THE UTILIZATION OF SAWDUST FOR BRIQUETTES, SEAWEED (*Eucheuma spinosum*), PAPER AND CORNSTARCH AS BINDING MATERIAL

College of Agriculture and Natural Resources
BOHOL ISLAND STATE UNIVERSITY
Zamora, Bilar, Bohol

KRISTEL JANE A. EVANGELISTA

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A Thesis
Presented to the Faculty of the
College of Agriculture and Natural Resources
BOHOL ISLAND STATE UNIVERSITY
Zamora, Bilar, Bohol

In Partial Fulfillment
of the Requirements for the Degree in
Bachelor of Science in Agricultural and Biosystems Engineering

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Kristel Jane A. Evangelista

July 2022

APPROVAL SHEET

This thesis entitled **"THE UTILIZATION OF SAWDUST FOR BRIQUETTES, SEAWEED, (*Eucheuma spinosum*), PAPER AND CORNSTARCH AS BINDING MATERIAL"**, prepared and submitted by **Kristel Jane A. Evangelista** in partial fulfillment of the requirements for the degree Bachelor of Science in Agricultural and Biosystems Engineering (BSABE) has been examined and recommended for acceptance and approval for oral defense.

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ACKNOWLEDGEMENT

This humble piece of work crafted by the researcher was possibly materialized into what is now through the encouragement, guidance and support of the different persons. With great gratitude and respect, the researcher would like to thank the following:

Dr. Marietta C. Macalolot, OIC- Campus- Director for the final approval of the study;

Noel T. Lomosbog Ph.D., Dean, College of Agriculture and Natural Resources, for his valuable suggestions, support and time spent and approval during the proposal of the study;

Engr. Erwin G. Ludevese, The Thesis Adviser and Chairperson, Department of Agricultural and Biosystem Engineering (DABE), for his fatherly approach and advices, valuable suggestions, advices, patience, constructive criticisms, physical, mental, and moral support during the conduct of the study;

Julian E. Torillo Ph.D., Thesis Adviser, for his guidance, suggestions, advices, encouragement and effort in supervising the study, for burning midnight candles in reading and correcting the manuscript and for interpreting and imparting his knowledge to the researcher;

Engr. Jamel M. Salo, Statistician, for spending his time and effort in analysing and interpreting the data;

Victor M. Balandra Jr., Thesis Expert, for his precious time checking errors in the manuscript and efforts in editing the manuscript;

Special thanks to the family of the researcher; Eleno and Teodosia (Parents) Ian, Rolyn, Ana Mae, Neil Victor, Glace Aiza, Jannine and Janesse (Siblings) Isabelita (Aunt) Andre (Nephew) Telesforo , Isabel (Grandparents) for the supports financially, emotionally and morally throughout the entire conduction of the study, and to my lablab Jeric and his parents Ate Necitas and Kuya Samuel for allowing me to stay in their home and use their wifi while conducting my research study, friends and to significant others for their constant inspirations and encouragements during the conduct of the study.

Above all, to God Almighty who showers his blessings of wisdom, knowledge, for granting the courage, strength and perseverance to the researcher that successfully finishes this research despite of hindrances and difficulties.

Again, no words can explain how the researcher appreciates all those things. Those people whom the researcher failed to mention but contributed a lot in the success of the study, a grand salute to all of you.

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ABSTRACT

The main objective of this study was to produced briquettes from abundant biomass wastes in different level of binders using a locally fabricated briquette molder primarily design for cottage industry or small-scale level of production as alternative source of energy. The study was conducted at Bohol Island State University- Bilar Campus, Zamora, Bilar, Bohol. Specifically, it aimed to determine the density, combustion rate and ash content of the briquettes. The experiment was laid out in Complete Randomized Design (CRD) with nine (9) treatments and three (3) replications in each treatment. The amount of binders as additive that was used in different treatments were 198.15 cm^3 for 10%, 396.30 cm^3 for 20%, and 594.45 cm^3 for 30%, calculated based on the total volume of the three replications accounting 1,981.50 cm^3 allotted for the amount of sawdust. Based on the results of the evaluation, the binders that were used in the study, which were paper, cornstarch, and seaweed, as binding substances to sawdust for making a briquette. However, briquettes with the right amount of binding agent are better energy fuel. The observation of the study was made in each treatment in which the treatment produced the best results and performance, as determined by the list of notes and documentation of the study. T6 Cornstarch (0.52%) got the highest total mean in terms of density, T3 of Paper in ash content got (3.39%), highest mean in terms of its combustion rate were T3 of Paper (0.21%). The test results also showed that when (T1) paper obtained the lowest mean, with a density of about (0.1%), (T4) ash content obtained the lowest mean of about (1.86%). Statistically, it was found out that the briquettes using different percentage level of binder was affected in terms of density, ash content and combustion rate of briquettes. In addition, there was significant differences were observed on the performance in terms of binder in all parameters. Based on the result of the study, the researcher formulated the following recommendations: conduct the similar study in order to validate the results of the study. It is better to use (T6) cornstarch (10%), since it was found out in the study that the T4 of cornstarch showed better performance among treatments on the performance of briquettes.

Chapter 1

THE PROBLEM AND ITS SCOPE

Rationale

Sawdust and other by-products generated in forest industries are often considered a problem in work areas and woodlands, since disposal can create wildfires during periods of intense heat, generating dust in the air, and block areas in production facilities. Biomass, particularly agricultural residues seem to be one of the most promising energy resources for developing countries (Wilaipon, 2008). Rural households and minority of urban dwellers depend solely on fuel woods (charcoal, firewood and sawdust) as their primary sources of energy for the past decades (Onuegbu et al., 2010). Global warming has become an international concern. Global warming is caused by greenhouse gasses which carbon dioxide is among the major contributors. It was shown that increased emissions of CO2 have been drastically reduced owing to the fact that the rate of deforestation is higher than the afforestation effort in the country. These by-products may appear in the form of sawdust, bark, or chips, and are considered biomass with ideal potential for thermal energy production through briquette densification with applications in generators of steam, boilers, and turbines. Briquettes are solid biofuels made with or without additives from biomass densification, and with specific properties derived from the proportion of material/additive, pressure, temperature, and time utilized in their manufacture as well as the typical physicochemical properties of biomass (Gwenzi, 2020). The production of briquettes promotes the cleanliness and care of the environment because they are made from waste, and expanded production promotes local economic development, reducing energy dependence on fossil fuels (Díaz-Artigas et al., 2020). The particle size of sawdust from which briquettes are manufactured significantly affects their physical and mechanical properties as well as combustion characteristics (Chaloupková et al., 2018). Additionally, processing parameters such as moisture content of the sawdust, pressing temperature, and compacting pressure are factors that have a significant impact on briquette quality and strength. Generally, briquettes with lower moisture content are of lower quality. However, it has been determined in some studies that excessively low moisture content degrades the mechanical properties of briquettes (Brožek, 2021).

According to Kers et al. (2010) briquettes manufactured at lower pressures (30 to 60 MPa) fall to pieces easily, but at higher pressures (150 to 250 MPa), are consistent and compact. Additionally, increasing the compaction temperature causes plasticizing of the particles and activation of natural binders in the material, increasing the strength of the briquettes (Rizki et al., 2010). For this reason, making briquettes with the right proportion of different particle sizes is important, because briquettes obtained with irregular particle sizes and shapes suffer some disadvantages (Tumuluru, 2020). Consequently, it is recommended to use sawdust mixtures with different proportions of particle sizes and evaluate their biomass characteristics in terms of physical, mechanical, and energy properties to produce briquettes with consistent physical properties (size, shape, and density) that facilitate the feeding of furnaces and boilers.

