Biogas: Digesting Organic Wastes Anaerobically to Generate a Renewable Energy Source; Looking for a Solution

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Abstract
In lieu of an abstract, below is the first paragraph of the paper.

In the past decade alone, it has become increasingly important that consumers find alternative energy resources to provide some relief for the environment. Carbon based fuels, like propane and natural gas, are running in short supply and it won't be long until another fuel source will be needed to sustain the energy needed for a growing world. Not only are scientists concerned about the energy crisis, they are also concerned with ozone depletion as a result of methane and carbon dioxide buildups in the atmosphere. This excess methane comes from a source that is well known worldwide: livestock. Livestock are the brunt of the dairy and meat industry across the globe and as long as there are livestock around, there will always be waste. It is true that livestock are some of the biggest producers of gas, methane in particular, and something must be done. This gas is collecting in the stratosphere and damaging the ozone layer. According to Renata De Winter-Sorkina, a writer for Atmospheric Environment, creating holes in the ozone layer will lead to an increase in UV radiation that reaches the Earth's surface. In turn, this will also increase in the incidence of skin cancer, cataracts, and impaired immune systems, cause damage to forests and aquatic organisms, and lead to a decrease in crop yields. Consumers can't un-do the damage that has already been done to the ozone layer, but scientists have been looking for ways to decrease the emissions causing the devastating problems in our atmosphere.
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Recent studies have examined the potential use of the gas that livestock give off as a renewable energy source. Through two different approaches, the ways of collecting biogas and measuring its potential using different mediums were investigated. Before we can examine these two approaches, however, we must first discuss the problems associated with livestock, the history of biogas production, how it works through the process of anaerobic digestion, and the arguments against using biogas as a viable resource.

To sustain the needs of a growing human population, the amount of livestock slaughtered annually must increase. However, these livestock come with a price to the environment. The manure and animal slurries produced each day represent a constant pollution risk to ground water and air. Excess nitrogen and phosphorus are in such high levels from this waste that it can pollute drinking water to levels that are harmful to humans. The manure can also emit greenhouse gasses, which are detrimental to the ozone layer. Livestock can produce enough carbon dioxide, methane, and nitrous oxide to even play a role in global warming (Chase 2009). From the biogas utilization perspective, we are most concerned with the gasses emitted by livestock, particularly methane. If handled properly, the gasses given off by manure can be a valuable renewable energy source and the “left-overs” can serve as a source of nutrients for crops in the form of fertilizer. Through a process called anaerobic digestion, methane gas can be isolated from decomposing organic wastes.

The Benefits of Anaerobic Digestion
Anaerobic digestion of animal manure has the goal of creating two valuable products, one being biogas and the other being digestate, which can be used as a fertilizer in agriculture (Holm-Nielsen et al. 2009). Anaerobic digestion is an established method of generating methane-rich biogas. There are several different types of anaerobic digestion which include pyrolysis, direct liquefaction and gasification which generate biogas leaving fuel, combustible oils, and charcoal, respectively. The way in which these methods differ is in the preparation of the organic wastes. For example, in direct liquefaction, wastes are diluted with water so the medium is easy to stir and is very uniform, but in gasification, the organic wastes are not stirred or liquefied. The gas is strictly collected from the solid wastes. Since the preparation methods for the mediums differ, the consequent byproducts also differ (mentioned above as fuel, combustible oils and charcoal). Anaerobic digestion can be defined as the breakdown of complex organic wastes through the above mentioned processes that produces chiefly methane and carbon dioxide. A community of microorganisms is added to the waste mixture and the process begins with three main steps — hydrolysis, fermentation, and methanogenesis (Cantrell et al. 2008). Hydrolysis prepares the wastes for fermentation, which implies the “anaerobic” portion of this digestion (fermentation being an anaerobic process). The
methanogenesis does exactly what its name suggests, which is to generate methane gas. This process is relatively simple and has striking benefits.

A fuel called methanol can be created through the process of anaerobic digestion. It is made and collected in a digester that can be built underground or directly next to a building. The digesters that house this entire process are practical in many ways. In fact, they can pay for themselves in as little as five years and can function in homes as well as large scale businesses and livestock buildings. Since digesters may be part of the solution to the energy crisis, it is important we promote the use of this technology worldwide. It is speculated that if we were to use these systems in third world countries that new jobs could be created, and the methane emissions from that area can be drastically reduced. More jobs and increased technology in third world countries can help reduce poverty. Instead of burning carbon based fuels to meet the energy needs of a growing world, meeting some of those needs with the energy from anaerobic digestion will decrease the carbon footprint, and deal with the shortages of fuels created by the energy crisis.

**Potentials of Solid Organic Wastes**

Upon closer examination of the way biogas production works, it has been found that not only is animal fecal matter capable of producing biogas, but the actual organic materials from slaughterhouses like blood and hair can also produce methane through anaerobic digestion. Viewing this phenomenon through two different scientific approaches in the form of scientific experiments, we can see how practical the future of biogas really is.

