WSU Digester Research

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I'd like to take this opportunity to share with you some of the activities that are occurring at WSU related to anaerobic digestion. We have developed a very active program on anaerobic digestion in the Department of Biological Systems Engineering. Our group includes a number of post-docs, graduate students and research techs. We are also associated with the Center for Sustaining Agriculture and the Natural Resources. Outside the department we work with Dr. Richard Shumway from Economics, Craig MacConnell from Whatcom County Extension, Joe Harrison from Animal Sciences, Dave Sjoding from the Energy Program, and Chad and Dave Granatstein from CSANR doing outreach. So we have a big group working in this area in different capacities.

I'd like to share with you the outline of my presentation. First, motivation. We all have different motivations to do this. Secondly, the goal. You have your goal, we have our goal. Thirdly, approach. What approach we are taking and its status. Finally, I'd like to share with you some of the current research projects that we have.

Motivation—I think in this regard we share the same motivation. We all recognize there is a new demand for anaerobic digestion technology. This is primarily because of a concern about global warming and climate change, and also other environmentally related issues that have to do with animal manure management. Thirdly, the increase of energy price. So those are the main drivers for us seated in this room to talk about anaerobic digestion. If you look at what we have right now for animal manure management, we have a system based on lagoons. Lagoons are a pretty good practice but unfortunately lagoons cannot stop the methane emission. As I was speaking, all lagoons are making methane. Lagoons have some other problems particularly related to odor. And after storage in the lagoon, we apply the manure on land. We have concerns about excess nutrients and odor issues there as well.

This is what we have now. What are we going to use in 20 years? You think about the car that we're driving now. It's so different from 20 years ago, but our system of waste management didn't change very much. How about in the future? We at the university need to look into the future and develop a vision. The next generation of waste management systems is going to be something like this. It will have these components.

First, the centerpiece is an anaerobic digester. A major problem we have with current animal operations is the accumulation of nutrients within the farm boundary. As the size of the farm increases, we have a lot more feed coming in and the main nutrient export is milk. There is not much else. Cull cows are not very much in terms of mass. So we have lots coming in and don't have enough going out. As a result, we have a nutrient accumulation. So when we write a nutrient management plan for the farm—that's the critical part. How much land do we have available so we can use the land to absorb the nutrients. Well, unfortunately we cannot grow the land. The land is fixed. But our operations have had to grow to remain competitive. To solve the problem, we need to make the whole thing flow. We have things come in and need things to go out. So we have nutrients coming in as feed, bedding material, other processing through the animal, and then we have this anaerobic digester. Within the digester, we have several processes going on.

The first process is to convert the carbon to methane. Second is nutrient extraction. If we don't extract the nutrients, we just run through the digester, all it does is convert the organic nutrients into inorganics. The solid component does not contain a lot of nutrients. Right now, we are exporting the solid part, the fiber, out of the system, but it does not contain the majority of nutrients. Unless we have another system that can extract the nutrients into a form that can be exported out of the boundary of the farm, then we don't have a flow. We need that component, nutrient extraction, to concentrate the nutrients in a form, like a slow-release fertilizer, that can be exported out of the farm to another region.

The third component is fiber. After anaerobic digestion, we can process the fiber in such a way to give it improved qualities and then export it out of the farm boundary. What we have then is feed and bedding coming in, carbon going out as methane and electricity, and extracted nutrients and fiber going out of the farm. If this system operates well, then we have in and out balance, no nitrogen accumulation. That's our vision.

We like this concept because it has several unique aspects. The first one is anaerobic digestion. We want to improve the current technology, make it better, and we also want to develop a nutrient extractor so we can concentrate the nutrients. Lastly, because the processes involved are complex, we need to have computer software that will allow us to track the nutrients, management activities, and optimize operations. We have been working on all three components. We got a USDA grant to work on the computer program for the last 5 years. We do have a prototype program that can track the nutrient flow and help the farm manage the different daily activities to minimize the impact to water. We also have activity going on to work on the nutrient extraction aspect. Dr. Harrison is going to talk about that later.

My presentation is going to focus on the first component, the digester part. If you look at the big picture, the potential is pretty significant. We have about a quarter million cows in Washington State. What happens if we put all the manure from the cows through a digester? That is a significant impact. We can capture methane with a carbon equivalent of some 6.3 million pounds with a potential value close to $20 million. Then we have value in the electricity, in nitrogen if we can recover that, and phosphorus. So that's pretty encouraging.

