

Anaerobic Digestion 101

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Good morning. I'd like to get an idea of who's in the crowd. How many actual people are in dairy production, please raise your hand. Pretty good turnout. How many of you are affiliated with government, be it state or federal? Okay. How many of you are economists? Okay, so I have to watch what I say because I'm an economist, I'm not an engineer, I'm not a microbiologist. My interests are in the technology and how we can make this thing pay, which will be a topic for this afternoon's discussion.

I usually start out by asking what do dairy cows, hogs and chickens have in common, and that's this thing called the anaerobic digestion process. A microbiologist might explain it as being a complex consortium of hydrolytic fermentative acidogenic and methanogenic bacteria, but my basic microbiology lesson was given to me on the banks of a lagoon one day by a dairy farmer, a long time ago, and he said, "Bugs eat stuff and fart methane." I guess that's about as close as I can come. Bacteria do make biogas, and you can make a lot of things from it. The biogas coming off a digester is substantially similar to natural gas produced from the wellhead; you can compress it, liquefy it, manufacture electricity, make many kinds of chemicals, make hydrogen, dimethyl ethers and theoretically make diesel and even ethanol from methane. Of course odor control is a big reason why farmers are interested in digestion. But here is a graph of natural gas wellhead prices over the past couple of years. The general trend is that energy prices are increasing and earlier this week crude oil topped at \$51 a barrel. The Chinese are incredible consumers of petroleum; half the steel, half the concrete in the world are now being used in China. The likelihood of seeing significant increases is pretty high.

The type of digester we use depends on a number of factors—feedstocks, basically there are thousand types of digesters out there in the world today and most are good, but the art is matching the feedstock to the type of digester. One of the key break points is total solids concentration of the feedstock. For example, I wear a lot of hats in my life. One of my hats is working in the area of municipal solid waste digestion where basically we're dealing with feedstocks at 35% total solids concentration. Now transferring that technology to a farm would not necessarily work. Recently I became a part owner in a company that manufactures an anaerobic digestion technology that I'll talk about later. And I will put that hat on so you'll know when I may have a conflict of interest. Other factors include management structure and bedding.

But to the economist in me, the key breakpoint is the type of manure management system one has. Do you flush or do you spray? Flush barns generally have very dilute manure, less than 5% solids. I've worked on a project that had a 0.3% total solids concentration and, once again, the total solids concentration is a key factor in determining the type of digestion system that you're going to be using. Here's Charlie Campbell, Randley Dairy in 1987; he gave me my microbiology lesson. I'll show a picture of the project we put in there, another example of flushing that led to a low total solids digestion system.

There are basically two families of digesters in the world—suspended growth and attached growth-type systems. In a suspended growth system, solids basically means the bacteria. The bacteria like to form a colonial mass—I kind of like to think of it as a coral bed. And as a result they don't move. You have to present the food to them and solids retention time is equal to hydraulic retention time. So roughly if you have a 20-day hydraulic retention time, which is a common specification, every day you're washing out 5% of your biomass. You basically have two options—covered lagoon or complete mix (or CSTR-type) reactor.

In an attached growth system, solids retention time and hydraulic retention time are decoupled. That's because you present more surface area for the bacteria or the biomass to attach to, and as a result you can have, in general, smaller vessels. Fixed film is a technology that's just being seen in the marketplace, basically Florida, Michigan State, a project in New York and a project in North Carolina that I'm going to discuss. And there are a number of others in the development pipeline coming out of industrial applications and transferring to agriculture.

This is Randley Dairy in 1987. The photo credit goes to RCM Digesters. This was a 160-head Jersey farm. It was the second covered lagoon project built in America, the first one being on Roy Sharp's farm near Tulare, California. It is a three-cell lagoon system; we took the first cell, excavated it 22 feet deep, made it 80 feet by 80 feet square, and put a "baggie" over the top, using the industrial fabric, XR5, HDPE. There was a retaining wall; we had a header and a partial vacuum that sucked the biogas up and ran it to a farm boiler. It was a demonstration project. Since that time covered lagoons have had some success. But we tried to transfer this to a hog farm in North Carolina. Given the low total solids concentration, we wound up having to dig a hole 270 x 270 feet that held roughly 7 million gallons of liquid to be treated. Because of the dilute nature of the feedstock we did run into some technical issues, and I would be the first to admit that this project was not an overwhelming success.

