About Dry Fermentation in Agriculture

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Lately there has been a revival of discussion about dry fermentation. Especially in southern Germany there is renewed interest in dry fermentation. Several locations are considering constructing biogas plants based on this technology.

This article was written in response to the recent interest in the marketplace over this process. Since Krieg & Fischer Ingenieure GmbH has experience with dry fermentation both in theory and practice it was decided to re-evaluate this method. This paper is offered as a contribution to the current discussion and it is hoped that the partly euphoric discussion gives way to a more sober view that acknowledges both advantages and disadvantages of dry fermentation.

Background

At one time biogas plants were classified as either storage or flow plants. This division is not practical today as nearly all biogas plants are flow plants. Other divisions are still in use such as the digester temperature; mesophilic vs. thermophilic or process step distinctions such as; single stage, two stage or multi stage, etc.

Other distinctions commonly used for biogas plants focus on the water content of the fermenting substrate, especially when discussing organic waste fermenters. In organic waste fermentation the concept of dry and wet fermentation has been in use for more than ten years. Generally plants with a water concentration of about 85% are classified as wet fermenters and those with moisture levels between 75-80% are designated as dry fermenters.

The division between wet and dry fermentation is rather arbitrary and has no exact definition. From a biological standpoint the distinction is not practical as microorganisms can only live and extract nutrients in a liquid environment. Microbial activity can only flourish in those areas where there is sufficient water. In a dry fermenter with low water levels, this activity will occur in pockets rather than throughout the fermenter.

Dry fermentation agricultural biogas facilities have been around for some time, indeed Switzerland has pioneered this technology in the 1980’s. The developers were aiming at fermenting manure in its natural state – that is without chopping or grinding. However, this technology has not succeeded.

Types of dry fermentation

There are several ways to ferment organic materials in dry fermentation processes. One possibility is to apply horizontal fermenters like those distributed by the Swiss company Bühler and their German offshoot Kogas GmbH. In those systems, hydraulically operated horizontal shafts are used for mixing the digesting suspension, with total solids of 30 to 35%. Due to the high forces which have to be used the costs for the fermenters are extremely high. This alone places these technologies out of reach for agricultural applications.

Similarly, mixing approaches where gas is injected into a high concrete silo tank filled with fermenting substrate are also too expensive for agriculture. An example of this is the one sold by Steinmüller Rompf. This system and the Bühler-approach described above involve relatively low moisture or dry substrates. Generally these systems have not been successful due to the extremely high energy requirements as well as poor results for mixing the contents of the digester.

A third option, which might prove to be better especially with respect to cost, is known as percolation technology. In this approach the solid substrate is placed in a chamber or tub and is showered from above with water or “percolate”. This liquid is captured after it flows through the heap to a storage or buffer tank where it can be pumped again to the shower heads (see fig. 1)