But why are people not using digesters? There are two reasons. The first one is economics. If the economics is there, then people would be interested in using it. Secondly, it is the limited capability for solving water quality problems, solving the nutrient balance. We believe that current technology, although it has gone through many generations of development, is still more art than science.

This morning Phil made a statement that said experience is priceless. That's another indication of the art part of the technology. We believe that we can develop new science and incorporate it with existing science to improve the existing technology. We like setting goals to do that. We set up goals that are pretty ambitious. We can do that because of the research nature of our work. So we set a goal of 30% cost reduction for digesters. How will we accomplish that?

The first 10% will come from improving the process. The second 10% will come from optimizing a system. The third 10% will come from improved equipment and infrastructure. So we work on those three related areas to try to achieve a 30% cost reduction. If we can do that, based on field estimates, your payback period of 10 years now shortens to how many years? And from 3 years to 1 year? That's our goal, but we haven't accomplished it yet.

Another goal we have is to develop a better AD system for flushing dairies in cold climates. If it would work for dairies, then it would create opportunities for other wastes. And as a university research program, new knowledge would help disseminate the information.

Our approach is based on the challenges related to anaerobic digesters, and previous speakers have referred to these. Think about dairy manure, that's most difficult to digest. The first challenge is a slow fiber breakdown rate. The fiber that we have in animal manure breaks down so slowly that we think it is not degradable. So can we can speed up that breakdown rate?

Yes, but it can be costly. That's a challenge. To address that, we decided to separate the solids. That's one way. Secondly, we're using enzymatic enhancements. We can put an enzyme in to help break down the fiber. Those are two approaches. Then the other challenge is we have mixed bacterial populations in the system. The bacteria that produce acid and bacteria that produce methane, they are not the same. The environments optimal to them are not the same. So if you mix them together, nobody is very happy, but they can survive. Is there a way to separate the environments so they can accommodate the bacteria population better? That's what we're doing. We use the phased processes. Steve, this morning, mentioned some aspect of that.

The next challenge is the slow bacteria growth rate. The bacteria grow very slowly. So if you want to pass the liquid, the manure, through the system very fast, we may flush out the bacterial population. So in certain cases if you have to dilute manure by the use of fixed film processes, we fix or immobilize the bacteria on the surface of the supporting material. There the bacteria have an anchor. No matter how fast the liquid goes through, the bacteria will stay inside. So that's the third approach we are taking.

To summarize, that's what we are working on for a flush dairy system. First, we have the concentration system to separate the solids from the liquid. After we get solids, we design the solid reactor to treat the solids separately. Then we send the liquids through a high rate digester and produce methane and the nutrient-rich effluent. Now why do we want to separate the solids?

First of all, the solids are not doing anything. So if the solids stay in the reactor for 20 days, not doing anything, why do we need the solids to be there? Secondly, once we separate the solids, we can put in enzymes and the other treatment because the size of the digester is smaller. We can treat it separately. Thirdly, because of that advantage, we can increase the temperature, we can reduce the coliform and other pathogen counts. Our main assumption is that we need to produce a high quality fiber from the solids in order to make the process economical. High quality fiber means it can be used for bedding materials, for soil amendments.

After we capture the methane, we have the effluent with inorganic nutrients. We go through this process to extract phosphorus as struvite, which can be exported as a slow-release fertilizer. Joe is going to talk more about this aspect.

In terms of methodology, how are we doing this? We start with the laboratory tests. We do lab bench scale tests for processing improvements, we then do pilot scale tests for reliability improvements. We adjust load the system in such a way to know when it breaks, then we know when it breaks, how it breaks, and we improve that. And then the third aspect is mathematical modeling. The process is complicated and we cannot test all the possible scenarios. The model to allow us to evaluate many different operating conditions and the performance system.

Let me give you an example of what happens in our lab. In our lab we have a hot room set at a temperature for the mesophilic process. This is 35°C. We have multiple reactors in the same room, at the same temperature, to allow us to do different things. For example, here is a series of reactors, two rows of reactors in a series, together 10 reactors. This setup allows us to look at all kinds of combinations. Different hydraulic residence time, different solids concentration, different operating parameters, then we look at the gas production. We recognize that the lab results and the real facility can be quite different. But the lab allows us to look at what's happening in the system.

