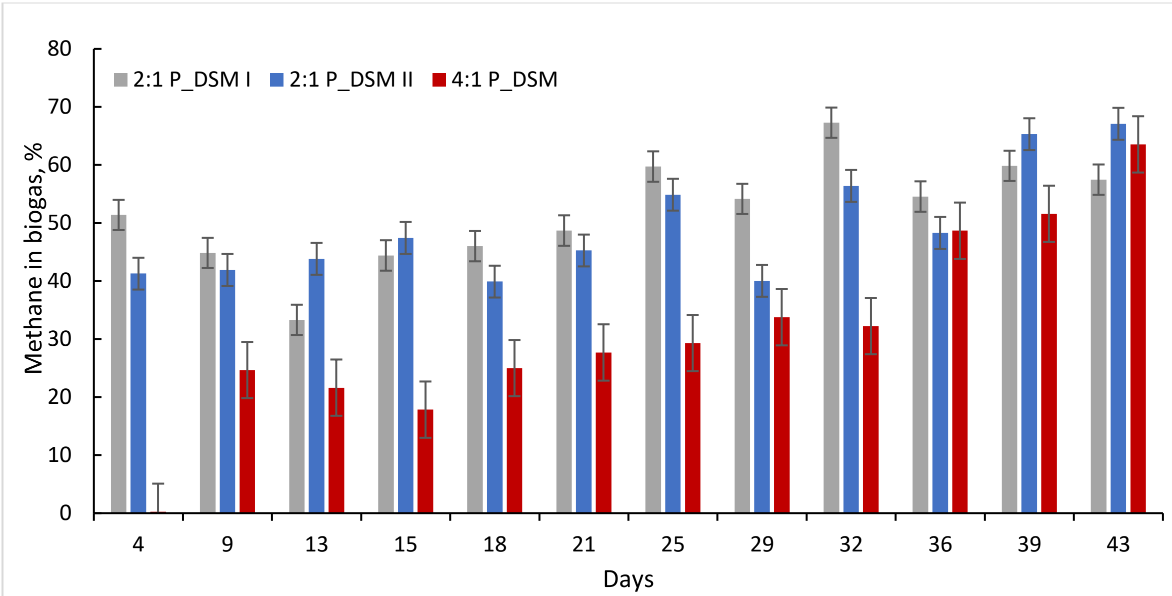

Figure 3. Methane production in biogas of three reactors.

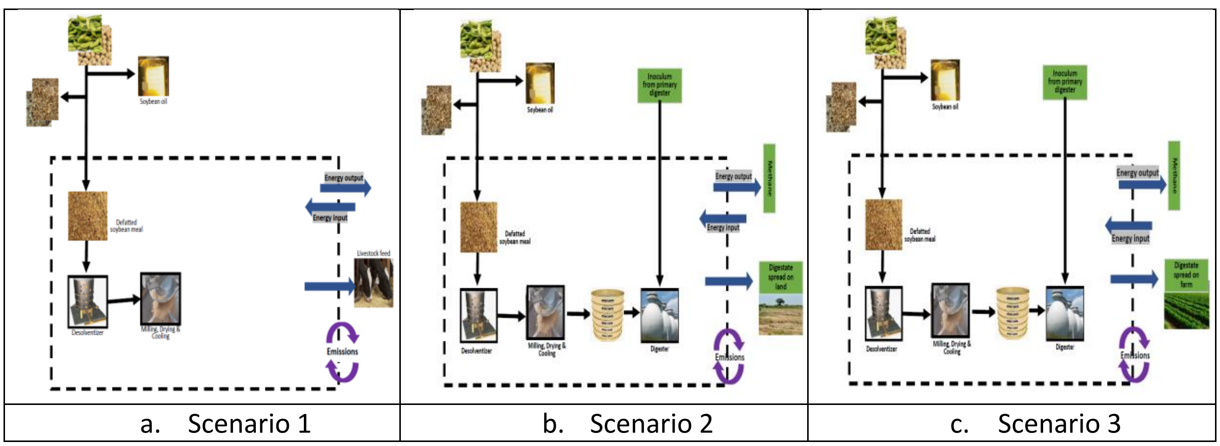

Figure 4. System boundary and three scenarios of the LCA.

e. Work to be Completed

To advance the ongoing experiment, the following tasks will be carried out:

1) Set up the experiments using three 2L bioreactors with a 2:1 DSM-to-manure mixing ratio.
2) Continuously monitor the anaerobic digestion (AD) process over 40 days, collecting gas and slurry samples according to the proposed procedures, and analyzing these samples in the laboratory.
3) Prepare a comprehensive dataset for input and output flows between the technosphere for the LCA of the three scenarios. This task is currently in progress.
4) Evaluate the environmental indicators for the three LCA scenarios using SimaPro software.
5) Analyze the collected data, publish the findings in peer-reviewed journals, and present the results at local and national conferences.

f. **Other relevant information: potential barriers to achieving objectives, risk mitigation strategies, or breakthroughs**

Potential barriers to achieving the objectives include technical challenges of maintaining consistent anaerobic digestion performance, equipment malfunctions, and variability in manure composition. To mitigate these risks, regular equipment maintenance, strict adherence to experimental protocols, and comprehensive pre-analysis of feedstock properties will be implemented.

g. **Summary**

In summary, the current study highlights the potential of DSM as a viable feedstock for biogas and biofertilizer production through AD. The ongoing pilot experiments, conducted under mesophilic conditions, demonstrate promising results, particularly for biogas yield and methane production at a 2:1 DSM-to-manure mixing ratio. While equipment challenges impacted data reliability, the 2:1 setup showed promising biogas accumulation and methane generation. Methane concentrations ranged between 50–70%, underscoring the suitability of DSM for biomethane production.

LCA scenarios further validate the environmental and economic benefits of DSM utilization, emphasizing its role in sustainable agricultural practices. The final conclusions will depend on completing the ongoing experiments, analyzing slurry samples for biofertilizer quality, and conducting comprehensive LCA evaluations.