LITERATURE BACKGROUND

Legal Basis

On January 26,2001, the Republic act (RA) 9003 otherwise known as the Philippine Ecological Solid Waste Management Act 2000 was signed into law. This law provides for the necessary institutional support mechanisms and instructs all local government units (LGUs) to establish an ecological solid waste management program within their jurisdiction. Triggered by problems emanating from the ubiquitously improper waste disposal, the Philippine Congress envisioned RA 9003 to provide integrated solutions suited for a developing country at the time while recognizing future opportunities for policy enhancements through the creation of a multi- agency (National Solid Waste Management Framework, 2004). The Philippine government agencies such as the Department of Energy (DOE), Department of Environment and Natural Resources (DENR), Department of Science and Technology (DOST) and other entities are currently promoting the development and widespread use of biomass resources through pilot testing, demonstration and commercial use of technologies such as biomass charcoal briquetting. The production and use of briquettes from abandoned resources like biomass and urban wastes are growing due to increase in fuel prices. Converting them, among others into briquettes, gives an opportunity to dispose of wastes and at the same time cleans the community of unwanted wastes, conserves the forest and reduces greenhouse gas (GHG) emissions and provides alternative/additional livelihood to the urban and rural poor communities (Banconguis, 2007).The process of briquetting involves the compression of a material into a solid product of any convenient shape that can be utilized as fuel just like the use of wood or charcoal.

Related Studies

Several studies exist regarding the use of compacted biomass as an energy source. Many of these studies are focused on comparing the economical-environmental impact of compacted biomass as a substitute for traditional fuel materials with emphasis on the effect of greenhouse gases, in which the value of biomass briquettes highlighted as a cost-effective option to reduce CO and CO_2 and meet the millennium development objectives according to the United Nations. The biomass briquettes and pellets are mainly produced from agricultural waste material, livestock, industrial/urban waste or a mixture thereof. However, the material mostly commonly used is a typical waste from the timber industry: sawdust. Compared to agricultural raw material, sawdust has a lower ash content, lower risks of corrosion and dirtying, requires high temperatures of ash deformation (>1200ºC) and also requires no additives or thickeners to increase production costs since humidity and the actual wood lignin work as natural adhesive (Jenkins et al., 1998; Nikolaisen et al., 2002; Olorunnisola, 2007). The usage comparative between sawdust and other agricultural waste with regard to the main feature and advantage of these material: the low percentage of ash content in dry material and the low percentage of sulfides and chlorides in ash after the combustion. To upgrade the specific heating value and combustibility of the briquette, certain additives like starch, gum arabica, soil, animal dung or waste, charcoal, wood, paper waste and coal are added in very fine form. About 10-20% burnt fines can be employed in briquetting without impairing their quality (Rousset et al., 2011). The density also increases with binder ratios and is influenced by type and amount of binder. They can improve the mechanical strength and the energy content like calcium carbonate, sawdust, ash chipping, nut shell, rice shell, husks of grape-vine and cuttings of grape-vine etc. Lignin of such additives acts as stabilizer of cellulose molecules in the cell wall. The more lignin the material contains the more of it can be released to produce briquettes with higher quality. The briquettes with additives are compact, no crumbling, no cracking in drying phase, and it is possible to cut and engrave them. Density is an important parameter to characterize the briquetting process. Briquettes with higher density have a longer burning time (Lehtikangas, 2001). Higher density leads to higher energy/volume ratio which is desirable in terms of transportation, storage and handling.

Composite materials derived from biodegradable polymers, such as polysaccharides, proteins, and lipids, are highly sought by the current research community due to their distinctive features when compared to synthetic polymer materials, *i.e.*, their nontoxicity, biodegradability, and abundant availability (Vieira et al., 2011). Starch is one of the most common green plant-originated polysaccharide material. Starch is widely utilized in both food and non-food applications, such as edible packaging, adhesive materials, textile sizing, and cosmetic products, due to its easily obtainable, abundantly available, cheap, biodegradable, and biocompatible qualities (Lafargue et al., 2007). Starch is essentially comprised of linear amylose and branched amylopectin. The relative amount of both of these macromolecular components in starch is dependent upon the source of the plant. It is known that cornstarch is composed of 30% amylose and 70% amylopectin. A starch-based polymer known as thermoplastic starch (TPS) can be prepared by heating starch granules in the presence of a plasticizer, commonly water or glycerol. Although starch-based films are transparent, odorless, and oxygen-impermeable, the fact that they are brittle and hydrophilic in nature has restricted their use in many applications (Wu and Zhang 2001). An effective way to overcome these drawbacks is by mixing the films with other natural polymers that have compatible interactions with starch (Poeloengasih et al., 2017).

To fulfill the surging demand for natural and renewable materials, biobased polymers from the marine environment, *e.g.*, seaweed, have been receiving plenty of attention recently. Seaweed could be a suitable candidate as a biodegradable polymer because it is made up of bountiful polysaccharides, providing a large array of functional properties such as its gelling ability, recyclability, thermal stability, and effectiveness against health risk (Thakur et al., 2017). Seaweed, one of the marine resources has a high economic value but easily damaged in fresh condition. Drying is a process to reduced water content from substances by using thermal energy to obtained dry product (Wilhelm et al., 2004). The benefit of the drying process is decreased water activity for inhibited growth microbe, maintaining a quality of product and reduced storage volume (Shishir and Chen, 2017). The main problem of drying method was used a high temperature for the drying process. Seaweed contains polysaccharides, minerals, vitamins and substance of bioactive such as proteins, lipids, and polyphenols (Chandini et al., 2008; Chan and Matanjun, 2017). However, the organic component in seaweed will be damaged if exposed to high temperature and a long period of drying time (Galaz et al., 2017). The high temperature in the drying process will be damaged a lot of nutrition (crude lipid content and amino acid), decreased the physical properties, rehydration and antioxidant activity of seaweed (Tello-Ireland et al., 2011). The other problem in the drying method is used energy wastefully (Djaeni and Boxtel, 2009). The amount of energy can be reduced if the energy efficiency of the drying process increased. At present, the ranges of energy efficiency on the drying system are 30-60%, which means that the energy must be provided 2-3 times from the really needed.

THE PROBLEM

Statement of the Problem

The goal of this study was to create briquettes from abundant biomass and urban waste with varying levels of binders using a locally fabricated briquette molder primarily designed for household or small-scale production as an alternative energy source. Specifically, this study aimed to determine the effects of the seaweed, paper, and cornstarch as binding material for the briquettes in the different level in terms of density, combustion or burning rate and ash content.

Null Hypothesis

There is no significant difference among briquettes produced in seaweed, paper and cornstarch as binding material for the briquettes in different level when analyze in terms of density, combustion or burning rate and ash content.

Significance of the Study

The results of the study are greatly useful to the following.

Community. This study will help to the community to lessen the people who have no work. Applying briquettes as replacement of fuel for cooking.

Agricultural Engineers – This study will aid engineers in creating inventive briquette machines that would make the process of generating briquettes simpler and faster.

Entrepreneurs. This study will help the entrepreneurs by giving ideas in creating and discovering a product. They can use this as their tool to start a business that would help them to sustain their daily needs.

Economic Impact. The success of the study would be helpful to the community as it would give additional income.

Environmental Impact. This study would minimize the agricultural waste disposal in the country.