For example, what happens if the manure particle is still in the first reactor. After 5 days there is some transformation. What's the transformation, what's happening there? Those types of information allow us to understand the process better. After we got the lab results, we implemented a one-cow digester. Our technology providers design system for 1000 cows. At the university we work with one cow first. And we see what happens in the one cow digester and see if we are on the right track or not. So that's what we do in the lab. We know the digester is not a black box. It may look like a black box, but there are so many processes going on, and we have to understand those processes in order to design a better reactor.

We have four major processes going on after the manure gets into the digester. The first one is the big particle becomes a molecule. Then the molecule becomes fatty acid or a simple sugar. Then that simple sugar, amino acid, produces acetic acid. Finally, acetic acid converts to methane. Those processes are accomplished by different groups of bacteria. Each has its own growth rate and characteristics. That is a biochemical process.

Now you can look at spatial and physical processes. We have a liquid to liquid interface, we have a liquid to gas interface, we have methane produced in the water. How can we get the methane out of the water? You can analyze the manure, and it has different composition and different components: carbohydrate, protein, lipids. Those different components go through different pathways. What's the percentage of each of the components and what are the pathways? What is the maximum yield you can get? So those kind of analyses will help to understand the process and to design the system better. We have a computer program implemented right now, ADM-1. There is an international group of scientists, headed by European scientists, that developed this complex mathematical model of a digester. Twenty-four equations, so many parameters. It is complex, but once it is run, it will tell us what happens if you change one thing, say, the pH. What happens in the first chamber if the pH changes, then what kind of reaction will it cause later?

I need to emphasize that our research so far is limited to lab-scale tests and basically it's small. We have separated the liquid and the fiber. We can treat the liquid rapidly in 3 to 5 days from dairy manure. In this time, we get the majority of the gas produced. We are also incorporating in the digester the biomass immobilization technique. Also, by separating the solids from the liquid, this allows us to set up a system better suited for co-digestion. We can treat the solids of various manure and the food wastes in the solids digester, then send the liquid through the liquid digester. When it goes through the liquid digester, the bacteria can't tell the difference where it comes from. So the separation is started from the liquid and allows to handle better that situation.

This is just the very first prototype solids reactor. This work allows us to generate some of the operating parameters. The first goal of this solids digester is to produce a high quality fiber. Secondly, within the digester we want to recover all the nutrients and send them to the liquid digester but we don't want to use a lot of water. We also have pathogen production. We need to look at the total coliform reduction from different tests in the solids digester run between 35° and 60°C temperature. Here are actual results at 50°C. There was a significant reduction in coliform from the original solids manure to after the solids digester. We started with about 8,000 and we now ended with 80 to 100. Now we know we can impact this aspect in the solids digester to meet the fiber requirements of the market.

The other thing about the fiber is its physical property. Our target use is not a soil amendment, rather it is replacement of peat moss for container plants. We want to produce a fiber that can replace peat moss. We compared some of the basic properties of the fiber and the peat moss. Then we send the fiber for a growth study, with potential for commercial plants. This is one study that Craig MacConnell did using the fiber produced from one of GHD's digesters, not from our pilot. If you look at it as a replacement for peat moss and plants grow very well, then this is a pretty attractive alternative.

Our current research has four major projects. The first one is a 5-year project to improve the digestion process, funded by the Paul Allen Family Foundation. We also have a pilot digester project funded by Washington Technology Center in collaboration with the Andgar Corporation. We have another pilot digester project funded by the Washington Department of Ecology. And we have a USDA NRCS Conservation Innovation Grant project for co-production of fiber and fertilizer. Both RCM and GHD are providing fiber for that research.

Questions?

Question—How much research on digesters is going on around the country?

I think probably more than you can count. Right now the major groups are at universities, California-Davis, Utah State University, North Carolina State University, and Washington State University. There are some other universities but I think those are the most active.

Question—

How long? Right now we treat the solids for a 24 hour residence time. It's not a biological process that we were doing. It's just a physical process of washing the nutrients out of the solids from the fiber.

Question—

We do have a process where we can add enzymes. We developed a process to use dairy manure to produce cellulose. That cellulose can help break down the fiber. We have that developed but right now we're concentrating on the fiber quality. We are debating: If the fiber has value, why do we want to digest it more? We can just sell the fiber. But for different operations we have different ways to do that.