With covered lagoons, you want to dig them fairly deep so that you can minimize surface area. But in areas with high water tables this is pretty much impractical. They must be lined where you have highly permeable soils. Depending on where you live, there may be a long start-up period—it may take one to two years to achieve steady-state biogas production. And the digestion rate is significantly dependent upon ambient temperature. We used to say that north of the Mason-Dixon line a covered lagoon would probably not be a good technology. We can look at a hypothetical digester in Oklahoma and you can see a bell-shaped curve for gas production; the bugs are more active in the warm summer months, then going more dormant in the winter months. I don't know how it would be in this area of the world but I tried to do a little sensitivity study and the only place with a nice flat line for gas production was in south Texas or southern Florida. If you're going to try to use the energy, the valuable methane that we've gone to all this effort to produce, where do you size an engine generator? Do you size it down here, do you size it up here, do you shoot for the middle? What are you going to do?

Here we have a fixed-film digester project at Harris Hog Farm in North Carolina, a 1600-animal unit, a demonstration project. We were funded by the State of North Carolina. Here is the digester, solids separator, and because phosphorus removal is a key goal for the State of North Carolina, we're using a process that will be installed later this year to precipitate out phosphorus and potassium. What makes this work is common 3-inch tile pipe. What we've done is pack that reactor with roughly 50 miles of this media which gives the bugs more surface area to party on. As a result, we have a lot of benefits—2- to 6-day hydraulic retention time (I'll put my hat on so you don't get confused) versus 20-day for suspended growth. It costs less than a complete mix reactor, with higher methane yields. In hog farms it achieves up to 65% volatile solids destruction; for dairy manure it might be 35 to 40%. The tank is heated so the biogas production should not vary significantly and it does meet an approved NRCS Conservation practice, so it qualifies for cost sharing.

The real story with animal waste treatment is the volume of water used. If you have 250 gallons of flush water per cow per day, you're pretty locked into a covered lagoon technology. Somewhere around 100 gallons per day, a fixed film. At 50 gallons per day, maybe you can consider a complete mix digester. If you don't use any flush water or you can segregate that flush water out, a plug-flow digester might be the better solution. Each situation is a bit

unique. Waste water reduction, in my opinion, is somewhat imperative but it's a dimension not usually measured.

With a scrape system, you can also consider a slurry mix or a complete mix digester. Basically they look the same. I like to make a differentiation because the complete mix uses a propeller. Manure technically is non-Newtonian semi-solid pseudo plastic material. As a result, any solids that are in that manure quickly drop out of suspension. A complete mix digester uses a propeller or agitation type system to keep that material in suspension. Slurry mix basically uses biogas or some compressed air to keep the material in suspension, and a plug-flow can use this as well. You can't use any excess water or sand bedding is my understanding. An example—this was the first farm digester installed on a hog farm, Mount Pleasant, Iowa, 1972, installed for odor control. It uses reinjection of the biogas to keep the materials in suspension.

Here is another type of digester installed in Maryland in 1994; once again a slurry tank where the solids in the biomass are kept in suspension by reinjecting the biogas, and a big storage tank for the treated liquid.

Here's another blue steel tank complete mix digester. Coming through the center, a propeller that periodically spins throughout the day to keep the solids in the biomass in suspension.

A plug-flow digester at the Double A Dairy in upstate New York. One-fifth of this reactor is filled every day and by displacement the material moves down the plug and, as the manure is degraded and methane is produced, total solids is decreased so that at the end of the march, the plug is discharged.

There are many types of digesters, thousands of them out there. Here is a small centralized digester in Switzerland where three farmers got together, two of them piped their manure a couple of kilometers to the digester. They also have a small trap here where they accept slaughterhouse waste. They get a tip fee for it. They have an accounting practice where the farm owner is compensated by a mutual agreement for his time and efforts in hosting the system.

