Production of Biomass Briquettes Made out of Maize Straws and Waste papers as Fuel for Cooking

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ABSTRACT

Wastepaper and maize straw are one of the most produce biomass in the planet. In the Philippines, maize straw placed 2nd in the most produce of agricultural waste. While wastepaper comes 2nd in the most produce solid waste in Metro Manila alone. This piqued the interest of the researchers to convert this waste materials into a biomass briquette. The research purpose is to be able to create an alternative source of cooking fuel that can have a lesser environmental impact. The objective is to create biomass briquettes that are of quality and can be feasibly used by common households as an alternative. Lastly, the researcher’s goal is to create biomass briquettes with high density and humidity resistance. The design of the research is quantitative-experimental research. The briquettes were tested by weighing them and burning them to measure their density and resistance to humidity. All the data that was obtained was treated by using t-test to convert into meaningful data. The briquettes that made by the researchers gave a significance in terms to its resistance to humidity but shows poor demonstration in density.

CHAPTER 1
Introduction

Background of the Study

According to the Britannica Encyclopedia (2020), "Paper is a uniform, felted sheet, composed of fibrous and non-fibrous additives, which has been formed on a fine screen from a water suspension and, subsequently, pressed, dried, and calendared. The sheet may also be sized and/or coated depending on its intended endues." Paper has been around since time immemorial and is currently being used everywhere; however, such product is also one of the major waste contributors around the world. In Metro Manila alone, wastepaper is doted as the second most produced solid waste after kitchen wastes, contributing 19% to the 6,700 tons of wastes produced per day in the capital (Parayno, P. & Busmente, M., u.d).

On the other hand, in the category of agricultural wastes, corn stalk comes second after rice, accumulating exactly 7,218,816 technical tons of waste (Tadeo, B.D, 2015). Included in this statistic are all the parts of the corn crop that is turned into waste, including what is called a maize straw or corn stover. According to the Encyclopedia of Agriculture and Food Systems (2014), "Corn stover is the stalks, leaves, and husks that remain in the field after corn harvest. It is mainly composed of cellulose (~ 35% w/w), hemicellulose (~ 20% w/w), and lignin (~ 12% w/w)." Both waste paper and maize straw qualify as potential biomass sources as per its legal definition in RA 9513 (Sec. 4b); whereas, biomass is any "non-fossilized biodegradable organic material originating from naturally-occurring or cultured plants, animals, and microorganisms including agricultural by-products or residues."

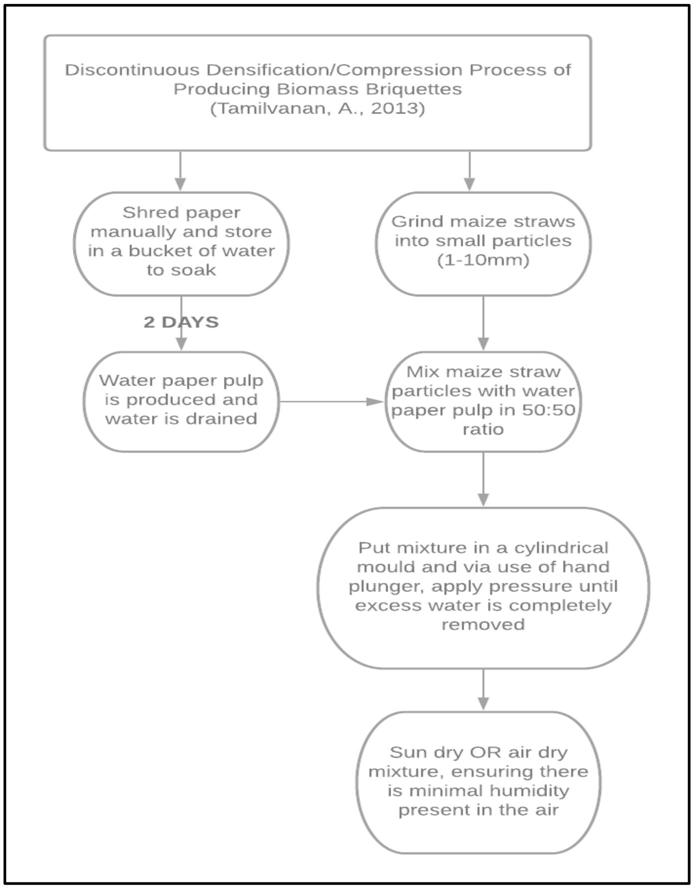
Biomass is one of the most common sources of sustainable fuel, mostly because it produces less carbon footprint compared to fossil fuel combustion (Rejinders, L., 2004). Carbon footprint production is one of the major contributors to greenhouse gases that have ultimately caused climate change, one of the most detrimental environmental challenges that current society is facing. Multiple efforts of lessening this carbon footprint have been introduced, and usage and production of biomass is one of the proposed alternatives; it only comes down to the sources of biomass and how well they combust to efficiently mimic the qualities of fossil fuel minus the carbon footprint, which ultimately leads to the inspiration of this investigatory project.