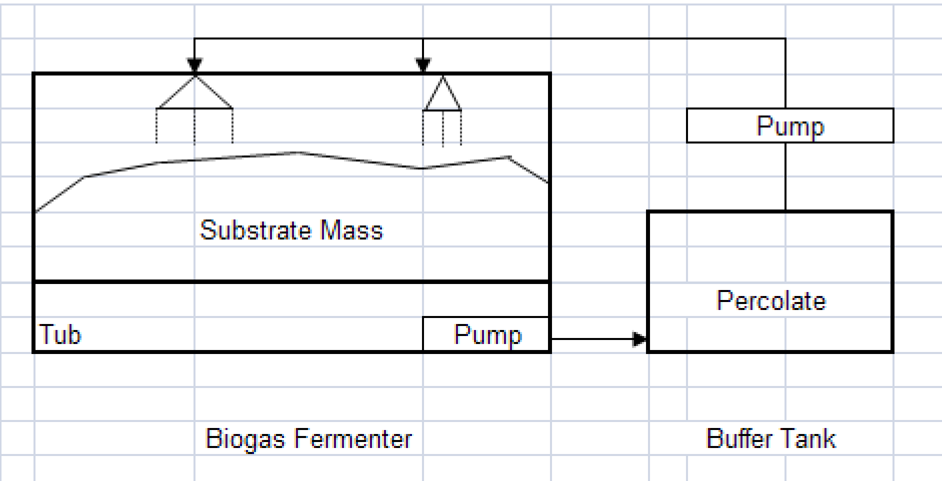

Fig. 1 Percolation System Schematic

All of the percolation technologies offered on the market are batch processes. This approach involves filling the fermenter with fresh substrate, closing the chamber and allowing it to ferment then removing the entire contents at the end of the cycle. After the fermenter is empty the steps are repeated again and again. In contrast to this are continuous processes to which fresh substrate is fed frequently in quantities of much less than the entire contents of the digester at one time. At the same time an equal corresponding amount of spent substrate is removed from the fermenter.

Microbiological processes in the Percolation Technology

In all biogas plants the digestion process passes through the same steps; hydrolysis, acidogenesis, acetogenesis and finally the methane phase. In the first step the substrate acidifies on small scale at favorable sites in the substrate. The products of this step then must come in contact with the appropriate microbes to pass through the subsequent steps to the production of biogas. In a single stage wet agricultural fermenter all surfaces of the material are favorable sites and products can be easily transported throughout the liquid. In percolation technology the theory of this process is somewhat more difficult to comprehend.

In dry fermenting, the biological dismantling processes takes place where free fluids accumulate, for example on a wet leaf surface. Microorganisms start by putting solid materials into solution (hydrolysis), mainly through development of organic acids. Since there is no active mixing in the percolation system, transport of these dissolved materials must take place by the circulating percolate. Percolate is sprayed on top of the fermenting pile in the chamber. This fluid flows down through the pile picking up the organic acids and transporting them and mixing them with the next stage microorganisms, so that decomposition can continue. By design the ideal place for these steps to take place is in the buffer or percolate storage tank. In this way a considerable share of biogas is produced there.

Processes in the biogas fermenter

Percolation technology was originally used for simulating processes that happen in the ordinary garbage dump on a landfill site. There rainfall water seeps through the layers of garbage promoting fermentation and biogas is the natural product. Years ago operators of landfill sites thought about capturing water, known as leachate, at the bottom of the dump, then spray it again over the top. This mainly aimed at helping to decompose the buried rubbish, reducing the potential for contaminating the groundwater below the landfill and shortening the period of concern regarding gas emissions. The anaerobic processes in landfills are identical to those in biogas plants. Landfill gas differs in that its methane content is usually lower and it contains (hazardous) trace gases from the rubbish substrate.

Those basic landfill processes were adapted and incorporated into dry biogas plants. They contain several parallel elements. Both function only if the percolate is able to seep through the substrate. To encourage this, a comparatively coarse structure is needed in the mass, one with sufficient interconnected pore spaces. These pore spaces allow the percolate or drainage water to flow throughout the mass. Without an open structure there would be no percolation. The leachate would accumulate in the substrate layers or dam up in the substrate mass. As a result the height of the substrate pile must be considered. Higher substrate piles place more pressure on the lowest layers and close the open pore spaces making it hard for the percolate to get through. From these examples it can be said the first limitation factor on the function of the percolation fermenter is the substrate structure, which is a mechanical problem.

To compensate for this mechanical limitation the percolation system requires a relatively coarsely structured substrate pile. However the biological degradation process proceeds in proportion to the surface area. The smaller the particle size the larger the available surface area and the faster degradation will proceed. The usual biogas plant will strive to grind the input substrate as fine as possible. For the percolation technology this is not desirable due to purely mechanical considerations. Hence, a percolation system requires longer retention times to obtain the same amount of biogas from the substrate than a comparably fed wet plant.

In wet processes the fermenting material is thoroughly mixed either continuously or on a schedule throughout the day. In the percolation system the distribution of nutrients and microorganisms occurs only by the circulation of the percolate through an arbitrary set of pathways in the substrate pile. There will be areas which get better access to these microbes and nutrients than others. This means that there will be areas within the dry anaerobic fermenter which are decomposed well and other areas that are not. In an attempt to get around this and optimize the process, some dry biogas facilities will inoculate the fresh substrate by adding fermented substrate to it. This way the digestion process begins throughout the substrate pile and shortens the “lay phase”, the period between placing the substrate in the fermenter and the start of methane production. On the other hand, inoculation material uses fermenter volume; it must be intermixed well taking equipment and energy which increase costs. The digested material tends to get wetter sooner than the fresh substrate and packs more tightly, reducing pore volume and the finer digested material clogs the percolate channels.