Then you can have very large digesters—this is a huge system, centralized system, in Denmark. Blending digesters and wind power, that works. A slurry truck bringing fresh feedstock basically goes around to each farm on a systematic basis, draws the slurry out, comes back and puts it into an equalization tank and, depending on the type of farm, the truck is cleaned and made secure from a biological perspective. Another picture of a very large centralized

digestion system—this is a low-pressure bag for storing biogas so there are some fluctuations in daily production, so if you want a nice flat line from an engine generator, store the biogas.

How do you use the biogas? Water boiler, yellow engine making electricity, orange engine making electricity, green engine making electricity, blue engine making electricity. I'm not going to say it's uncommon, but that's basically the preferred choice, at least in America. But in Europe they also can clean and compress the biogas and use it as a transportation fuel. Of course, the bureaucrats there, they drive Volvos and Saabs, but they can even run on it.

This is Uppsala, north of Stockholm in Sweden, similar to what you might see in the big city. You have a couple of tanks up here on the top of the bus. They have a community digester where they take the manure and all the organics produced in the local area, and they run their heavy vehicles, the buses and the garbage trucks, on biogas.

The other part, I'll talk more about this this afternoon, is co-product use. You get the biogas, but what else do you get? With dairy farms, you get fiber. And to get the fiber, you need a solids separator of which there are many brands and models. Here is fiber on the hoof. It comes out of the digester a little hot biologically from my perspective, and it needs a little bit of aerobic polishing. In this area with your climate and low rainfall, it shouldn't be a problem, but how do you sell it? What's the value of this? It is site-specific. On many farms, neighbors come in and take a pickup load for \$6, \$10, \$12. The fiber is substantially similar to peat moss, a wonderful product in terms of its tilth and moisture-holding capability which, once again, in an arid climate might be worthy of greater consideration. Bagging it, this is Bob Foster's farm in upstate New York where he spent a long time developing a branded product, and now he sells 40-pound bags of fiber, blended to an agronomic specification, for \$6. Six dollars a ton versus \$6 a 40-pound bag, and the rumor is that Bob's making more money selling digested fiber than he is selling milk, but Bob will be the first to say that it cost him a lot to get into that game.

Where do the nutrients go? The simplest explanation is follow the mass. In my opinion, the nutrients are contained in the suspended solids which are not readily capturable by a solids separator and wind up in the liquid. Nitrate is converted in the digestion process into ammonia which is why this shot in Denmark, they're trying to inject the filtrate (the liquid fraction) to retain as much of that ammonia as they can as close to the ground as possible. Now if ammonia conservation is important, that's just another consideration how you store this material, because in South Dakota, for example, where I live, with relative wind speed 15 to 20 miles per hour

during the winter months when you can't apply the liquid, a substantial amount of it could wind up in Minnesota. But just another example of how to inject the filtrate.

Does it smell after digestion? Well, research indicates that digested material has a 97% reduction in the threshold odor number versus storage. Manure huffing is very popular among the Amish and anybody who has been around would recognize Richard Mattocks as a manure pusher, but I just want to say that the only way we can stop this scourge of manure sniffing is to destroy those volatile solids and prevent the permanent brain damage in American teens, so not only is it a good thing from an energy security issue but also from a public health basis.

There are hazards, of course, the methane. You don't want to smoke near the tank or pit—it's a dangerous gas. But it's a manageable risk, a risk that you have to factor into your farming regime.

What's the market status? There is an increased emphasis on farm, industrial, and municipal organic waste management. Odor control—I was a consultant for the Department of Energy and I had the great privilege of wandering around our good country and interviewing farmers, why did they get into digestion, what had they learned, what would they do differently. Everybody said, "Odor control," and I'll talk about that a little bit later this afternoon. Pathogen reduction, food security, volume reduction of the manures, and, of course, farm nutrient balances.

Limiting factors—why do they fail? Bad design or installation usually leads the list and you rarely consider a firm without significant experience. Poor equipment and material selection—we all want to minimize cost but cheap pumps aren't good, good pumps aren't cheap. Use life cycle costing. In farm management, a digester is a biological organism, a living creature, and it needs some attention every day; it doesn't need a whole lot, but if you ignore it, it pretty soon gets an upset tummy and things go into disarray. An engine generator needs a bit of observation as well, check the engine oil, change the engine oil regularly, more regularly if you don't scrub out hydrogen sulfide.