Future Researchers. This study will serve as a reference to the future researchers whose aim to conduct an experimental study related to the utilization of sawdust as fine aggregate in concrete mixture for brick production.

Researchers. The research will help the researcher more knowledgeable and able to apply the learning gathered in conducting the study.

Social Impact. This result of this study would encourage the community to utilize sawdust rather than disposed and burnt it.

Scope and Limitation of the Study

This study focused on the utilization of sawdust mixtures to produce briquettes in different binding materials such as seaweed, paper, and cornstarch as alternative sources of energy from abundant biomass and urban wastes using a locally fabricated briquette molder primarily designed for household or small-scale level of production as an alternative source of energy.

RESEARCH METHODOLOGY

Research Design

This study was conducted through experimental research using Complete Randomize Design (CRD) in Figure 1. The treatments were evaluated are the following:

Research Environment

The study was conducted at Bohol Island State University-Bilar Campus, Zamora, Bilar, Bohol and for compacting using a manual briquette molder and oven drying of the materials was done in the Auto Shop Civil Technology Building.

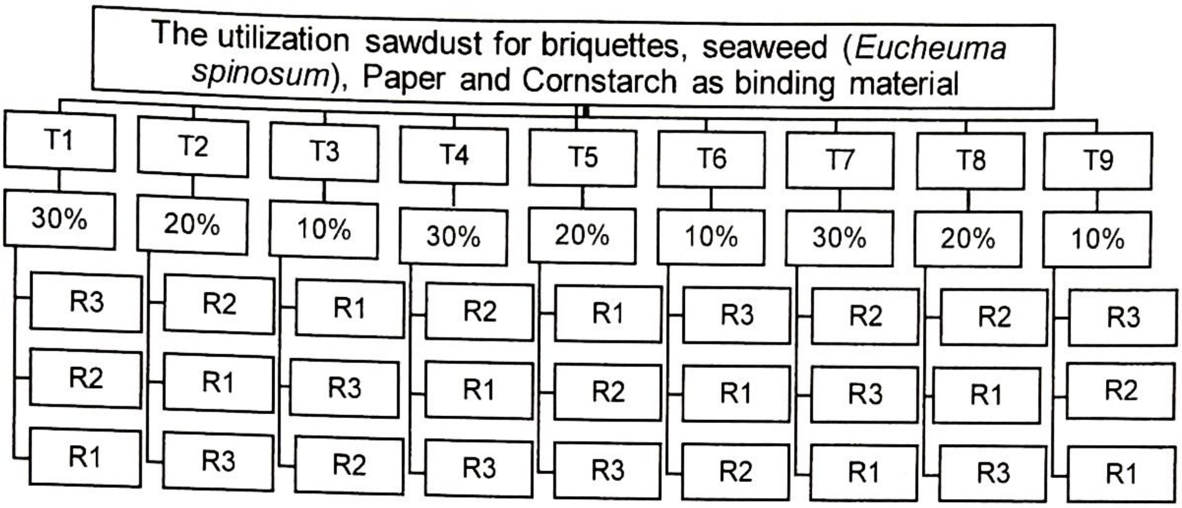


Figure 1. Experimental Layout in Complete Randomized Design (CRD) of the study

Research Material

The materials that would be used in the study was sawdust. Paper, seaweed, and cornstarch as the binding materials. Basin, manual briquette molder, C-clamp, and additional tools such as cameras for photo documentation, notebook, pen, digital scale, ruler, sieve, and stopwatch.

Research Procedure

A simple briquette molder was developed to produce briquettes at the household level. The briquette molder was constructed using GI pipe. It was fabricated at automotive shop laboratory with a size of 5cm diameter and 15 cm height making it easier for adoption of a local community decide on small-scale production of briquettes.

Preparation of Materials

Presented in Figure 2, there are four materials needed for this study, namely, paper, cornstarch, seaweed, and sawdust. The papers that were used were a waste combination of mostly computer printouts and corrugated paper (cartons) that was soaked and pulped for 2 to 3 days. Pulping was done to disentangle the fibers and the excess water from the pulped papers was squeezed using a plastic net bag. The biomass waste, on the other hand, was made available in sacks. The coconut sawdust was sieved to a smaller size. Cornstarch and seaweed (guso) were boiled in a liter of water to produce a gelatinous material. After cooling the binder, this was mixed with the materials (sawdust and its combination) with the corresponding percentage, which is 10%, 20% and 30% by hand until a homogeneous state was attained.

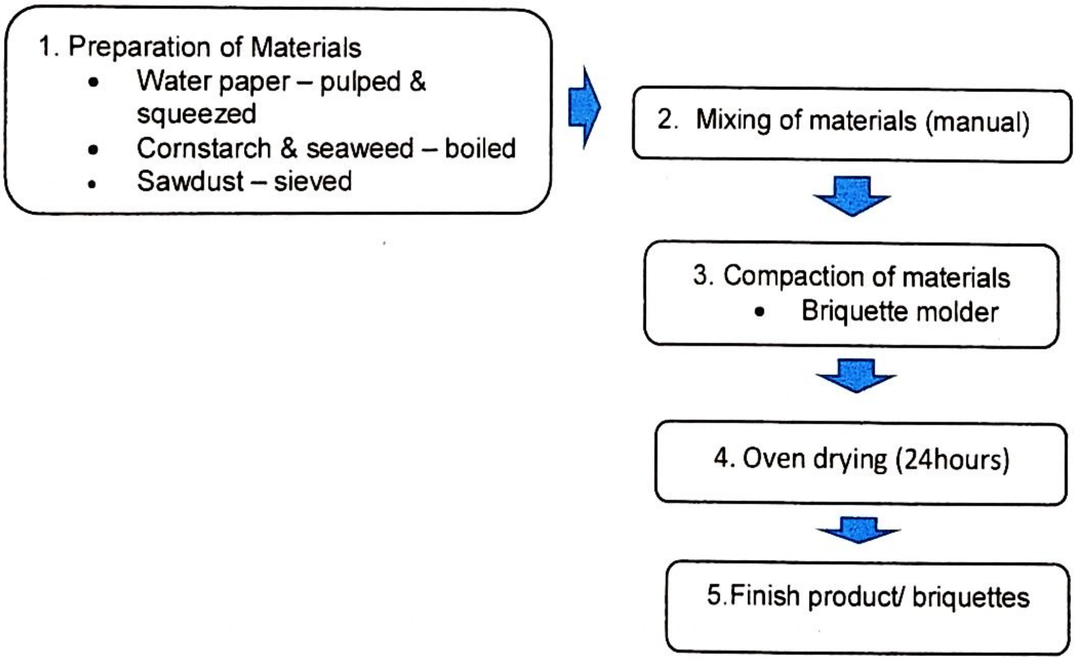


Figure 2. Flow of procedure for the production of briquette

Production of Briquettes

Three different types of briquettes with different levels of binders were produced using urban wastes. Presented in Table 1 are the different mixing proportions of the test materials. Treatments 1 to 3 were produced using 10%, 20%, and 30% paper that was pulped prior to briquetting. Treatments 4 to 6, on the other hand, were made of 10%, 20%, and 30% of cornstarch, and treatments 7 to 9 were also used with 10%, 20%, and 30% of seaweed as binding materials. All the treatment was mixed with 1,981.5 cm^3 of sawdust. Each treatment was replicated on at least three specimens.