More often than not, heating systems in large developments depend primarily on electricity, oil, or propane. In the case of livestock buildings, a lot of energy is used to keep the temperature high enough so that the animals can grow to their fullest potential. As stated before, methane, or biogas, can be used as a means of energy to make up for large amounts of heat needed in heating livestock buildings. In a recent study by Axaropoulos et al. (2003), researchers aimed to answer the questions of whether each livestock unit can produce enough biogas to cover all energy expenditures used to heat the building they are housed in. Conveniently enough, the medium for which the biogas is made from is found in copious amounts in a livestock building. The animal wastes can be collected easily through means of draining into a collection tank. To address the question of self-sustainability in biogas production, Axaropoulos et al. (2003) created an experiment that measured the biogas potential of a livestock building, known as a swine unit, using a solar assisted anaerobic digester as a means of collecting biogas. Northern Greece is the geographic location of this experiment where the climate can change in the matter of a few miles. The location of this experiment is almost as important as the results that were yielded.

What makes this change in climate important is that the amount of energy needed to keep the temperature constant is higher for a swine unit in colder temperatures versus one in moderate temperatures. Representing these different climates are swine units in lerapetra and Ioannina. Lerapetra has an overall higher ambient air temperature, while Ioanna has an overall colder climate. Consequently, the amount of solar irradiance received by these areas differ (solar irradiance meaning the amount of energy that is provided for by the "solar" part of the solar assisted digester). It is assumed that Ioannina would have higher energy consumption because it is in the colder climate, and would also have a lower solar irradiance level due to the lack of warm temperatures.

The waste of the livestock unit was collected in a digester housed underground with a solar panel facing at an angle towards the sun. The digester was always well mixed and kept at a uniform temperature to ensure digesters at both locations functioned properly. The target temperature for both swine units was equal, making the variable in this experiment the amount of energy needed to reach the target temperature. The methane production for each swine unit was measured in kilowatt hours per day to complete the comparison between swine unit requirements and actual production of biogas (methane). However, the overall “question” of this experiment was how effective would biogas be in adding to the necessary energy requirement? To do this, the methane was collected in the digester and its potential to be heat energy was calculated and compared to the energy consumed in heating the swine unit.

The amount of energy yielded from the biogas was compared to the energy needs of each swine unit in kilowatt hours per day over a period of approximately one year (360 days). Results showed
once the methane produced was converted into energy in the same units as the heating requirements, that the amount of energy produced substantially surpassed the energy requirements. The methane produced in both areas completely ensured the coverage of annual space heating requirements of the swine unit and also provided a surplus of methane which could be used in other ways. As far as the variability of climate goes, the swine unit at Ierapetra had a much higher energy requirement because the overall ambient air temperature was much lower than that of the unit in Ioannina. Despite the higher energy requirements, the methane produced was still enough to cover those energy needs as well as a surplus.

With these findings, it is easy to speculate about the future of biogas production and anaerobic digestion. We must first consider why this experiment was so successful. The sustainability of any anaerobic digester depends strongly on how the methane is used. In the case of this experiment, all of the methane was directed towards the energy needed for heating. We must keep in mind there are other sources of energy expenditure in a swine unit, such as lighting. It would be interesting to see if the surplus of methane produced would be enough to cover the lighting energy costs in each swine unit. Since there are so many livestock buildings across the globe, it might be beneficial to examine the environmental potential of these units. Not only could these systems (solar assisted anaerobic digesters) be used as a means of alternative energy, they could also be used for waste management (Axaopoulos et al., 2003). Waste management is another concern not only with animal fecal wastes in livestock buildings, but organic by-products in animal slaughterhouses. Slaughterhouses provide different mediums in which anaerobic digestion can be applied. To test the potential of this different medium, researchers conducted an experiment in a slaughterhouse in Denmark.

Slaughterhouse Wastes to Energy

The demand for meat has risen in past years, thus more and more livestock are slaughtered annually. In Denmark, where this study was conducted by Hejnfelt and Angelidaki (2009), over 24 million pigs are slaughtered annually. In the past, slaughterhouse wastes were treated and used as animal fodder, or livestock feed, because of its high lipid and protein content. But now that more and more consumers are environmentally and health conscious, this practice emerged as a major concern to businesses in the meat industries. It was found that diseases such as bovine spongiform encephalopathy in cows, and Creutzfeld-Jacob Syndrome in humans were both on the rise when slaughterhouses used wastes as feed. To eliminate the spread of such diseases, hygiene controls have become tighter, and the treatment of the wastes is different. Regulations on what is done with slaughterhouse wastes have also been tightened. However, these rules do not include any restrictions against using the wastes for anaerobic digestion. This experiment aimed to find out how practical it is to use slaughterhouse wastes to create biogas.

A few problems arise when using the slaughterhouse wastes as a medium. High lipid and protein content make the wastes good for animal fodder, yet this is also what makes it difficult to digest. As stated before, anaerobic digestion is used to isolate the methane given off by the wastes. Even though protein degradation through digestion releases the target gas, methane, lipids are particularly difficult to handle in anaerobic digestion. Lipids are long fatty acid chains (LFACS) that tend to float along the surface of the digester and may also promote floating scum (an accumulation of LFACS). This becomes a problem only when the animal wastes aren't prepared and diluted correctly for anaerobic digestion. This experiment tests to see which levels of dilution are best for biogas production, and also which combination of animal wastes are best for the production of methane.

