Experimentation and Design of Biofuels and Biofuel Refinement, to be Implemented In Energy Starved Locations, Using a Modified Bomb Calorimeter

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Abstract

Current modern energy sources cannot feasibly address the energy needs for many energy starved geographical locations around the world. In 2015, 1.3 billion people went without access to electricity, primarily in Africa and India (IEA 2015). Unlike other energies, biofuel has the potential to be used as a budget friendly alternative in this regions. Throughout Africa and India there are a multitude of resources that can be implemented as biomass. The two greatest prospects are lignocellulosic plants and animal manure. Lignocellulosic materials are abundant and contain the components necessary to create efficient biofuel, however, there are obstacles that must be overcome first in the refinement stage. Animal manure is another abundant resource that has a more simple application, but is harder to collect. This project's procedure is designed to refine and autonomously test the efficiency of a variety of fuel sources including lignocellulosic plants and animal manure. A self designed and constructed bomb calorimeter while be used to collect data from fuel efficiency testing. Through self-refinement and testing this experiment is designed to provide data that can be implemented in energy starved locations.

Introduction

Key Terms: Energy, Biomass, Pre-treatment, Bomb Calorimeter

It is among one of the world's highest priorities to improve upon the field of energy. Today, energy consumption rates forecast that around 18% of the world population is without energy everyday (IEA 2015). The development within the field of sustainable energy as a whole can be greatly influenced by research specific to regions that are included in this statistic. The 18% mark represents roughly 1.8 million people out of the total world population that do not have accessible electricity; it was also concluded 98% of these individuals live in Sub-Saharan Africa and Asia (UNEP 2011, IEA 2015). The project will focus on identifying and addressing an alternative sustainable energy source in order to bring electricity to the semi-arid and arid regions among these territories.

To the average person, alternative energy is typically thought of in terms of solar, wind, and hydro formats. Within the group of alternatives, there exists biofuel or ethanol, which is classified as a substance produced from renewable sources of biomass. Commonly made into liquid form, biofuel has the potential to bring energy to the areas of the world where there is currently none. This is made feasible through assessing the resources native to regions within Sub-Saharan Africa and Asia. This project aims to determine the best biomass to test and use for large scale biofuel production.

One of the greatest assets to the biofuel industry today is lignocellulose based species. Many plants are comprised primarily of lignocellulose and if harnessed, they can produce large quantities of biofuel. The first step to achieving this is to break down the lignocellulose into its different components. From this step the cellulose derived from the separation can be used to produce biofuel through means of enzymes and fermentation. The initial process however is where breakthroughs in methods and pre-treatment play a large role in making decomposition of lignocellulose material possible. This biomass is one of two distinct and strong contenders for biofuel production in energy starved locations. The other source of biomass is animal waste. This option presents numerous opportunities in both Africa and Asia due to the cost-effective nature of producing animal waste and because of the sheer quantity of animals available to harvest from (Kemausuor et al. 2014). This method of refinement utilizes drying and fermentation in comparison to enzyme pre-treatment and fermentation. To supplement these biofuel production stages our team has determined that the construction of a relatively inexpensive bomb calorimeter is necessary in order to gain insight into the comparative effectiveness of any biofuel created. This will allow us to gauge our success and determine what will be best for our target demographics.

Enzyme pre-treatment is currently thought of as one of the most effective ways to generate maximum biofuel production from lignocellulosic material. One recent study involving pre-treatment using green liquor acquired interesting results that may help progress in the field. Found most effective at 140 degrees celsius, green liquor was used to pre-treat four different species of woody biomass, masson pine, poplar, moso bamboo, and miscanthus (Wang 2015). This study showed that the resulting materials were affected primarily based on the strength of their individual composition. It was found that the plants, miscanthus and moso bamboo were affected the most profoundly because their composition was most closely to that of more porous material like grass (Wang 2015). This pre-treatment method makes sense for porous materials because their nature allows the green liquor to immerse itself inside of the species enabling the decomposition of materials in an internal fashion. Similarly, another pre-treatment study utilized diluted sulfuric acid to test the removal of lignin, hemicellulose, and cellulose from rice straw (Zhu et al. 2015). This pre-treatment was found to be most effective on rice straw at 100 degrees celsius because the unwanted parts were discarded, while the cellulose remained and suffered very little weight loss from the rice straw (Zhu et al. 2015). While both experiments are valid, the first experiment holds a greater value due to the diversity in subjects. Nevertheless, these are all biomass that could be of potential use within the areas of Africa and Asia, whereas rice straw is more specific to less arid regions typically found within Asia.

In contrast to plant biomass, animal manure is an attractive alternative for biofuel production. Animal manure is essentially a forever existing source of energy that can be found in almost any environment. Biomass conversion has been calculated in a few studies suggesting results that can help areas without electricity.

