Biodigestion: Quantifying Glycerol to Maximize Biogas Production

Sarah Becker, Nicholas Elvinger, Eliza Hazen, Hannah Twombly, Arben Ukperaj, Evan Wood,
Advised By: Jacob Archbold, David Burnham, Taylor Fargo, Samuel Kenworthy

THE ISLAND SCHOOL cape eleuthera bahamas

CAPE ELEUTHERA INSTITUTE
RESEARCH SUSTAINABLE DEVELOPMENT OUTREACH

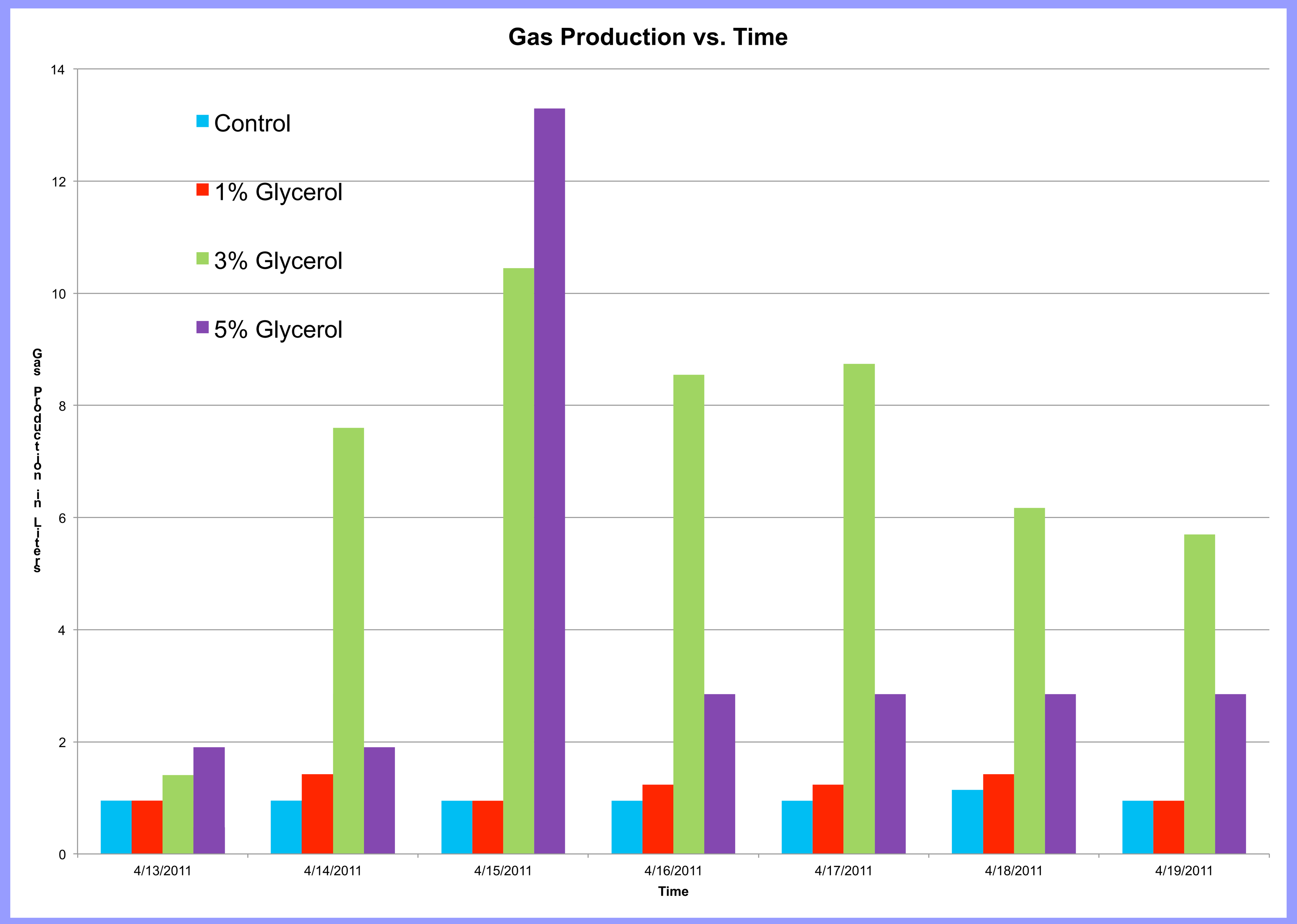

Fig. 1 Inoculation #1 Gas Production vs. Time

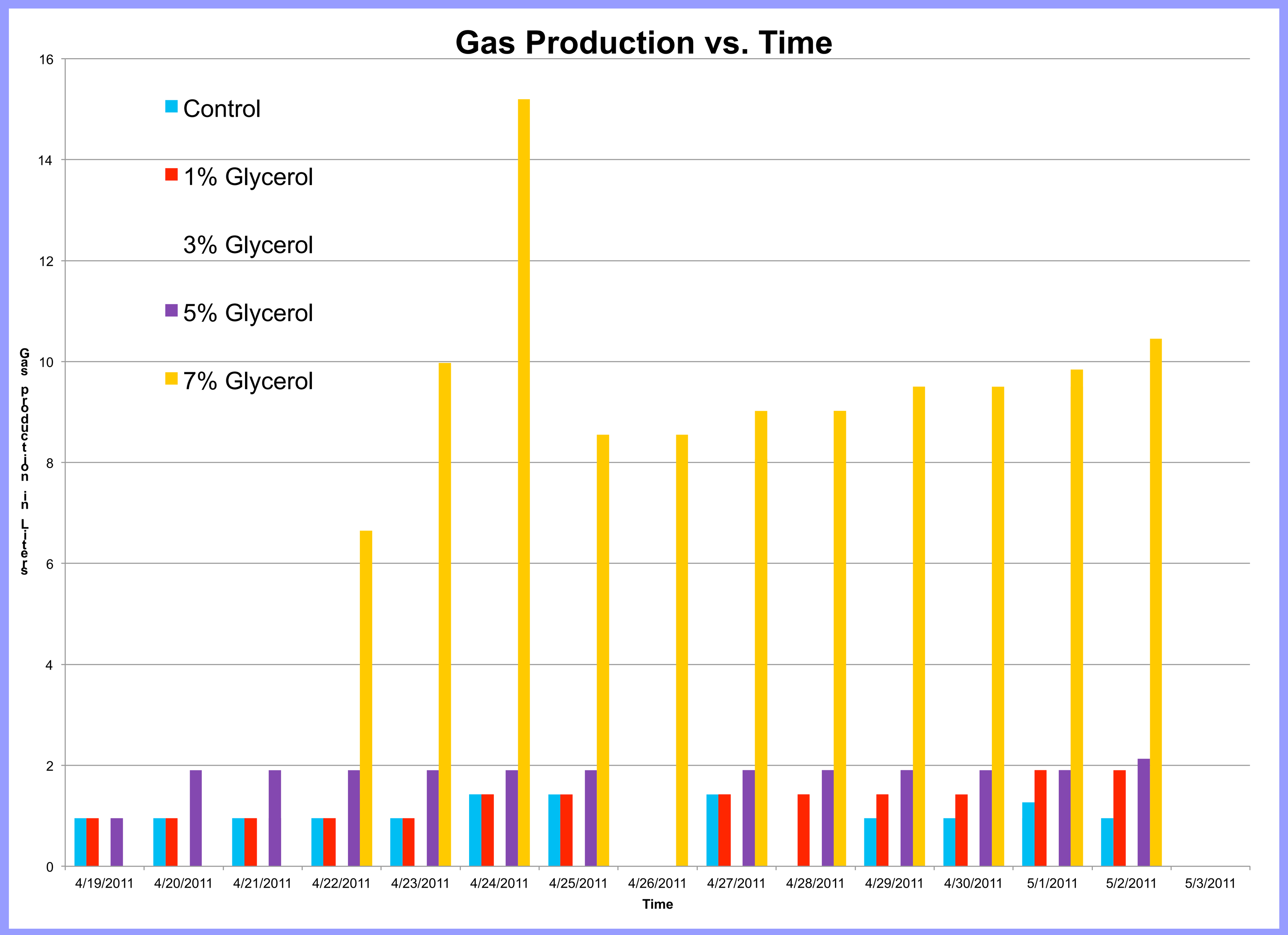

Fig. 2 Inoculation #2 Gas Production vs. Time

Biodigestion: The process of breaking down organic materials in an anaerobic setting.

Biogas flow →

INTRODUCTION

As the world's economy and population grows, it becomes more difficult to manage waste while being sustainable. Common methods for disposing of waste that are used today include transporting waste, burning it, or letting it sit in a landfill, where it can potentially pollute the air and groundwater. Alternatively, recycling systems have become popular around the world, but are not accessible in all settings and do not completely solve the problem of human and animal waste management. Because recycling facilities are not always available, settings like the island of Eleuthera rely on dumps, which are harmful to the environment, economy, and human health.