To represent variability in the slaughterhouse wastes, five different substrates were collected to test at various dilution levels. These include fat, blood, raw waste (meat fat and bones), intermediate product (pressed raw waste), and bone flour. Each substrate was macerated and homogenized. Once the five substrates were pretreated, they were diluted to 5, 20, 50 and 100 percent solutions and incubated at 55 degrees Celsius. The cumulated methane production for the different slaughterhouse by-products was measured in decimeters cubed and plotted against kilograms of substrate. The amount of methane for each dilution was also calculated and plotted on the same graph as to compare dilution with amount of methane produced.
It was found that solutions of organic animal by-product that were most diluted yielded the highest production of biogas. This concept makes sense when reviewing the properties of the slaughterhouse wastes discussed above. Since the by-product is mainly protein and lipid based, diluting these substances would “spread” the lipids apart, exposing them to the substrates that carry out anaerobic digestion. This experiment also compared the amount of biogas yielded from fecal animal wastes to that of the organic by-product and it was found that the slaughterhouse wastes actually produced more methane after undergoing anaerobic digestion. These results are promising for the future of biogas production in livestock buildings. Slaughterhouses have the potential to produce more methane to fuel energy expenditures than ever expected based on the knowledge that more biogas is produced with more diluted solutions. A 100-fold increase in the amount of biogas produced is observed as the solution is diluted from 100% to 5%. This tells us that a solution of organic wastes that is diluted to 5% is more productive than a 100% solution (Hejnfelt and Angelidaki 2009). Combining these theories with those concluded from the first experiment suggests that the future of biogas is brighter than ever.

The Future of Biogas

The results from these experiments reveal the future potential of biogas. Both approaches examined the possibilities of biogas using anaerobic digestion and consider the ideal medium to be organic animal wastes. Biogas is measured in ways that are useable in practical terms, such as heat. In the first approach, the methane produced was used to heat the livestock buildings and in the second approach, the biogas was considered in terms that are practical for heating or lighting. However, as similar as these two approaches were, their overall question varied. Only animal wastes (feces) was considered in the first approach, whereas the second approach considered the potential of all animals wastes, even those from slaughterhouses. The experiment done by Axapoulous et al. (2003) also put a “cap” on energy expenditures (only considering the energy required to heat the livestock building) whereas the experiment by Hejnfelt and Angelidaki (2009) viewed each “trial” with the possibility of it producing an unlimited amount of biogas. As successful as these two experiments were, I speculate about the future of using biogas on a large scale. With this knowledge, why haven’t scientists already attempted to use this technology to replace oil?

Using biogas on a large scale is completely practical and ideal, considering the amounts of carbon based resources running out at a very fast rate. With the human population growing exponentially, we must consider alternatives to energy sources, so that the depletion of ozone does not continue. Utilizing livestock for an energy source seems like the most quintessential way of aiding in the energy crisis, as well as reducing carbon based emissions like methane and carbon dioxide. By collecting livestock wastes for the purpose of generating biogas, green energy would be utilized, while at the same time increasing sanitation of these facilities. Collecting wastes in digesters would prevent air and water pollution as well. Since the profitability of any digester depends on the extent to which the methane is used, it would be practical to use the gasses already being released by wastes for something good. All in all, greenhouse gasses would be reduced, which puts less strain on the already changing global environment.

It may seem unreasonable to think that trapping methane produced from livestock can eliminate a major environmental stressor that depletes the ozone, but we must remember that these harmful emissions are coming from somewhere. According to Walsh, a writer for the Encyclopedia of Environment and Society, 14 percent of the global emissions contributing to ozone depletion come from farm animals. These numbers only include methane, not carbon dioxide, which is just as potent. With 1.4 billion cattle present across the globe, it seems like a tangible idea that the gasses given off by their wastes are having an impact.

The analysis of these two approaches specifically covers the emissions from livestock alone, but we must also consider other waste producing animals globally. The human population is the largest it has ever been and our very own wastes have been collecting and giving off emissions as well. Ideally, in the future we will be able to utilize the anaerobic digestion technology and somehow incorporate it into our very own septic system. As it is now (in most developed areas of the world) septic tanks house solid and liquid organic wastes from households. Instead of strictly collecting the wastes
as the system does now, it may be important to see how using biogas fermenters aid homes in energy expenditures. To possibly reduce the need for propane or natural gas, a system that converts biogas into energy that is practically for use in an individual’s home should be created.

The more and more biogas is used globally, it is inevitable that we must learn more about it. It is natural to find glitches in systems once the system is actually “tried out”, as well as new alternatives to make the process more simple and efficient. At this point, biogas is not utilized to the extent it could be, but hopefully in the near future we turn to use it as a viable energy resource. After examining two mediums for the production of methane using livestock organic wastes, it is evident that promoting the idea of using livestock for energy might be a good idea in the near future.

Works Cited