Table 1

Briquette Component

Treatment	% / cm^3			Sawdust (cm^3)
	10	20	30	
Paper	198.15	396.3	594.45	1,981.50
Cornstarch	198.15	396.3	594.45	1,981.50
Seaweed	198.15	396.3	594.45	1,981.50

The three different binders with their respective levels were added with a liter of water and cooked until a homogeneous mixture was attained. The binders were placed into each basin and mixed with 1,981.5 cm^3 of sawdust. The mixtures with their different levels of binder were placed in their molders for compaction at a 10 cm height as recommended. The materials were compacted by closing and pressing down using the C-clamp until the materials were completely compact.

After compaction, the movable top was lifted to take out the briquettes produced. The briquettes were placed on trays and oven dried for 24 hours. Once dried, the fuel was weighed.

Data processing and analysis

The following parameters were analyzed for this study:

Density. Density is defined as mass per unit volume of a sample material (kg/m^3). Meter balance would be used to determine the mass of each sample. For accurate reading, there would be three replicates for each mixing ratio the volume would be estimate from the dimensions obtain (height and radius).

Density can also be calculated using this formula:

$$\text{Density} = \frac{M}{V} \ (g/cm^3)$$

where:

M= Mass of briquette (g),

V= Volume of briquette (cm^3)

Combustion or Burning Rate. The burning rate is the ratio of the mass of the fuel (in grams) burned to the total time (in minute) taken. This would be done by burning briquettes until it is almost consumed. Stopwatch would be use on determining how long the briquettes burned.

Ash Content. Ash content would be measured by weighing the ash content of the briquettes after it was totally burned and divided by the initial weight of the briquettes multiplied by 100%.

Ash Content can be calculated using this formula:

$$\text{Percentage ash content} = \frac{D}{B} \times 100$$

where:

D= Weight of ash

B= weight of dried sample (g)

Statistical Treatment

Since the study would compare the significant difference between the means of nine treatments (Paper 30%, 20%, 10%, Cornstarch 30%, 20%, 10%, and Seaweed 30%, 20%, 10%), the researcher would use the Analysis of Variance (ANOVA). The ANOVA test allows a comparison of more than two groups at the same time to determine whether there was a significant difference among treatments based on the density, combustion rate, and ash content of briquettes in different levels of binding substance. A post-hoc test using Fisher's Least Test Difference (LSD) was conducted to test which of the parameters showed significant.

DEFINITION OF TERMS

The following definition of terms is provided for a better understanding of the study:

Binders. Binders are substances, organic or inorganic, natural or synthetic, that can hold (bind) two things or something together. Two types are combustible and noncombustible binders.

Biomass briquettes. Biomass briquette is made from agricultural wastes. It is a renewable source of energy. Lignin and cellulose are the two major compounds of biomass.

Charcoal briquettes. Charcoal briquette is a common type of briquette made by compressing pulverized wood charcoal with a binder. However, other activator such as sodium nitrate is added as an accelerant.

Solid waste management. It is a term that is used to refer to the process of collecting and treating solid wastes.

Sawdust. refers to a by-product of cutting, grinding, drilling, sanding, or otherwise pulverizing wood with a saw or other tool; it is composed of fine particles of wood. It is also the byproduct of certain animals, birds and insects which live in wood, such as the woodpecker and carpenter ant.

Chapter 2

PRESENTATION, ANALYSIS AND INTERPRETATION OF DATA

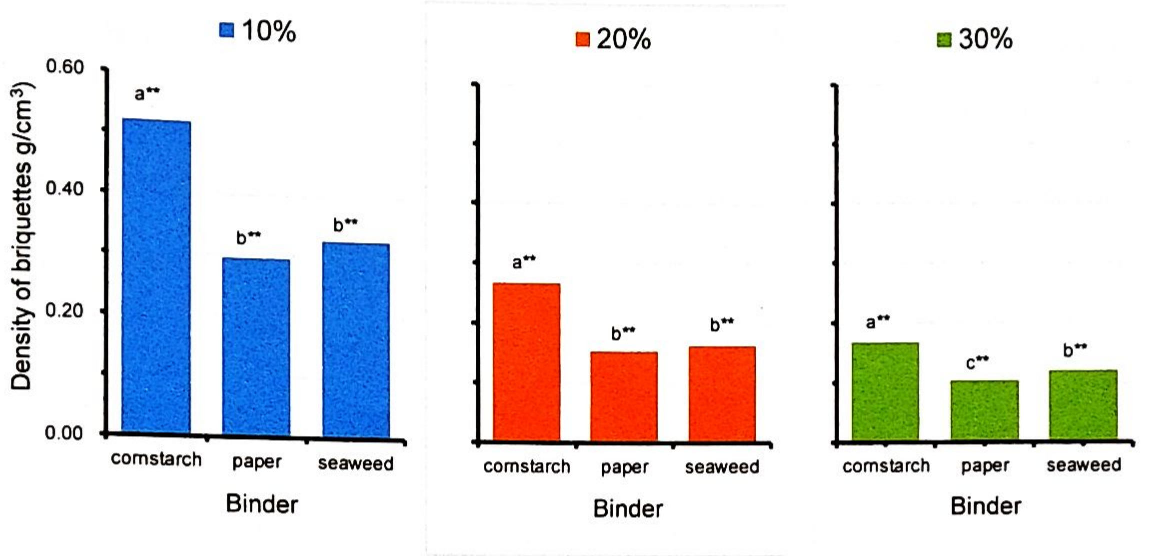
This chapter deals with the presentation, analysis and interpretation of the gathered data on the utilizing of sawdust mixtures for briquettes, seaweed (*Eucheuma spinosum*), paper and cornstarch as binding materials.

The briquettes produced were analyzed in terms of (density, combustion or burning rate and ash content). The gathered data were recorded and statistically analyzed as shown.

Density of Briquettes

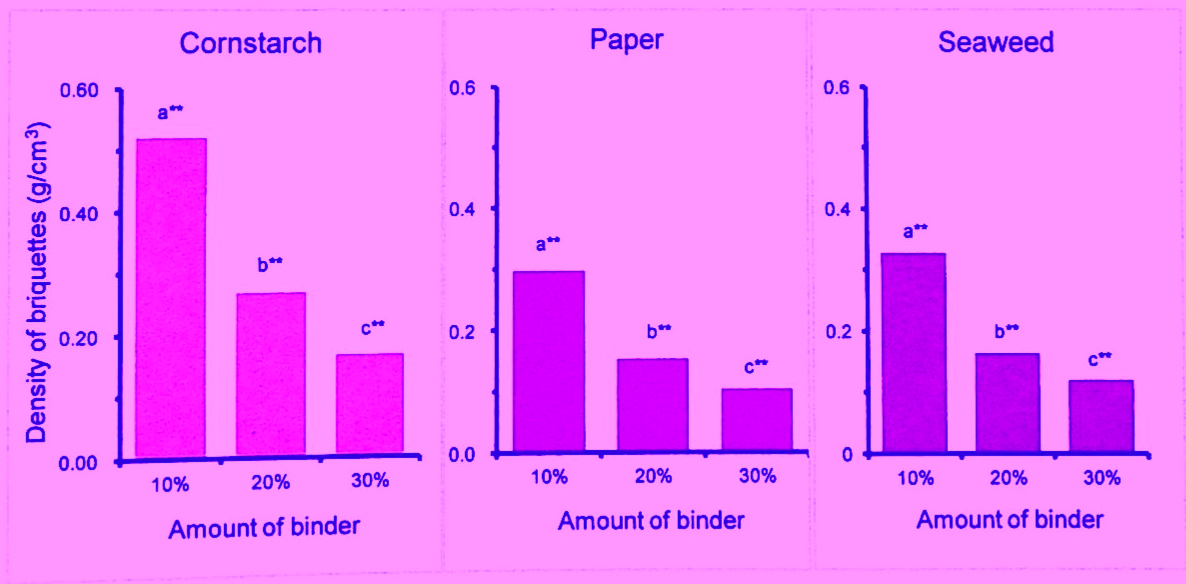
The analysis of the variance in briquette density made with binders is shown in (Table 3, Appendix D). The analysis of variance reveals a significant difference in binder and level at a confidence level of 1%. The density of briquettes in the binder was analyzed using the Summary of Post-hoc Test utilizing Fisher's Least Significant Difference (LSD), shown in (Appendix E, Tables 6 and 7). Figures 3 and 4 show that the 10% (T6) of cornstarch has significantly higher in binders of any treatment, at about 0.52 %. On the other hand, shows that at level 10 of paper (T3), the lowest mean density of around 0.1 %.

