Effectively Utilizing Organic Waste Through Anaerobic Digestion

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INTRODUCTION

Humans have developed a habit of collecting bodily waste and as a result, different methods of disposal have been established. Large sewage treatment plants are present in many developing countries but the task of building and maintaining these plants is burdening. In turn, people resort to burning human waste or burying it in the ground at landfills. Both situations occur on the island of Eleuthera, The Bahamas, because when living on a small, relatively undeveloped island, many people see no alternate means of disposal. Not only does burning or burying discarding waste impact the environment in an extremely negative way, it also causes abundant waste build up over time. Specifically at The Island School where a zero waste initiative has been adopted, it is necessary to find an alternate outlet for waste streams, such as glycerine and cardboard. A process that would be a solution to such a problem is anaerobic digestion, otherwise known as biodigestion.

By definition, anaerobic digestion is the sequence of microorganisms breaking down waste inputs in the absence of oxygen, in four stages (Hansen et al 2006), and has been a working technology for centuries. Anaerobic digestion began in Bombay in 1859 where the first digestion plant was located. By 1895 the process was being used in England where biogas was taken from the sewage treatment facility and used to fuel street lamps (Monnet 2003). Since then, research has led to improvements in AD technology that have allowed for simple replication of a time tested, effective and sustainable means of creating energy and dealing with waste.

Previous studies have used pig manure, cow manure, and glycerine as inputs. It is also shown that the addition of glycerine has increased methane production. In order for any of this to be achieved however, it is pertinent that certain factors are considered. The carbon to nitrogen ratio, the solid to liquid ratio, temperature, and pH of the slurry all influence the survival of the biogas forming bacteria in the feedstock (Verma 2002). The ideal carbon to nitrogen ratio is within the range of 20:1 and 30:1 (Monnet 2003). Such a ratio is reached because human waste is nitrogen-rich but is balanced by inputs such as cardboard, which are carbon-rich. The optimal solid to liquid ratio is 9:1 where the liquid is always water. The two optional temperature ranges for anaerobic digestion are mesophilic, 25-35 degrees Celsius, and thermophilic, 35-55 degrees Celsius (Monnet 2003). Lastly, pH should be within a range of 6.4-7.2 and a buffer, such as glycerine, can help maintain optimum pH.

Implementing a large scale digester at The Island School would take care of three major waste streams and simultaneously yield usable byproducts. Currently human waste is pumped out and dumped in the same manner as the waste of the population of Eleuthera. Glycerine is a byproduct of biodiesel production that occurs on campus, and cardboard is collected from all the shipments received at The Island School. The combination of human waste, cardboard, and glycerine, when maintained at the optimal ratios of carbon to nitrogen, liquid to solid, pH, and temperature ranges allows for successful anaerobic digestion, generates biogas (methane and carbon dioxide) and fertilizer.

The objectives of studying anaerobic digestion were to eventually build a large-scale digester on The Island School campus, find the best combination of feedstock, and the most effective digester model. Unused resources would be removed from The Island School campus and put in a place where they can be helpful. The digestion of all these inputs would decrease their presence and byproducts would be used as fuel and for growing crops, furthering The Island School's effort in being more sustainable.

Adding glycerine to the digester

Adding waste to the digester

The Fall 2009 biodigestion research team

SOLAR RADIATION

WASTE

Human waste is collected from The Island School community.

CARDBOARD

Cardboard is an input that is collected from the various shipments that arrive on The Island School campus.

GLYCERINE

Glycerine is an input that is a byproduct of the biodiesel lab located on The Island School campus.

BIOGAS

Biogas is an output comprised of carbon dioxide and methane.

FERTILIZER

Fertilizer is an output comprised of the waste water and digestate in the digester.

Sealed biodigester containing feedstock. Biogas escapes via silicon tubing.

METHODS

An array of six biodigesters was constructed out of 2.4 L plastic containers, painted black for maximum heat absorbance. Six gas traps, each built out of a 500 mL plastic bottle, were connected to the digesters using 1/8 inch plastic tubing. All seals were made airtight using silicon sealant.

Each digester was loaded with feedstock consisting of human waste, collected days prior to the experiment's start, cardboard, collected from packaging, crude glycerine from the biodiesel lab, and water, collected from rain to avoid salinity problems. The composition of each digester is listed in Table 1. Acting as the control, digester group A used only human waste and cardboard as feedstock. All digesters had a solid:liquid ratio of 1:9 by mass in order to maintain a low solid ratio (Verma 2002). The mass of waste and volume of water in each digester was also held constant. The digesters were 75% filled with feedstock.