Rationale

As supported by the previously stated facts in the background of the study, the raw materials for this investigatory project can be easily procured. These raw materials are waste products that may accumulate and pollute the environment unless reused or recycled. This investigatory project chooses to recycle these waste products into a briquette that can be used for cooking, which is an essential daily task for all. In this study, not only are the waste products recycled and postponed for dumping in landfills, but the biomass briquettes that these will be able to create can provide an alternative source of cooking fuel that has a much lesser carbon footprint than commonly used fuel.

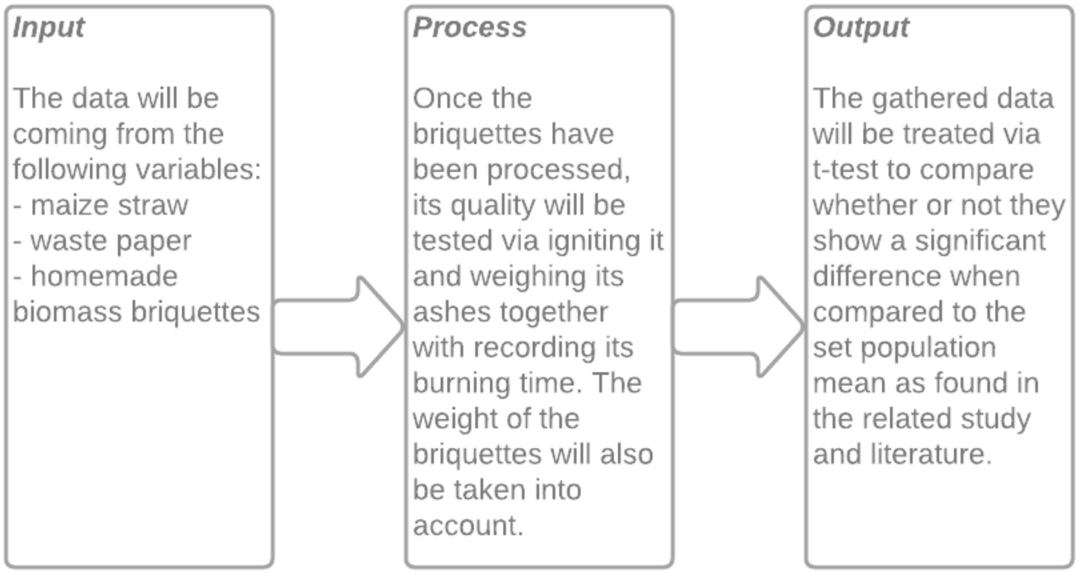
Conceptual Framework

Figure 1: Discontinuous Densification/Compression Process of Producing Biomass Briquettes Tamilvanan A. 2013)



Input-Process-Output Graph

Figure 2: IPO Graph



This investigatory project's primary purpose is to provide a clean alternative to conventional cooking fuel via amassing biomass products, maize straw and wastepaper, and turning them into biomass briquettes. To achieve this purpose, the paper aims to measure and quantify the quality of the produced biomass briquettes, specifically under the density and resistance to humidity parameters via measuring its burning time and weighing its ashes post-burning. Once these data are recorded, they will be treated using a t-test to check if the briquettes show sufficient density and resistance to humidity to be classified as satisfactory.