Figure 4 showed that binder, on the other hand, showed that the amount of sawdust that was compressed to molder increased as the amount of binder added decreased.



**Significant difference at p≤0.01 level of confidence

Figure 3. Fisher's Least Significant Difference (LSD) test on the density of briquettes according to the percentage level



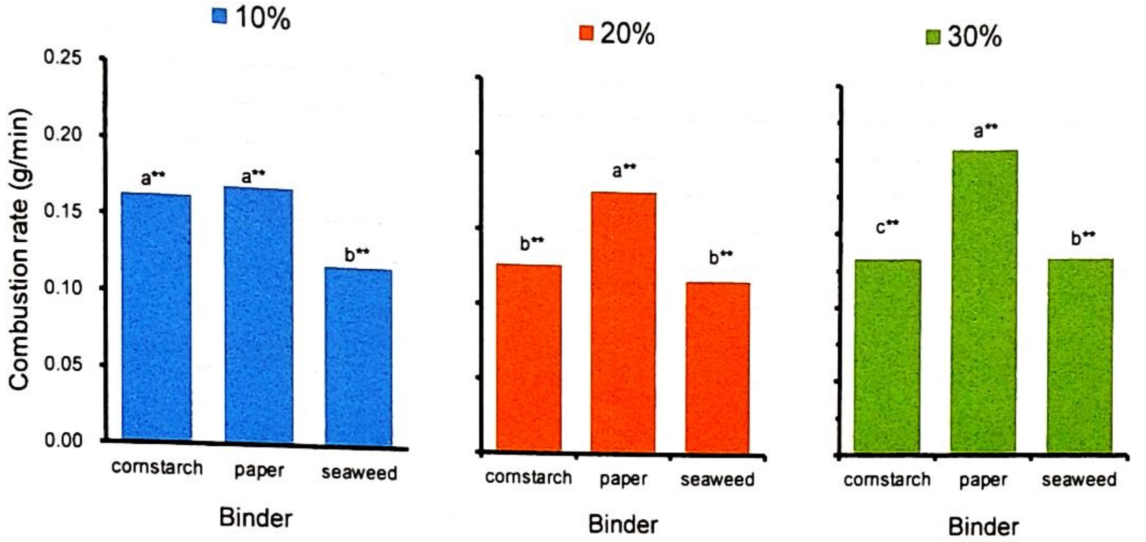
**Significant difference at p≤0.01 level of confidence

Figure 4. Fisher's Least Significant Difference (LSD) test on the density of briquettes according to the type of binder

This means that sawdust cannot effectively absorb paper and seaweed since it is similar to a fluid gel, whereas cornstarch is quite thick and can be controlled to increase the density of the briquette. High-density briquettes are more compact and tend to have a longer burning time and release more heat, according to Lehtikangas (2001).

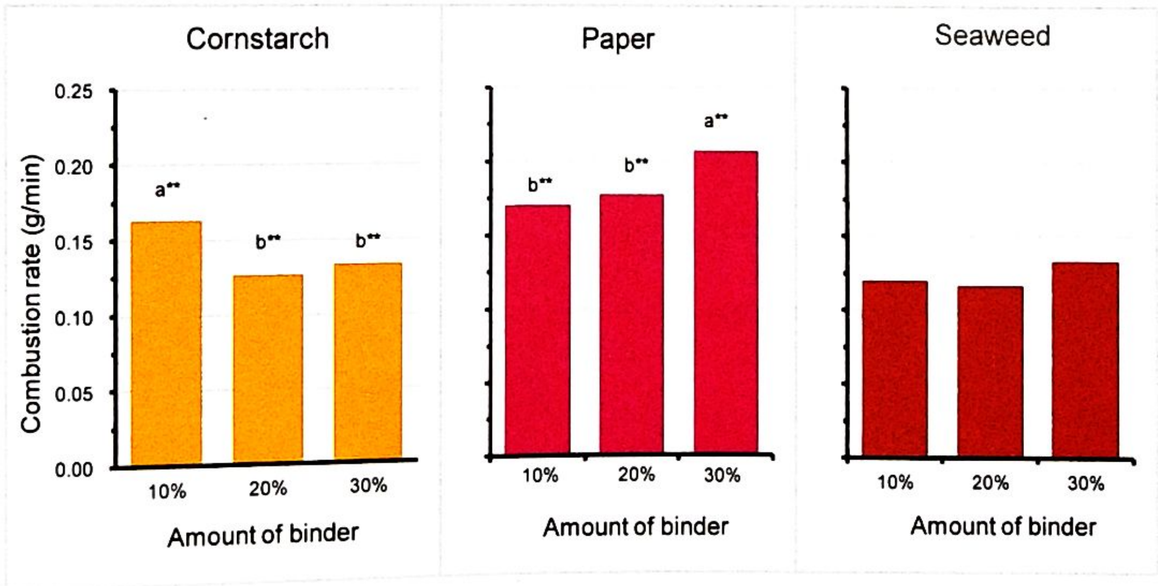
Combustion Rate

The analysis of variation for the briquettes combustion rate is presented in (Table 4, Appendix D). The results of the analysis of variance showed that the difference in binder was very significant at a 1% level of confidence. To determine which change in the combustion rate of briquettes produced significant findings, a post-hoc test utilizing Fisher's Least Significant Difference (LSD), depicted in Figures 5 and 6, was carried out. The results show that the combustion rate of briquettes made with (T1) 30% paper is at about 0.21% significantly higher than that of briquettes made with cornstarch and seaweed and T4 (30% cornstarch) had a significant low of around 0.1 %. As the percentage level of the binder rises, paper and seaweed become constantly higher while cornstarch continues to dropped. This explains why dried seaweed and paper grow lighter as they become drier. Briquettes burn more easily when they are less thick. Because of this, briquettes made of paper and seaweed burn the fastest. Additionally, as the briquettes are oven dried, they become light in weight and burn more quickly, paper and seaweed are not suggested for compact and extended usage. The lighter-colored briquettes are those that are less dense (not compact). Darker-colored briquettes are heavier or burn longer than lighter-colored briquettes (compact). This provides compelling evidence that the quantity of binder utilized can have a considerable impact on how quickly briquettes burn. (Shown in Appendix E, Tables 8 and 9).