To take a more sustainable approach to waste management, humans must learn from nature and mimic its example of using any waste that it produces. One form of this mimicking is biodigestion, an anaerobic process that takes organic materials, such as human, animal, or garden waste, and transforms them into a nutrient rich fertilizer while simultaneously creating biogas, a useful energy source. On Eleuthera, the soil lacks sufficient nutrients for maximum growth, and most people get energy off of diesel plants; having a biodigester on the island is ideal because it addresses three major issues Eleuthera currently faces: the need to have food security, adequate waste management and reliable energy independence. (M.A. Stocking). One system that The Island School utilizes to produce energy is biodiesel. However, the biodiesel creation process produces a large quantity of glycerol as a byproduct, which IS has not yet developed a significant use for. Not only would biodigestion put glycerol to use and manage human waste, but it would also produce a usable biogas to be used for fuel and electricity. During the Spring 2011 semester the Biodigestion Research Team aims to quantify the right balance between inputs, human septic waste and glycerol, while maximizing the outputs, biogas.

Fig. 3: Using the nutrient rich effluent, a final product of the biodigestion process, as a fertilizer.

Fig. 4 An application of biogas used as energy

METHODS

Five digestion systems were constructed: a control digester without glycerol, and the other four having 1%, 3%, 5% and 7% glycerol respectively (see figure 6). All systems were divided into three stages, each stage consisting of one 5-gallon bucket. Connecting each stage were siphoning tubes, sealed through holes drilled in each stage (see figure 4). In the first stage, pig waste and glycerol are broken down by bacteria. The volume ratio for this stage was three and a half gallons of water to one kilogram of pig waste. Attached to each first stage was a valve to regulate the biogas being produced and stored in the second stage. This way, new batches of waste could enter the system without releasing any gas. The biogas produced would travel through a siphoning tube connecting the tops of the first two stages. Each second stage was filled with four gallons of water that incoming biogas would push through a siphoning tube to the third stage. Each third stage was raised two cinderblocks above the other two stages. These constants of elevation and water pressure created more resistance, resulting in more biogas storage capacity. In addition, the volume of water building up within the third stage served as a way of measuring the displacement of the water caused by biogas production. Therefore, the digester with the greatest volume of water in the third stage would be the digester with the highest biogas yield. Data and biogas volume was collected every morning between 8:00am and 9:00am and every evening between 6:00pm and 7:00pm. Once the trials were complete, the data collected was statistically analyzed through an ANOVA test, an analysis of variables, which determined which results were significantly affected by glycerol.

Fig. 5 The final set up of all scale digesters after inoculation.