Research Considerations

One consideration is the practicality of procuring raw materials in time of the pandemic, whereas, researchers may be limited in their movement, especially due to the quarantine restrictions. Another research consideration is the theoretical feasibility of introducing DIY homemade briquettes to common households due to the factors of time, effort, and labor that may discourage these households, the potential benefactors.

Scope and Limitations

This investigatory project will make use of all types of paper (newsprint, printing and writing paper, industrial paper, kraft paper, corrugating medium, sack, and tissue paper) according to their availability, thereby limiting the ability of the study to compare and measure which among the types of paper can yield better quality briquettes. Next, this project will also make use of all types of maize straws coming from all classifications of maize (waxy corn, flint corn, dent corn, and amylomaize) according to their availability, thereby again limiting the ability of the study to compare and measure which among the types of maize can yield better quality briquettes.

Moving forward, this study will only cover the manual (mould and press) discontinuous densification/compression method of producing briquettes due to limitations of acquiring industrial equipment and because it will not be feasible to use such pieces of equipment in a home setting.

Additionally, this study will be limited only to the use of a standard stainless steel flat pan (for even surface heat distribution) to test for the effectiveness and efficiency of the briquettes to combust enough heat to cook. In line with this, the study will only be using a regular sized egg as the food to be used in checking for the heating and cooking ability of the briquettes.

Lastly, the study will not tackle any topics regarding cooking time and comparison of the briquettes produced from wastepaper and maize straws to briquettes produced from other biomass products; however, this must not be confused with burning time, which will be measured in the study together with the briquettes' resistance to humidity (crumbling effect) – both of which will be used to determine the quality of the briquettes produced. Other forms of measuring briquette quality (i.e calorific value, combustion efficiency) will not be tackled due to the unavailability of equipment.

Statement of the Problem

This investigatory project seeks to answer the following questions in order to assess the sustainability and feasibility of using wastepaper and maize straws as biomass sources for alternative briquettes:

1) Is the process and chosen method (discontinuous densification/compression) for producing the briquettes feasible for common households in terms of time and labor/effort as compared to simply buying readymade commercial fuel (LPG) in terms of:

   a. amount of waste paper needed per briquette (in terms of grams)

b. amount of maize straw needed per briquette (in terms of grams)

c. amount of time needed to produce single briquette, from the procurement of raw materials stage until the drying stage (in terms of days)

2) In determining the briquette quality via measuring its density, how long do the briquettes burn (average amount of time in terms of minutes)?

3) Contingent to the previous question regarding the briquette's quality, what is the average amount of crumbled briquette (in grams) after 15 minutes?

Hypothesis

Null: Wastepaper and maize straw cannot produce biomass briquettes with satisfactory density and resistance to humidity that can act as sufficient and efficient fuel for cooking.

Alternative: Wastepaper and maize straw can produce biomass briquettes with satisfactory density and resistance to humidity that can act as sufficient and efficient fuel for cooking.

Significance of the Study

Environment. In essence, the biomass nature of the briquettes will allow for lesser carbon footprint produced by households that continue to depend on commercial (LPG) fuel for cooking.

Households. Households seeking to cut on budget may find this alternative as cost-efficient since the raw materials needed are easily accessible and free.

Future researchers. Future researchers that would like to assess the extent of biomass products and their ability to produce sustainable materials, including briquettes. Additionally, future researchers may use this study as a reference to improve on the methodology of the paper or to widen its scope.

Definition of Terms

Biomass – a non-fossilized biodegradable organic material originating from naturally-occurring or cultured plants, animals, and microorganisms including agricultural by-products and residues

Briquettes – it is a compressed block that is mainly composed of combustible materials (i.e., paper, sawdust, wood chips, or peat)

Combustion – a process where the briquettes being burned

Maize – also known as corn, it is a cereal plant that produces big grains arranged in rows on a cob.