**Significant difference at p≤0.01 level of confidence

Figure 5. Fisher's Least Significant Difference (LSD) test on the combustion rate of briquettes according to the percentage level



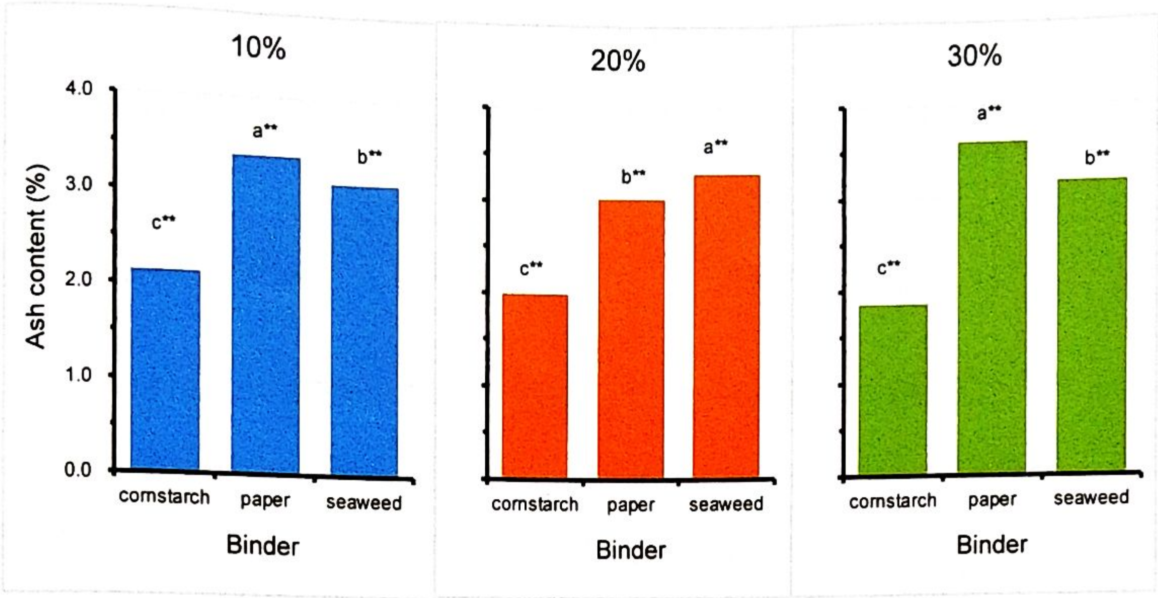
*Significant difference at p≤0.01 level of confidence
Mean with no letter designations are not significantly different

Figure 6. Fisher's Least Significant Difference (LSD) test on the combustion rate of briquettes according to the type of binder

Ash Content of Briquettes

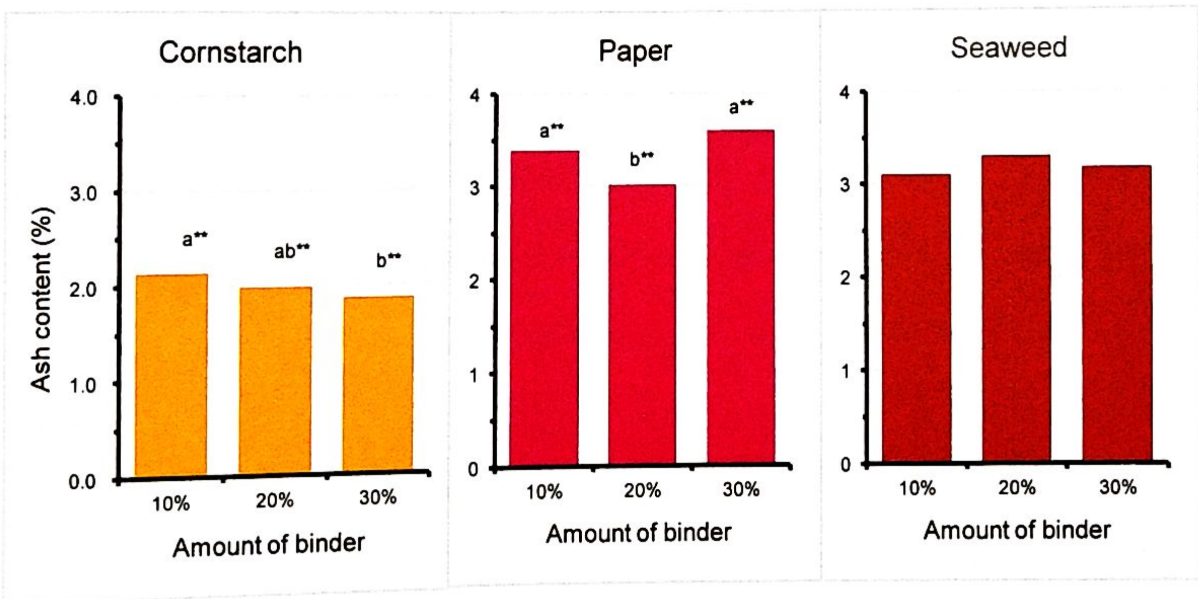
The analysis of the variation in briquette ash content is presented in (Table 5, Appendix D). The results of the analysis of variance showed that the difference in binder was significant at a 1% level of confidence. The ash content of briquettes variation was tested for significance using a post-hoc test utilizing Fisher's Least Significant Difference (LSD), as illustrated in Figures 7 and 8. Compared to cornstarch and seaweed, T1 (30 percent paper) has a significantly higher in ash content (3.39 %). Additionally, the ash content of Figure 5, (T4) 30% cornstarch, was significantly low of about 1.86%.

According to Figures 7 and 8, paper generated the most produced ash, whereas cornstarch generated the least. As was also noted in the study, paper burned in briquettes the quickest and for the shortest amount of time because, when dry, it was less compact than seaweed and, unlike cornstarch, remained quite compact and created less ash than other materials. This means high ash volume is a disadvantage. The higher ash content, the more impurities there are in briquette. The low ash content benefits improved combustion and reduced ash production (Grover and Mishra, 1996).



**Significant difference at p≤0.01 level of confidence

Figure 7. Fisher's Least Significant Difference (LSD) Test on the ash content of briquettes according to the percentage level



**Significant difference at p≤0.01 level of confidence
Mean with no letter designations are not significantly different

Figure 8. Fisher's Least Significant Difference (LSD) Test on the ash content of briquettes according to the type of binder

Chapter 3

SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Summary of Findings

According to statistics, the density, ash content, and combustion rate of the binding material had the only impact on how well the briquettes performed. Significant difference at 1% level of confidence was found in the binder in terms of, density, ash content. It could be inferred that the amounts of binder used have significant influence on the performance of the briquettes.

Conclusions

Based on the findings, the binding agents used in the study are suited for producing briquettes. However, this study also assesses which binder and percentage level among the applied treatments stand out. The data collected in the study revealed which treatment performed the best and met all the necessary criteria. T6 with 10% cornstarch obtained the highest overall mean density, with a value of 0.5%. T1 (30% paper) has the lowest combustion rate of 0.21%, while T3 (10% paper) has the highest mean ash percentage of 3.39%. T4 had the lowest mean of combustion rate and ash content at about 0.10% and 1.86%, respectively. The test results also showed that when T3 with the 10% paper was used, it got the lowest mean density of 0.1%.

However, a different binding substance and level that is appropriate for briquettes and better as a fuel energy performed well in the T6 (10 percent cornstarch). The analysis of the results revealed that the briquettes displayed acceptable values for all the evaluation criteria. T6 is more compact and better for combustion and ash content. High density and low ash content are better in briquettes.

Recommendations

The researcher offered the following advice in light of the findings of the analysis and test-related observations:

1.To verify the study's findings, carry out a comparable investigation.