In summary, although there is increasing interest, digesters are still viewed as a risky technology. The utility interface can be problematic. Certainly Mark has a wealth of horror stories on trying to get an agreement with an electric utility to interconnect with a farm digester. Inconsistent government support—sometimes digestion is a hot topic, sometimes the Department of Energy says we tend to ignore that. Financing—this is where having a pool of interest such as

we have here today can bring some assistance. Limited supply or industry—but that's improving. Track record is spotty and that's improving.

So where do we stand today? The numbers change every day. Roughly 50 farm digesters are installed in the U.S. RCM Digesters has roughly half the market share. GHD and Steve Dvorak are in second place but growing, and Agri-Clean—we have a couple of systems out there as well—and it's still a cottage industry. If we're going to get to the level of Germany which has installed 2,000 digesters over a 10-year period, the industry is going to have to grow. There is a lot more to be had from cooperation in building an industry than there is from ruinous competition.

What did I learn over the past year? Putting my Agri-Clean hat on, from our commercial demonstration, these things are pretty obvious when you look back at them, but it's not just a digester but it's a component—it has to fit into the overall farm waste management program. Nutrient management, overall permitting, waste capture system, material handling—every project is still unique. We haven't standardized the customer. It's difficult to change a farmer's production method. It's tough to meet mutual expectations and, from a digester industry perspective, I think this is where we need to work with the customer—getting a clear set of expectations, what we can do together. Not having that as an understanding can lead to a big train wreck. Meeting financial goals and trying to bring research to replicable engineering practice was a significant challenge. Design issues—these have to be flexible. Knowledge is power, but experience is priceless.

This is my latest painting—Impressionistic Cows.

I'd be happy to take any questions.

Question—

Answer: I would say that the EPA website is incorrect. I know that one system that they label as a plug-flow actually the farmer had to do about \$100,000 worth of modifications, basically put a chopper pump in.

Questioner: All four of them working great.

Answer: Okay, well then why don't you give a presentation? Flush farms, how much water did they mix? Less than 2% solids using a plug-flow. Mark, are you here? Do you have any comments? Not now, okay, but I hope, once again, Mark is the leading practitioner in terms of the applications, practical and replicable, engineering of plug-flow digestion systems. Perhaps

as an ignorant economist, I've bought into a certain belief system and I'm willing to change my opinion and obviously if you've done the research I'd like to talk with you afterwards and get the benefit of your opinion. Thank you. Any other questions or comments; that was a good question.

Question:

Answer: The reason that digesters are so prevalent in Europe is the government pays down the cost of installing the system and mandates that the electric utility buy back electricity as green power at a higher rate. They have decided that that's their social objective, they have a social agenda which is much different than our cowboy economy that we practice in America. And I'm not advocating that the government get into the business of subsidizing digesters, I'm a performance-based kind of guy. I think if we put incentives based upon actual performance, kilowatt hours or BTU generated rather than just on capital cost, we'll see that. Also, once again, our country is founded on two unsaid principles—cheap food and cheap energy. And our government, despite our incredible reliance on foreign oil—during my presentation we have exported roughly \$25 or \$30 million to the Middle East to buy imported petroleum. We've lost jobs, we're supporting tyrannical regimes that have no interest in preserving our western way of life. I feel strongly about this, and our government has no energy policy that consistently promotes the use of renewable energy technology such as anaerobic digesters. There is a disconnect here between what is publicly said and what is actually enacted. But as a result, the European systems are tremendously more expensive than they are in the U.S.

I did a project a couple of years ago where a German company was involved in the bid and it came back as a \$2 million digester. You're never going to see that system deployed cost effectively on a farm, given today's economic conditions. It's a wonderful system, the process controls all computer monitored, but you can't afford it. I think that if European technology providers want to get back into the U.S. market, they need to go back to the technology that they first developed 20 or 25 years ago.

Thank you for your time.