Using solar radiation, the digesters were heated to an average temperature of 35 degrees Celsius, the optimal temperature for mesophilic digestion (Monnet 2003). To ensure anaerobic digestion was taking place, the cumulative volume of gas produced was recorded twice daily, at twelve hour intervals. The weight of each loaded digester was noted prior to digestion as well after completion of the experiment. Completion was determined by a reduction in the amount of biogas produced by the digester, at which point the digestate was removed and used as fertilizer, while the biogas was tested for methane composition.

	Human Waste	Cardboard	Glycerine	Water
Group A	165 g	5.24 g	7.1 g	1.485 L
Group B	165 g	1.42 g	0.0 g	1.485 L

Table 1: Feedstock inputs for digesters

RESULTS

Once the digestion process had reached completion, it was found that the mean biogas production of Group B (510 mL) was greater than that of Group A (183.3 mL). In particular, digester B2 had the highest amount of biogas output (905 mL). Digesters A1 and A3 never produced any biogas; observations indicated that those two digesters had ineffective seals. It was noted that the majority of biogas production occurred when there was substantial solar radiation. In contrast, at night and during a cold front (days 3-7), production was minimal. A student t-test was conducted on the cumulative biogas production of Group A versus Group B, and yielded a p-value of 0.296. This shows that there was no statistical significance between the biogas production of the two groups.

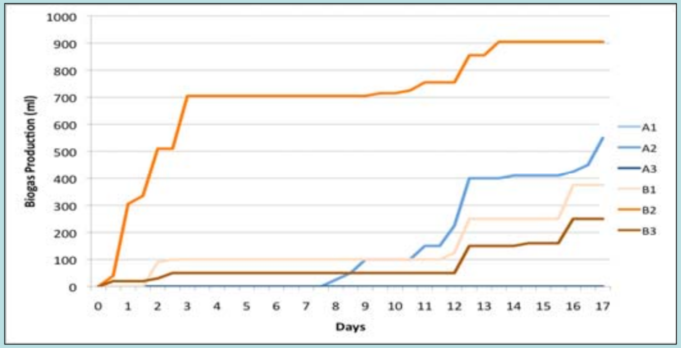

Figure 1: Individual biogas production of digesters over time

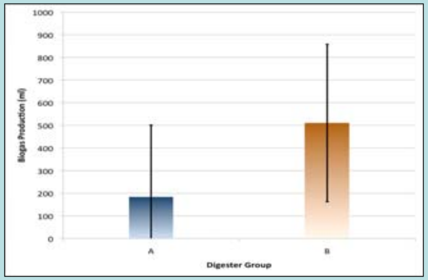

Figure 2: Cumulative mean biogas production of digester groups

DISCUSSION

The purpose of this study was to determine the best input combination of human waste, cardboard, and glycerine for a future community-scale digester at The Island School. This experiment gave insight to the aspects of anaerobic digestion that need to be controlled to achieve success on a large scale. The results show that temperature, controlled by solar radiation, is crucial to digester success and that glycerine did not inhibit gas production. Both of these variables should be studied in more depth in future experiments, which must be completed in order to secure data for digestion on a larger scale.

Since the results obtained were inconclusive, the percentage of glycerine added to the digesters should be investigated more thoroughly to resolve any concerns regarding the feedstock to be used for the large-scale digester. Many studies focused on large-scale digesters on farms suggest that 3-6% glycerine input is optimal (Wohlgemut 2008). It would be important to see how this ratio would work with human waste, rather than pig or cow manure.

The impact of heat from solar radiation on biogas production showed that temperature is crucial for the digestion process to occur. The drop in temperature caused by an absence of sunlight suggests that it might be beneficial to find an alternate way to maintain a constant temperature in the mesophilic range for a large-scale digester.

Another factor to take into consideration is the consistency of the slurry put into the digesters. Some of the donations for the trial were collected very soon before the digesters were sealed, while others were older. The breakdown of human waste begins immediately after it is excreted, so the waste that was sitting for a few days was already partially broken down, causing it to lose methane potential. This could explain the variation of the results. Therefore, slurry consistency and the age of the waste feedstock are factors to monitor in future experiments.

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