2. To use T6 (10% cornstarch) is recommended in briquettes for better compact, durable, low ash content and combustion rate.

3. To use an innovative design briquette molder for good compaction of briquettes.

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APPENDICES

APPENDIX A

LETTER – REQUEST

Republic of the Philippines Bohol Island State University BILAR Campus, Zamora, Bilar, Bohol

Dr. Noel T. Lomosbog
CANR DEAN
BISU Bilar Campus
Zamora, Bilar, Bohol

Sir:

Greetings!

As a requirement for graduation, I am currently conducting our thesis entitled **"THE UTILIZATION OF SAWDUST FOR BRIQUETTES, SEAWEED (Eucheuma spinosum), PAPER AND CORNSTARCH AS BINDING MATERIAL".** To date, I have my design ready for fabrication.

In this connection, I would like to request from your good office to allow me to use the AUTO SHOP as a venue for OVEN DRYING, during weekdays. I am hoping for your approval with this request. Your usual support is a great help to realize my dream.

Thank you so much and GOD bless.

Respectfully yours,

KRISTEL JANE A. EVANGELISTA
BSABE Student

Noted by;

ENGR.ERWIN G. LUDEVESE
DABE CHAIRPERSON

SEVERINO B. SALERA JR., Ph.D
AUTO SHOP INCHARGE

JULIAN E. TORILLO JR., Ph. D
THESIS ADVISER

Approved by:

DR. NOEL T. LOMOSBOG
CANR DEAN

Appendix B

LETTER- REQUEST

Republic of the Philippines
BOHOL ISLAND STATE UNIVERSITY
College of Agriculture and Natural Resources
Zamora, Bilar, Bohol

MARIETTA C. MACALOLOT, PhD
Campus Director
Bohol Island State University- Bilar Campus

Greetings!

The undersigned from the Department of Agricultural and Biosystems Engineering taking up Bachelor of Science in Agricultural and Biosystems Engineering would like to ask permission to conduct the study entitled "**UTILIZING SAWDUST MIXTURES FOR BRIQUTTES, SEAWEED *(Eucheuma spinosum)*, PAPER AND CORNSTARCH AS BINDING MATERIAL"** as requirements in the subject Thesis 3.

In the line with this, the undersigned would do experimental research for conducting the study. The result gathered will be treated with outmost confidentiality.

We hope to receive positive response from you.

Thank you so much and God Bless!

Sincerely yours,

Kristel Jane A. Evangelista,
BSABE Student

Noted by:

(Sgd) JULIAN E. TORILLO,
Research Adviser

Recommending Approval:

(Sgd) NOEL T. LUMOSBOG, PhD
Dean, CANR

(Sgd) MARIETTA C.MACALOLOT
Campus Director

Appendix C

RAW DATA COLLECTED DURING OPERATION

Table 2.

Raw Data collected during operation

Treatment	Binder	Level	Replication	DENSITY	ASH CONTENT	COMBUSTION RATE
1	Paper	30	1	0.11	3.8	0.19
	Paper	30	2	0.1	3.3	0.2
	Paper	30	3	0.1	3.7	0.23
2	Paper	20	1	0.17	3	0.17
	Paper	20	2	0.15	3.04	0.19
	Paper	20	3	0.14	3.01	0.17
3	Paper	10	1	0.32	3.43	0.17
	Paper	10	2	0.31	3.36	0.2
	Paper	10	3	0.26	3.38	0.14
4	Cornstarch	30	1	0.17	1.89	0.09
	Cornstarch	30	2	0.17	1.83	0.1
	Cornstarch	30	3	0.16	1.85	0.11
5	Cornstarch	20	1	0.26	1.98	0.12
	Cornstarch	20	2	0.27	2.02	0.15
	Cornstarch	20	3	0.27	1.95	0.11
6	Cornstarch	10	1	0.54	2.18	0.16
	Cornstarch	10	2	0.53	2.12	0.15
	Cornstarch	10	3	0.49	2.1	0.18
7	Seaweeds	30	1	0.12	3.17	0.13
	Seaweeds	30	2	0.12	3.23	0.12
	Seaweeds	30	3	0.12	3.12	0.15
8	Seaweeds	20	1	0.18	3.3	0.12
	Seaweeds	20	2	0.14	3.6	0.11
	Seaweeds	20	3	0.17	3	0.12
9	Seaweeds	10	1	0.33	3.11	0.12
	Seaweeds	10	2	0.32	3.07	0.13
	Seaweeds	10	3	0.33	3.14	0.11

Appendix D

Result on ANALYSIS OF VARIANCE (ANOVA)

Table 3

Analysis on the Density of Briquettes with in Binders

Source of Variation	Type II Sum of Square	DF	Mean Square	F Value	Pr (> F)
Binder	0.0937	2	0.0468	166.43**	0.0000
Level	0.3062	2	0.1531	543.84*	0.0000
Binder: Level	0.0245	4	0.0061	21.8	0.0000
Error	0.0051	18	0.0003		
Total	0.4295	26			

**= significant at 1% level of confidence

Table 4

Analysis on the Combustion Rate of Briquettes

Source of Variation	Type II Sum of Square	DF	Mean Square	F Value	Pr (> F)
Binder	0.0937	2	0.0468	166.43**	0.0000
Level	0.3062	2	0.1531	543.84*	0. 3965
Binder: Level	0.0245	4	0.0061	21.8	0. 0013
Error	0.0051	18	0.0003		
Total	0.4295	26			

** binder = significant at 1% level of confidence
Ns level *= not significant at 5% level of confidence

Table 5

Analysis on the Ash Content of Briquettes

Source	DF	Sum of Square	Mean Square	F Value	Pr (>F)
Binder	2	9.8193	4.9096	260.08**	0.0000
Level	2	0.0726	0.0363	1.92*	0.1750
Binder: Level	4	0.6241	0.156	8.27	0.0006
Error	18	0.3398	0.0189		
Total	26	10.8558			

**= significant at 1% level of confidence
Ns level*= not significant at 5% level of confidence

Appendix E

FISHER'S LEAST SIGNIFICANT DIFFERENCES (LSD) IN DATA ANALYSIS

Table 6
Fisher's Least Significant Difference (LSD) test on the density of briquettes according to percentage level

Binder	N	Level = 10 group	Level = 20 group	Level = 30 group
Cornstarch	3	0.1667 a	0.2667 a	0.52 a
Paper	3	0. 1033 b	0.1533 b	0.2967 c
Seaweed	3	0.3267 b	0.1633 b	0.1200 b

Means with the same letter are not significantly different.
Significant at 1% level of confidence

Table 7
Fisher's Least Significant Difference (LSD) test on the density of briquettes according to the type of binder

Level	N	Binder= cornstarch group	Binder = paper group	Binder =seaweed group
10	3	0.1667 c	0. 1033 c	0.3267 a
20	3	0.2667 b	0.1533 b	0.1633 b
30	3	0.52 a	0. 2967 a	0.1200 c

Means with the same letter are not significantly different.
Significant at 1% level of confidence

Table 8
Fisher's Least Significant Difference (LSD) test on the combustion rate of briquettes according to the percentage level

Binder	N	Level =10 group	Level = 20 group	Level = 30 group
Cornstarch	3	0.1633 a	0.1267 b	0.1000 c
Paper	3	0.1700 a	0.1767 a	0.2067 a
Seaweed	3	0.1200 b	0.1167 b	0.1333 b

Means with the same letter are not significantly different
Significant at 1% level of confidence