Straws – it is a dry stalk come from a cereal plant such as corn and it is an agricultural byproduct

Wastepaper – papers that are already discarded that can also be reuse

REVIEW OF RELATED LITERATURE

I. Biomass energy

Fossil fuel combustion is one of the most important contributors to air pollution (major source of CO2 emissions); however, the practice of such cannot be immediately halted as 82% of the world's energy comes from the burning of such fossil fuels (i.e oil, coal, natural gas) (IEA, 2012). Nonetheless, through the continuous development of science and research, a potential source of energy that is more sustainable has been introduced and is termed "biomass". Biomass sources are found in almost all organic wastes, including paper and corn, which is the focus of this paper. Energy production from biomass can decrease the demand for fossil fuel combustion (Van Loo, S. & Koppejan, J., 2008). This is because it ranks as the third largest energy resource in the world (Tumuluru, S.J., et al., 2011). One must not be mistaken; however, because biomass, according to Bilgili, F., et al.(2016), "is a complex source that can be processed through many ways, can be transformed into several products and can present multiple energy options." There are three ways of processing biomass sources: i) mechanical ii) thermal, and; iii) biological (Bilgili, F., et al., 2016). Only mechanical processing is relevant to this paper because this includes chipping, cleaving, pelleting, pressing, and briquetting, which is the goal of the investigatory project.

II. Biomass briquette

a. Process parameters

Compaction pressure. The amount of pressure is decided according to the type of biomass source's feedstock type, moisture content, shape, and particle size. Low compaction pressure is generally used for briquette raw materials that have a binding agent in its ingredients, which is essentially the wastepaper in this study. Meanwhile, high compaction pressure is used as an alternative for briquette raw materials that do not possess a binding agent in its ingredients. Feasibility-wise, usage of low compaction pressure is more ideal since it is cost-effective and durable (Bazargan, 2014). This is because the high compaction pressure method makes use of industrial machineries that may not be otherwise accessible to common household settings.

Temperature. High temperature generally enhances the binding capacity of briquette binders, but such may require higher energy input. In this study, the usage of wastepaper pulp and maize straws can densify a briquette at a temperature of greater than or equal to 80 degrees Celsius (Okot, et al., 2018).

Moisture content of raw materials. According to Tumuluru, et al. (2010), "moisture content of biomass facilitates starch gelatinization, protein denaturation, and fiber solubilization processes" which is essential to the densification of the biomass briquette. Low moisture content can hinder the binding of the raw materials while excessive moisture content will require more time, effort, and labor once the compressed briquettes are subjected to drying (Kpalo, S.Y., et al., 2020).

Particle size of raw materials. It is imperative that a particle size of 6-8mm is obtained in order to yield best quality briquettes, and smaller sizes (<2mm) make binding easier and produces high-density briquettes (Kpalo, S.Y., et al., 2020). Nonetheless, the optimum particle size has not yet been decided.

Feedstock composition. Biomass mainly consists of cellulose, hemicellulose, and lignin – all of which can be found in maize straws. The carbon needed for a biomass briquette to combust is largely produced by cellulose (Miranda, T., 2015). Hemicellulose is another form of saccharide that has adhesive properties and toughens when dehydrated (Tursi, A., 2019). Lastly, lignin, a type of starch found in plant cell walls, serves as an in-situ binder that enables the binding process in briquette production, and such cannot only be found in maize but in wastepaper pulp as well, thus supporting the previous statement that says waste paper pulp is an excellent binder for biomass briquettes (Kaliyan, N., Vance Morey, R., 2009). It may also be noted that lignin can yield more energy than cellulose when burned (Tumuluru, S.J, et al., 2011).

b. Practical applications of briquettes

There are at least 11 possible ways of using biomass briquettes and such are listed in the table below.

Table 1. Practical applications of briquettes (Mwampamba, T.H, Owen, M., Pigaht, M., 2013).