Water flow →

RESULTS

The preliminary results of our experiments demonstrate that glycerol can, in some quantities, increase gas output. Once glycerol was added to the pig waste slurry composed of pig feces and water, production increased at some point in the experiment as a direct result of glycerol additions. The control digester, which had no glycerol, produced almost no gas as expected. Even 1% had an impact on production, producing 1.2 liters in comparison to the control's 0.95 liters produced during the first inoculation. The digester containing 3% glycerol accordingly fell between the 1% and 5% in terms of gas production and produced 8.55 liters during its retention period (see Fig. 1). The digester containing 5% glycerol produced 2.85 liters of its retention period during the first batch. Within the 1st data set (Fig. 1), the 5% digester produced the most amount of biogas. However, once 7% glycerol was inoculated, it quickly led the way in gas production. At the height of production, it was observed the 7% digester producing almost one ounce per minute, producing an accumulated 10.45 liters during its retention time in the first inoculation (see Fig. 1).

Fig. : The final set up of all scale digesters after inoculation.

DISCUSSION

According to previously conducted research, gas production should increase with temperature. This has proven to be correct through this experiment; however, this was not the situation for all theories. Previous research states that a digester containing more than 6% glycerol becomes unstable and gas production ceases, but the 7% digester proved this theory inaccurate since it was the most productive of our study (Kryvoruchko, V., Amon, T. *et al*).

Throughout this study, the biogas collection was disturbed due to several different factors. The anaerobic setting may have been compromised from sealing errors for all the digesters, allowing gas to escape and oxygen to enter. This could have created an inconsistent setting, which would make it difficult to compare various levels of glycerol productivity rates. Obtaining materials that are more reliable would be beneficial for future research.

Future research projects could continue to quantify glycerol additions in order to find the upper limit of a stable system. Once this limit is established, research could be conducted using human waste instead of pig manure. It has been determined that 6% glycerol is not the upper limit for a stable system, however, it is unclear how much glycerol can be added in order to produce the maximum amount of biogas. With further investigation, this maximum amount of glycerol could be determined. Finding a conclusion to this study would be beneficial because it would allow communities to obtain the full potential of their waste by providing them with the highest amount of energy possible, along with a usable fertilizer.

REFERENCES

Amon, T., Amon, B., Kryvoruchko, V., Bodiroza, V., Pötsh, E., & Zollitsch, W. (2006). Optimising Methane Yield from Anaerobic Digestion of Manure: Effects of Dairy Systems and of Glycerine Supplementation. *International Congress Series*, 217-220.

Appropedia. (2009, September 26). *Making Biogas from Human Waste*. Retrieved April 5, 2011, from Appropedia: http://www.appropedia.org/Making_Biogas_from_Human_Waste

Clift, R., Doig, A., & Finnveden, G. (2000). The Application of Life Cycle Assessment to Integrated Solid Waste Management. *IChemE*, 279-287.

D.C.Wahl. (2006). Bionics vs. Biomimicry: From Control of Nature to Sustainable Participation in Nature. *WIT Transactions on Ecology and the Environment*, 289-298.

Friends of the Earth. (2007, September). *Friends of the Earth.* Retrieved from www.foe.org: http://foe.co.uk/resource/briefings/anaerobic_digestion.pdf

Kryvoruchko , V., Amon, T., Amon, B., Gruber, L., Schreiner, M., & Zolitsch, W. (2007). Influence of Nutrient Composition on Methane Production from Animal Manures and Co-Digestion with Maize and Glycerine. *Prairie Swine Centre*, 1-8.

Martin, A. D. (2007). *Understanding Anaerobic Digestion.* Manchester: University of Manchester.

Meyers, G. D., McLeod, G., & Anbarci, M. A. (2006). An International Waste Convention: Measures for Achieving Sustainable Development. *Waste Manage Res.*, 505-513.

Stocking, M. A. (2003). Tropical Soils and Food Security: The Next 50 Years. *State of the Planet*, 1356-1359.

Warmer Bulletin. (2003, March 4). Anaerobic Digestion. *Warmer Bulletin*, pp. 1-4.

Wohlgemut, O. (2008). *Co-Digestion of Hog Manure with Glycerol to Biogas and Methane Production.* Winnipeg: University of Manitoba.