Introduction Continued

A study from 2014 researched the waste production of livestock in Ghana (Kemausuor et al. 2014). It was recorded that chickens had by far the largest population of any of the animals (Kemausuor et al. 2014). The research also recognized that chicken manure was the most accessible and easiest to collect, therefore making it the best candidate for conversion out of all the biomass tested (Kemausuor et al. 2014). In comparison a study conducted 12 years early suggests similar findings. In 2002 a study published analyzed the effects of pyrolysis on different types of animal manure (Serio et al. 2002). The focus of the research was on the different chemical components and their weight percentages after being put through pyrolysis. It was concluded that chicken manure had the best response to pyrolysis because of its low ash and moisture content (Serio et al. 2002). While conducted in separate locations the data obtained by each research group draw parallels to each other. It was unanimous between both studies that chicken manure is the most feasible for biofuel production out of all of the manure samples tested. Bomb calorimetry is essential to the process of testing fuel efficiency. As it relates to this project, bomb calorimetry will test the efficiency ratings of our teams biofuels, further allowing us to optimize our processes. The conventional standard of bomb calorimetry is based around the use of a metal bomb (Parr Instrument Company 2007). Standard bomb calorimeters are pressurized units with storage for the mass being tested and are completely insulated by an environment of water and then by an insulation jacket (Parr Instrument Company 2007). Calorimetry also extends in the direction of glass bomb calorimeters. A glass calorimeter as it compares to a metal bomb calorimeter is immensely less expensive, and more safe. Despite these two approving conditions, they are also more prone to cracking which will compromise the results of a fuel efficiency test (Johnson 1999). In the event of this scenario a new glass bomb calorimeter would need to be created in order to resume experimentation. For these reasons glass bomb calorimetry is a good model for what our groups calorimeter will become.

Research into biofuel will open the opportunity for innovations relating to energy solutions. The significance of focusing on energy starved locations creates a need to think outside of conventional methods in order to develop practical solutions. Examples of this are already being shown through the use of diverse types of biomass and pre-treatment techniques. Feasibility is also important to this project because we need to stay within the confines of specific regions and the resources available. In doing so, the application of new techniques and measuring methods will be able to bring remote areas alive with energy prosperity in cost-effective ways. Our team strives to do exactly this through our research in the fields of biofuel refinement processes and calorimetry methods. It is our team's primary focus to compile the knowledge necessary to identify the energy crisis appropriately then create solutions that will bring energy to the 18% of the world that exists with a lack thereof.

Proposed Methodology

Procedure (Lignocellulosic Fuels)

1 . Clean off a good surface near a wall socket for testing.

2. Place the blender by the wall socket and plug it in.

3. Spray pans with a thin coat of sprayable cooking oil.

4. Acquire the specimen that you are going to test.

5. Chop the specimen into smaller bits so that it is easier for the blender to blend.

6. Once chopped place the chopped specimen into the blender and blend.

7. Add a little bit of water if need be to ease the blending process.

8. Drain the liquid from the plant matter.

9. Place the plant matter onto the pans and spread evenly across the pan.

10. Bake in the oven for approximately 20 minutes.

11. Remove from the oven using oven mitts. (Notice that the plant matter should have become very dry, this is the lignin in the plant.)

12. Remove the plant matter sheet and cut into 2x2" squares.

13. Weigh the plant matter on the gram scale. 14. Repeat steps (5- 13) when using other types of biomass.

15. Place 500g into the bomb calorimeter for testing.

16. Refer to the bomb calorimeter use guide.

Bomb Calorimeter Method/Procedure

BUILD

1. Acquire 1 (1/2 gallon) paint can

2. Drill 1 3/4 inch hole 3/4 of the way up the paint can on the round side

3. Clean the hole of any debris and weld the pressure valve onto it with the attachment side facing out of the paint can

4. Drill 2 1 inch holes in the middle of the base of the paint can. The holes should be 1.5 inches apart

5. Insert one steel rod in each of the two holes of the paint can, leaving about 1 inch sticking out of the bottom. Weld into place

6. Attach a hinge to the top of a paint can.

7. On the opposite side attach a clasp buckle

8. Weld the flat piece of steel to the hinge, in such a fashion that it can rest flatly on the lid of the paint can when closed.

9. Weld the clasp attacher to the end of the flat piece of steel, and ensure a tight seal with the lid of the paint can can be achieved when clasped shut.

10. On opposite sides, weld the clasp attaches to the bottom of the round outside of the paint can

11. Weld the clasp buckles onto the paint can stand so that they can attach and secure to the paint can during operation

12. Place the paint can stand into the middle of the cooler and secure into place

13. Place the paint can on top of the paint can stand and clasp into place

14. Drill a 3/4 inch hole into the side of the cooler at an equal height to that of the 3/4 inch hole in the paint can

15. Run the 3/4 inch steel tube through the hole in the cooler so that it may attach to the pressure release valve on the paint can. Note that there should be some tubing left on the outside of the cooler

Methodology Continued

16. Using adhesive caulking, caulk any gaps or openings left around the 3/4 inch steel tube hole. This should secure the tube during use.