No	Industry	Possible Application
1	Domestic use	Cooking, water heating, and space heating
2	Commercial and institutional catering	Cooking, water heating, grilling
3	Hospitality	Cooking, water heating, space heating (outdoor dining areas)
4	Industrial Boilers	Generation of heat and steam
5	Food processing	Distilleries, bakeries, canteens, restaurants, drying
6	Textiles	Dyeing, bleaching
7	Crop processing	Tobacco curing, tea drying, oil milling
8	Ceramic production	Brick kilns, tile making, pot firing, etc.
9	Gasification	Fuel for gasifiers to produce electricity
10	Charcoal production	Initiating pyrolysis to make charcoal production more efficient
11	Poultry	Incubation and heating of chicks

a. Density

The density of briquettes directly correlates to its burning time; thus, higher density means longer burning time and more heat release (Estiaty, L.M., et al., 2018). Not all biomass briquettes have the same density, mostly because this property is dependent on the raw material used together with its moisture content and particle size. Since the goal of biomass briquettes is to be a sustainable source of fuel, it must then also be able to actually compare to commercial sources of fuel; thus, according to Estiety, L.M, et al. (2018), a high-quality biomass briquette must at least burn for as long as 40-60 minutes, in comparison to coal.

b. Resistance to humidity

Biomass briquettes are highly susceptible to humidity because its principal binding component, lignin, is water-soluble; thus, water vapor released from the combustion of briquettes can naturally cause the briquettes to crumble; however, it must not crumble too fast because these crumbled pieces affect the quality of briquette by lowering its heat release since these loose pieces will elutriate unburned (Estiety, L.M, et al., 2018). In line with this, a standard was provided by Esteity, L.M, et al. (2018) which is: within 15 minutes of burning, the weight of the crumbled briquettes must not exceed that of 25% of the original briquettes weight. If it exceeds 25%, it may not be a quality briquette.

CHAPTER 2
Methodology

Research Design

This study, which is an investigatory project, is classified and will follow an experimental research design. Since it will test its hypotheses using a one tailed t-test statistic, it will be designated as a quantitative experimental paper.

This research employed a quantitative way to assess the differences between the samples, as well as an experimentation method to determine briquette quality in terms of density and humidity resistance.

Table 1: Sampling and Description of the Site

CONTROL VARIABLE	INDEPENDENT VARIABLE	DEPENDENT VARIABLE
Time	Wastepaper pulp	Briquette density
Temperature and humidity	Maize straw	Briquette resistance to humidity (crumbling effect)
Grinded particle size of maize straw		Egg

A. Briquette Making

The briquettes were created indoors, within the household of a research member. It was mainly created within the kitchen, where most of the needed research instruments could be found. There was an alternate between using the floor or the kitchen table counter. Much of the process of pounding was done on the floor to avoid any cracks or any other damages to the kitchen table counter. The mixing and molding process, on the other hand, was done on the kitchen table counter, mostly to maintain the calibration of the gram weighing scale that is essential for the 50:50 ratio mix of wastepaper pulp and maize straw needed for the briquette.

A. Briquette Quality Test

To ensure that minimal interventions influence the results while also maintaining the safety of the researchers, the process of burning the briquettes and cooking the eggs will be outside of the house, ensuring that there is proper ventilation to ensure optimal room oxygen saturation which is needed for the combustion of briquettes.

Table 2: Materials Used

A. Briquette Making	**B. Briquette Quality Test**
- Mortar and pestle	- Timer
- Round aluminium mold	- Gram weighing scale
- Tray	- Tongs
- Household grade blender	- Lighter
- Maize straw	- 4” or 6” stainless steel aluminium pan (depending on availability)
- Waste paper pulp	- Grilling tray
- Water	- Cooking oil
	- Regular sized eggs

Data Gathering Procedure

To check for precision and accuracy, the 12 briquettes that were made will be divided into 3 separate tests, leaving 4 briquettes for each test. Testing will be done subsequently, only once both of the conditions are met: a) egg is cooked, and; b) the fifteen-minute mark has been reached and all crumbled parts have been collected (note that once the egg is cooked before the fifteen minute mark, the researchers ought not to stop the burning of the briquettes, instead, only collect the egg and leave the pan on the grill until 15 minutes has been reached).