Another element to consider is the susceptibility of the percolation system to problems relating to sand and fine particles. As the percolate flows through the substrate it will convey these small particles down to the bottom and into the storage tank. To prevent clogging the operator must inspect and clean the screen at the bottom of the fermenter, the percolate collection system and pipes on a regular basis. In addition, this material can accumulate in the percolate storage tank and find its way to the pump and percolate spray nozzles.

One advantage for the percolation system is its high process stability. It is nearly impossible to bring this type of biogas plant to a state of complete acidification. This is because no matter how overloaded the system is there are always areas in the substrate mass supplied with low levels of percolate not affected by the acidified percolate. These areas will slowly but surely regenerate the entire system. On the other hand once wet fermenters are acidified they cannot be rescued. The only course of action in that case is to dump the total fermenter contents. Fortunately the fermenters used in agriculture are mixed and usually the input material consists of liquid manure or mixed manure which comes from a stable process and therefore by itself, leads to a stable process.

Process and substrate hazards

Commonly the fermenters used in the percolation system are modular gas tight containers. The fresh input material is brought in as a dry mixed stacked material.

This is either done by using a front end loader to fill baskets or cages with substrate then placing the baskets in the fermenter with the front loader or using the loader to bring the substrate directly into the container.

When the containers are full the fermenter doors are closed and the fermentation process is carried out. When it is complete the digested substrate is mechanically removed. This leads – when the doors are opened – to emissions of the residual biogas to the atmosphere.

As a safety concern, the atmosphere in and around the system goes through the explosive range twice each cycle. That is the point at which the mixture of methane and oxygen will sustain combustion. At this critical stage a spark will ignite the gas cloud in and around the container. This occurs first when the doors are opened and the spent substrate is removed and then again after the doors are closed the first methane is produced and mixes with the oxygen rich air introduced during the filling process. This critical period occurs only once in the normal life of a wet system at the initial startup.

When the doors are opened after fermentation is complete a real risk of ignition and explosion exists in and around the digester. This risk persists until the methane dissipates into the environment. Either the operator must accept this increased safety risk or install costly safety technology. These points are of great concern and so far no respective standards exist for approval procedures – neither with respect to emission control nor for required safety features and equipment.

Process monitoring and control

It is clear that the design and management of the percolate system is vital to the percolation style of dry anaerobic digestion of substrates. The circulating volume, the frequency of circulation and the equipment must be sized and sequenced. The challenge becomes more complicated in understanding each input material and how it will break down through the digestion process. Because of these variables and factors process control technology is important.

It must be noted that process data can be obtained only by a costly series of water tests to determine the relationship between organic load and buffer capacity. Analyzing the biogas itself provides no additional clue to help manage the process. For example the difference in pH between the fresh input material and the percolate results in a chemical process which expels carbon dioxide. In contrast to wet fermentation this CO_2 production has nothing to do with the biological process. Due to this lack of meaningful process data and control possibilities it is assumed that agricultural biogas plants using the percolation system must have a longer retention time.

Summary

The dry anaerobic percolation system has been in use for some time and is well known. It has not been shown to be preferable to the wet agricultural biogas plants. The percolation systems are advantageous in that they cannot be upset or acidified.

Their process stability is higher than wet fermentation if they are fed unstable material and it is only a matter of time until they regenerate.

It cannot be said that dry systems use more energy than the wet systems. This depends on specific procedures and technologies and can only be assessed on an individual case by case basis. In a similar way the fermenter volume is difficult to compare. Gas production from a percolation system of a given retention time is lower than from a wet system. Process monitoring and control of percolation systems is difficult. More importantly, there are serious safety concerns relating to the handling of bulk materials and explosive gas situations.

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