Research Report Evaluating Steer Manure and Sawdust Mixtures as Alternative Fuel for Improved Jiko Stoves for Women in East Africa

Submitted by:
Dylan Chambal, Kholood Aldahlan, Mohammad Alkandari, Xiaoying Tang

60% Design Report

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Dr. Dianne McDonnell

Abstract

Acknowledgements

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1.0 Introduction

1.1 Background

Biomass energy like firewood and charcoal, used for cooking in developing countries causes substantial indoor pollution, which has negatively impacted the health of many individuals [1]. Women in developing countries such as East Africa, are responsible for cooking and collecting wood as fuel. Those women are the target group who have a high exposure rate to particulate matter (PM) from the smoke produced from burning fuels while cooking, leading to a serious health conditions such as respiratory disease [2].

Figure 1: Map of Africa with Highlighted Region of Concern [3]

1.2 Research Goals

The Alternative Cooking Fuel Research Project proposes to test different ratio mixtures of sawdust and Steer manure, half dry and half pyrolyzed briquettes, to examine which mixture of fuel has the lowest PM emissions and the most efficient in boiling water. The main goal of this evaluation is to compare the briquettes testing data to determine the best fuel alternative for women to use in developing countries. Testing will be completed at the Northern Arizona University (NAU) Campus field station, Trotta's farm. In attempt to mimic the indoor conditions East African women are exposed to health issues. A 10'x10' tent will be erected for testing in an area with the most protection from weather factors such as wind.

1.3 Prediction

This evaluation of fuels consists of making mixtures using different ratios of sawdust and steer manure as dry and pyrolyzed briquettes. Table 1 below shows the team's prediction for PM emissions and boiling time for dry and pyrolyzed briquettes for different amounts of sawdust and Steer manure in each mixture.

Table 1: Dry and Pyrolyzed Briquettes Predictions

	PM Emission	**Boiling Time**
Dry Briquettes:	Highest amount	Shorter
Steer Manure > Sawdust		
Sawdust > Steer Manure		
Pyrolyzed Briquettes:	Least amount	Longer
Steer Manure > Sawdust		
Sawdust > Steer Manure		

The team predicts that the dry briquettes will have the highest amount of PM and will boil the water faster than the pyrolyzed briquettes due to the absences of organic matter in the pyrolyzed briquettes.

1.4 Constraints

The major constraint in this project is making the experimental variables such as wind speed, temperature, and pressure consistent. For the equipment used when making briquettes and burning the fuel, the team will be challenged to mimic the conditions in East Africa, which means the team could not use the equipment such as a compressor that ordinary families in East Africa have no access to. The safety problem also must be given attention. The team is supposed to assure that the flame would not ignite surrounding vegetation or the tent.

1.5 Further Research

The further effort of cooking fuel would focus on what types of clean fuel could be used. Though, normal families even in the developed countries would not have the access to the clean fuel. The challenge would be to how to make the families in developing country get access to clean fuel source such as ethanol fuel and electricity.

A study group directed by Karanja designed a type of fuel briquettes made by compressing biomass material. By evaluating the combustion properties, chemical composition, emissions of gases, and fine particulate matter, they found that charcoal dust briquettes bonded with soil was the safest for indoor air quality [4].

2.0 Methods

2.1 Preparing Site

The site of the testing conducted is the NAU Field Station as previously discussed. To use this facility, each team member had to complete the NAU Field Safety Training and NAU Chemical Hygiene training. A site visit and safety orientation was conducted with the NAU Lab Manager, Adam Bringhurst to obtain an understanding of where testing could be done on the site. Following the site visit, Mr. Bringhurst requested the team to complete a fire mitigation plan prior to testing to reduce as much potential risk as possible. The plan developed includes removing all surrounding vegetation from the testing area, digging a small trench around where the tent will be placed, and having an operational fire extinguisher on site.

The team and Mr. Bringhurst completed a walk through of the lab spaces needed within the engineering building, Soils Lab 118 and Environmental Lab 245. These visits focused on the equipment the team will be using such as available ovens, sheets for drying, heat protection, and personal protective equipment.

2.2 Testing Method

The testing method developed for the research conducted was created focusing on keeping the experiment as consistent as possible. The methods were also created to be repeatable in East Africa, focusing mainly on the wealth of the area, the equipment available, and the materials available. Before any testing or prototyping begins, the saw dust and steer manure were dried in an oven for 24 hours at 250 degrees fahrenheit. Having dry materials was essential to the briquette formation because the final briquettes were made by weight, thus all water had to be removed before weighing the materials for mixing. Before mixing can occur, the dried steer manure will be manually grinded in effort to make it a finer material ideal for mixing and weighing it in increments of 0.1g.