17. Weld the pump tube to the outside of this tube.

18. Drill 2, 1 inch wide holes in the middle of the cooler lid, approximately 6 inches apart.

19. Insert the stirrer in one and the temperature probe in the other. Seal any openings in these holes using adhesive caulking compound.

IGNITION SET-UP

1. Solder one electrical wire to the bottom of each steel rod in the bomb design. The wires should be welded on the outside exposed portion of the rod.

2. Spool the wiring of out of the cooler, ensuring that the wiring is not taut inside the cooler

3. Close the cooler, leaving at least 1 foot of wire outside of the cooler.

4. Keep a 9 volt battery ready, for when ignition is required.

IGNITION TESTING

1. Connect the ignition wires to the 9 volt battery.

2. There should be a visible spark between the two rods inside the bomb unit.

3. Disconnect the ignition wires.

USE

1. Insert 1/3 kg of fuel into the bomb.

2. Seal the bomb by placing the paint can lid on top, and laying the flat piece of steel over the lid and clasping it tightly shut.

3. Place the bomb into the cooler onto the paint can stand.

4. Line up the pressure release valve with the pump tube and attach them together.

5. Clasp the paint can to the paint can stand

6. Add 4 gallons of water to the cooler.

7. If the paint can floats, weigh the paint can stand down until the paint can is stable

8. Seal the cooler.

9. Begin pumping air into the bomb until it reaches a pressure of 60 psi, while simultaneously beginning to circulate the water with the stirrer..

10. Cease pumping, and connect the wires to the 9 volt battery, thus igniting your fuel.

11. Measure the water temperature once a minute until the temperature ceases to change.

12. Compare the starting and end temperature to determine the amount of energy expended during this process (equation is used for this).

Predicted Results

Expected Outcomes

Our group believes that biodiesel will have the highest energy output, but that ethanol will be the easiest fuel to acquire and use. This is because biodiesel requires the use of vegetable oils, and the process of creating ethanol through fermentation is easier. The energy output of the fuels will be tested using a bomb calorimeter. The ease of growing/refining fuels will be tested by attempting to grow/refine the fuels ourselves. Some variations in the testing could be present when testing the energy output of the biofuels. Since we are building our own calorimeter from scratch, the data may not be as accurate as industrial grade calorimeters. This could lead to discrepancies when testing, although proper build methods will taken to ensure the highest accuracy achievable. By being able to test the energy output of these fuels we will be able to analyze which fuel is the most efficient when taking into account ease of growth and ease of refining in areas such as sub-saharan Africa and India.

Data Analysis

The data we collect will both be qualitative and quantitative. The measurements from the bomb calorimeter will be quantitative because we will be collecting numerical data. Our qualitative data will come from seeing the ease in which we were able to acquire and refine fuels. This data will be important because while a fuel may be extremely efficient, if it is difficult to acquire and refine it will not be a good choice for implementation in energy starved locations. The quantitative data will be measured in degrees celsius within an accuracy of .001oC. This is due to the fact that bomb calorimeters operate by changing the temperature of the water around the bomb, and a high measurement accuracy is required to get a true and precise reading (Parr 2007).

Data has already been published regarding the energy output of biofuels such as ethanol and biodiesel. For example, ethanol has been recorded to produce between 18 and 21 MJ of power per liter, and biodiesel has been recorded to produce between 33 and 35 MJ of power per liter (U.S. Energy Information Administration 2015). However, those publications take into account high grade fuels, the fuel our experiment would be testing would be made from a crude refinement meant to simulate the conditions in impoverished areas where high grade refineries are not a viable option. We anticipate that our energy outputs will be lower because of this. By using this data we can see what biofuels will be the best for implementation based on ease of growth/growth rate, ease of refinement, and energy output. This will allow us to choose the best fuel for use in impoverished nations such as sub-saharan Africa and India and make different forms of electricity more accessible in these locations.

Conclusion

Research done for biofuel solution can provide much needed data for areas of arid and semi-arid regions, such as, Sub-Saharan Africa and Asia. The data can bring us closer to providing energy to the 1.8 million that need it (IEA 2014). Our group believes that sugarcane will have the greatest energy yield among lignocellulosic biofuel types, however, sugarcane does not grow properly without a large amount of rain. It is due to this fact that we predict Agave will prove to be a very efficient biofuel type in arid and semi-arid regions, because it does not require a large amount of water. Agave also shows promise because it can be easily cultivated and has produced a large amount of energy in previous studies (Somerville 2010). In impoverished regions, biofuel has proven to be the most acceptable. and effective solution for providing much needed electricity to those areas. Our group strives to provide useful data and information to creating a biofuel solution to impoverished and energy starved locations.