Table 9.
Fisher's Least Significant Difference (LSD) test on the combustion rate of briquettes according to the type of binder

Level	N	Binder=cornstarch group		Binder= Paper group		Binder= Seaweed group	
10	3	0.1633	a	0.1700	b	0.1200	a
20	3	0.1267	b	0.1767	a	0.1167	a
30	3	0.1000	b	0.2067	b	0.1333	a

Means with the same letter are not significantly different
Significant at 1% level of confidence

Table 10.
Fisher's Least Significant Difference (LSD) test on the ash content of briquettes according to the type of binder

Binder	N	Level = 10 group		Level = 20 group		Level = 30 group	
Cornstarch	3	2.1333	c	1.9833	c	1.8567	c
Paper	3	3.3900	a	3.0167	b	3.6000	a
Seaweed	3	3.1067	b	3.3000	a	3.1733	b

Means with the same letter are not significantly different

Significant at 1% level of confidence

Table 11.
Fisher's Least Significant Difference (LSD) test on the ash content of briquettes according to the percentage level

Level	N	Binder= cornstarch group	Binder= paper group	Binder= seaweed group
10	3	2.1333 a	3.3900 a	3.1067 a
20	3	1.9833 ab	3.0167 b	3.3000 a
30	3	1.8567 b	3.6000 a	3.1733 a

Means with the same letter are not significantly different

Significant at 1% level of confidence

Appendix F

MATERIALS AND EQUIPMENT

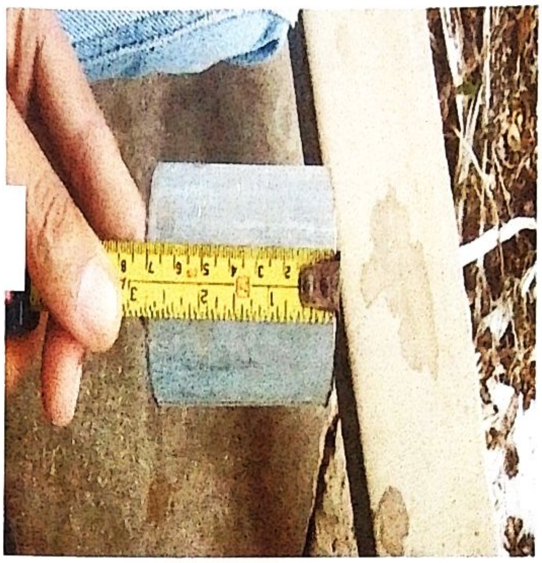
GLOVES

CANDLES

DIGITAL SCALE

OVEN

15 cm GI-pipe



7 cm GI-pipe

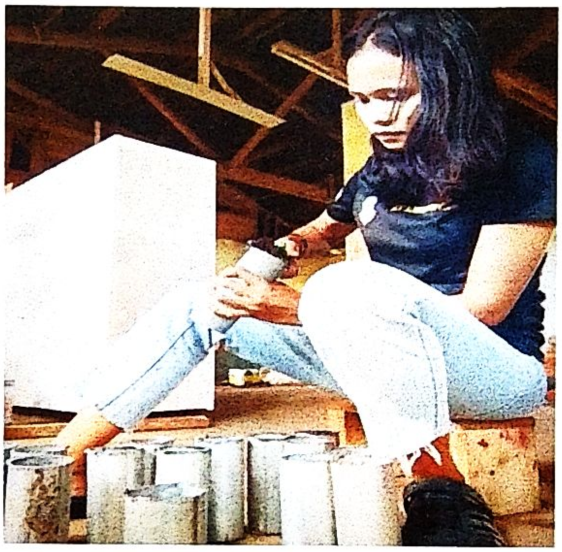
Cut off saw

C-clamp

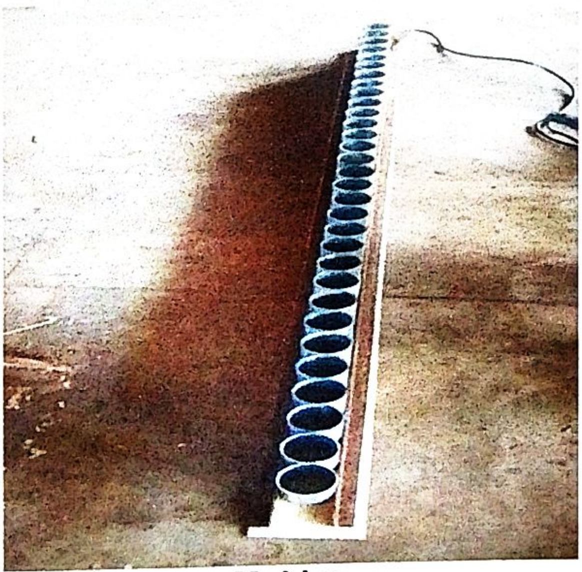
Appendix G

DUCUMENTATIONS

Cutting of GI pipe using cutoff saw



Polishing 15 cm and 7cm of GI pipe



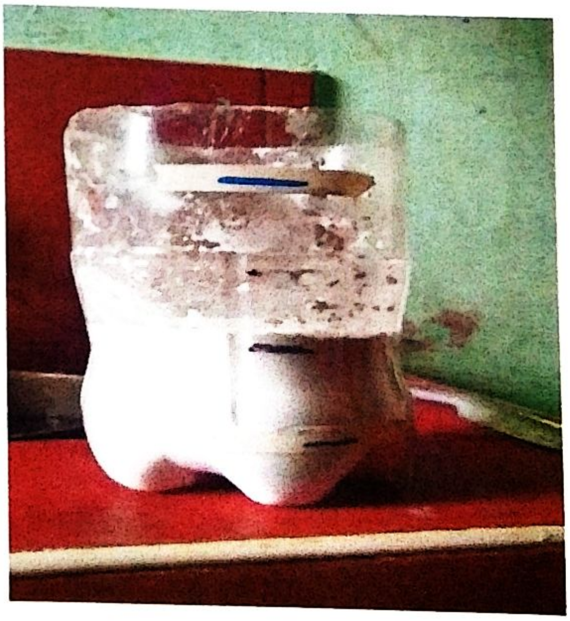
Molder

Seaweed

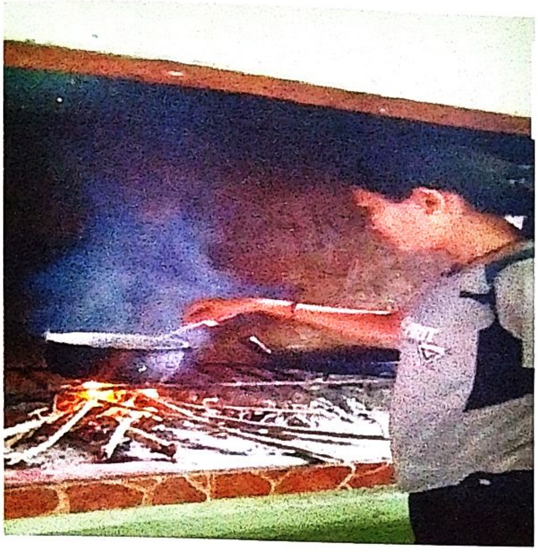
Seived Sawdust

Different proportions of sawdust

Pulped paper



Cornstarch



Cooked seaweed & cornstarch

Compaction of briquettes using C-clamps

Briquettes after compacting

Oven dry

Samples after dried

Burning of briquettes

Sample

Ash of briquettes

Gathering data

Ash samples

Paper

Seaweed

Cornstarch