2.2.1 Prototyping

For all testing, briquettes in different ratios of steer manure and sawdust were used by dry weight. The ratios tested are as follows:

- 10% Steer Manure and 90% Saw Dust (Sample 1)
- 20% Steer Manure and 80% Saw Dust (Sample 2)
- 30% Steer Manure and 70% Saw Dust (Sample 3)

Before the particulate emissions were measured, a prototyping phase was conducted to establish the size of the briquettes to determine which of the samples boiled water most effectively while meeting the size restraints of the Jiko Stove.The team initial planned and created three other ratios than the ones listed above; however, the mixtures containing a high amount of sawdust were unable to keep their shape after being mixed and dried. The ratios originally tried were:

- 70% Steer Manure and 30% Saw Dust
- 80% Steer Manure and 20% Saw Dust
- 90% Steer Manure and 10% Saw Dust

The briquettes were manually compressed and dried using a cooking sheet in the oven at 250 degrees fahrenheit overnight. The intent of the cooking sheet was to keep the briquettes shape and size consistent by cutting equal squares of briquettes from the sheet. However, the briquettes were not structurally stable enough to be removed from the sheet without crumbling when cut. Therefore, the team decided to form the briquettes as discs by manually compressing the maxed materials between the palms of the hands. Although the exact shape and size of the briquettes were less consistent using this method, the team used 15g of material per briquette, thus making the mass of all the briquettes the same. The same team member compressed the briquettes each time in attempt to keep the process as consistent as possible.

The second parameter tested during prototyping was the amount of binder used in the briquettes. The binder content was tested in attempt to conserve resources because cassava flour may not be readily available in East Africa. To account for this, briquettes of each ratio were made without binder to determine if it would be a viable option to reduce cost and materials used. In previous research done by Abdu Zubairu and Sadiq Abba Gana, 5-7% (by weight) of binder was added into their mixtures of sugarcane bagasse and corn cob, thus the team also tested the samples using 6% binder [5]. The total amount of binder testing of briquettes are as follows:

- Sample 1 with 0% Binder
- Sample 2 with 0% Binder
- Sample 3 with 0% Binder
- Sample 1 with 6% Binder
- Sample 2 with 6% Binder
- Sample 3 with 6% Binder

The final parameter determined from the prototyping phase was the amount of water to be added to the mixtures. The purpose behind this was to determine if steer manure will absorb more water than sawdust or vise versa. Similarly to the binder parameter, a set amount of water needed to be determined before the final testing to keep the final briquette designs as consistent as possible, but had to be tested using all three sample ratios. To determine the water content, the three sample ratios were tested using a total of 50 grams of material. Once the dry weight mixes were completed, 50 mL of water was added to each and thoroughly mixed to allow the water to be absorbed by the materials. This process continued in increments of 10mL of water until the mix couldn’t absorb any additional water and it began to pool at the bottom of the mixing container the sample was in. With the respective amounts of water recorded, the team determined the optimal amount of water to be used for each mix to be used in the final briquettes.

2.2.2 Final Briquettes

Once the size, shape, amount of binder, and amount of water were determined from prototyping, final testing could be completed. The final designed briquettes were formed using the predetermined parameters. The dry materials were mixed in a mixing bowl and then compressed manually and put them in a cooking sheet to be dried. Six different briquettes were tested for their effectiveness to boil water and the amount of particulate matter generated from burning. The briquettes formed and tested are as follows:

- 70% Steer Manure and 30% Saw Dust (Sample 1)
- 80% Steer Manure and 20% Saw Dust (Sample 2)
- 90% Steer Manure and 10% Saw Dust (Sample 3)
- 70% Steer Manure and 30% Saw Dust, Pyrolyzed (Sample 4)
- 80% Steer Manure and 20% Saw Dust, Pyrolyzed (Sample 5)
- 90% Steer Manure and 10% Saw Dust, Pyrolyzed (Sample 6)

2.2.3 Pyrolysis

Half of the samples being tested were pyrolyzed to remove the organic matter from the sample to determine if this technique had an effect on the particulate emissions and ability to boil water. To accomplish this, an oven set to 450 degrees Farenheit was set up with carbon dioxide being pumped into it to ensure the absence of oxygen. The pyrolysis was done indoors and to be in compliance with the NAU's laboratory regulations, a hose was connected to the top of the oven to release the emissions being burned off outside instead of indoors. Once the briquettes were dried in the drying oven with all of the samples, the samples to be pyrolyzed were placed in the pyrolysis oven for 4 hours for the reaction to occur.

2.2.4 Field Testing

For the final briquette testing, the team performed the burning at the designated field station location. Upon arrival to the site, the outdoor pressure and temperature were recorded. All testing was performed on days within 20 degree of each other to keep the results consistent from outside factors. Next, a five gallon bucket of water was filled and kept inside the field station building in attempt to keep the starting temperature of the water the same for all tests. While one team member was completing this, the others set up the tent for testing as well as the Jiko Stove, pot, particulate counter, and thermocouple within the tent. The particulate counter was placed one foot above the top edge of the pot of water for emissions testing. The thermocouple terminals were placed in the water, inside of the combustion, in the wall of the Jiko Stove, between the pot and Jiko Stove, and in the tent away from the assembly to record the temperature inside of the tent. Once set-up was completed, six briquettes were initially placed in the combustion chamber of the Jiko, lit using a micro torch, and allowed to burn for 30 seconds for complete burning to occur. After 30 seconds, 250mL of water was transferred into the pot and placed on the Jiko. Upon placing the pot on the Jiko, the stopwatch was started to obtain the time necessary for boiling as well as the particulate counter to begin recording the emissions produced.

Once the water reached boiling temperature, 98.3 degrees Fahrenheit, the flames were extinguished and the heated water was discarded from the pot. New briquettes were then loaded into the fuel chamber and 250mL of water were obtained from the five gallon bucket. With the new fuel and water, the same process for testing was repeated. For each of the six samples, five different tests were completed, resulting in a total of 30 tests.

2.3 Analysis

After obtaining the data an analysis was done using Microsoft Excel software multi-linear regressions functions to determine which parameter is affecting the emissions the most between time, temperature, and pressure. A line graph was generated to compare how the PM emissions and the temperature of the water changed with time for the dried and pyrolyzed briquettes. The x axis would be time to boil the water and y axis would be the emission of particulate matter. The results of briquettes in different ratio will all be one graph to make a comparison. The group of briquette's testing data, which is the closest to the original point of this graph would be the best choice of briquettes.

2.4 Results

During the burning, Particulate Counter and thermocouple were used to collect the data such as the emission of particulate matter, time to boil the water, temperature and pressure. Those data are used to evaluate the briquettes as shown in table 2 below.

	PM Emission (counts/ m^3)	Time (min)	Temperature (C)	Pressure (mmHg)
Dry Briquette (20% Sawdust-80% Steer Manure)				
Dry Briquette (30% Sawdust-70% Steer Manure)				
Dry Briquette (10% Sawdust-90% Steer Manure)				
Pyrolyzed Briquette				

(20% Sawdust-80% Steer Manure)				
Pyrolyzed Briquette (30% Sawdust-70% Steer Manure)				
Pyrolyzed Briquette (10% Sawdust-90% Steer Manure)				

2.5 Discussion

2.6 Recommendation

2.7 Cost of Implementing the Design

2.8 Statistical Analysis

3.0 Summary of Engineering Work

3.1 Schedule Modification

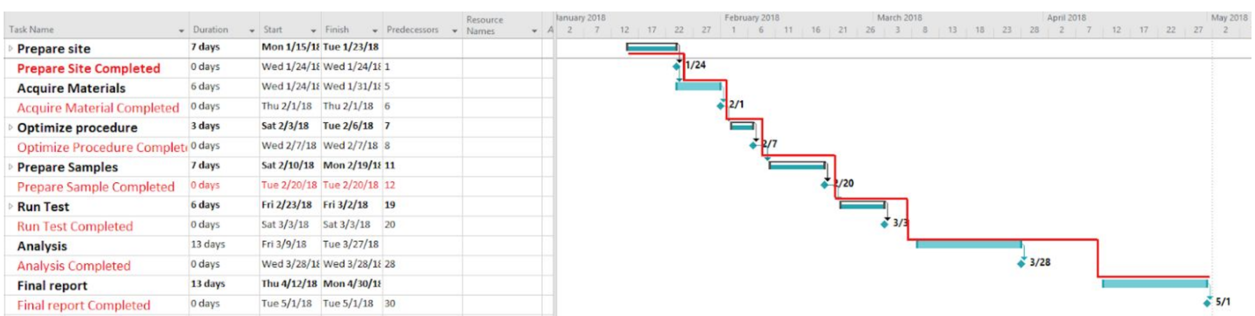

Figure 2: Original Gantt Chart of Project Schedule

3.2 Project Modifications

4.0 Summary of Engineering Costs

Table 2: Original Estimating Cost of Materials and Equipment

	Quantity	Unit	Unit Cost	Total
Sawdust	10	Pounds (lbs)	$2/lbs	$20
Steer Manure	2	Bag (CF)	$1.47/bag	$2.94
10x10 Tent	1	N/A	$109.99	$109.99
			Total Cost	$132.93

5.0 Conclusion

6.0 References

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Appendices