After each testing, the pan used must be cooled to room temperature first, washed, and completely dried, before doing another test. This is to ensure minimal influence of possible outlying factors to the results. Standard cooking procedure shall proceed; whereas minimal oil is used to grease the pan and the egg is cracked onto the surface before lighting the briquette. The pan is to be laid on a grilling tray whilst the 4 briquettes are underneath and are on a heat-resistant tray.

The briquettes are only to be lit using the lighter once the egg is cracked on the pan. During the cooking process, the egg must not be disturbed. Additionally, the egg is to be cooked as "sunny side up", since this cooking technique will allow for minimal disturbance to the egg. A runny yolk does not disqualify the egg for being cooked, because the basis of the egg being cooked is when the egg whites are fully cooked or no longer slimy, per se. On the other hand, a cooked yolk is still qualified, so long as the egg whites, again, are no longer slimy or are now fully cooked.

Once the researchers have completed repeating the test thrice, using a different batch of 4 briquettes each time, they will then once again burn these briquettes on a heat-resistant tray by lighting them all at the same time. Each time a briquette stops burning, the researchers must note this (in minutes), with an additional 15 minutes to each briquette since it was burned for 15 minutes during the cooking process. Consequently, if the egg was not cooked during the 15-minute mark, then adjustments to the added time will be applied. Lastly, the collected crumbled briquettes will be weighed (per trial) and the average weight will be computed – this is to test for the briquettes' resistance to humidity.

Data Analysis

The data analysis process of this investigatory project will be parallel to its statement of the problem (SOP); thus, the chronological order of this section of the paper will follow that of the questions in the SOP.

1. In accordance to the statistical data in the review of related literature and studies, the feasibility of procuring the amount of waste paper and maize straw needed to produce a single briquette will rely on whether or not it exceeds the recycling capacity of the total reported waste (paper and agricultural, specifically corn) in the Philippines. This part can also eyeball whether or not it is reasonable for a typical household to procure such materials (i.e if a household will need a total of 100 briquettes to last a month and each briquette will require nearly 800g-1kg of raw materials, it may not be as sustainable and reasonable for the household). Additionally, if the amount of time needed to create such briquettes exceed more than 2 days, it may be deemed

unreasonable. This is solely on the basis of the amount of days in a weekend, where people, both working adults and studying children generally have free time.

2. Precision-wise, the burning time of the briquettes must at least have a ±2 standard deviation to eliminate the possibility that there may be outside factors affecting its combustion properties. Accuracy-wise, as per Estiaty, L.M, et al. (2018), the mean burning time of a biomass briquette usually lasts for 40-60 minutes.

3. Precision-wise, the resistance to humidity property of the briquettes will be shown via measurement (weight) of the amount of "crumbled" pieces acquired after 15 minutes, and such weight must at least have a ±2 standard deviation to eliminate the possibility that there may be outside factors affecting its combustion properties. Accuracy-wise, as per Estiaty, L.M, et al. (2018), within 15 minutes of burning, the weight of the crumbled briquettes must not exceed that of 25% of the original briquettes weight. In this case, since the mean weight of all 12 briquettes is 10 grams, the crumbled briquettes must, collectively, on average, not weigh more than 2. 5 grams.

One-sampling T-Test Formula:

$$t = \frac{\bar{x} - \mu}{\frac{s}{\sqrt{n}}}$$

Wherein:

$\bar{x}$ = the mean ash weight and the mean burning time

μ = theoretical value

s = standard deviation (widespread of the data)

n = the sample size (no. of experiment that was conducted)

To get the conclusion, the researchers will use the t-table to find the "shaded" or critical region of the bell curve, from here, the bell curve will be the basis of the researchers in accepting or rejecting the null hypothesis. At the time the T-value lands in the "shaded" or critical region, the null hypothesis will be rejected, and the conclusion will be followed according to the alternative hypothesis (2-tailed), but if it lands in the "unshaded", the null hypothesis will not to be rejected.

Ethical Considerations

To maintain the integrity and quality of the study, only the information provided by the reference literatures, studies, and those coming from the gathered data will be used for the analysis and interpretation of results. Any discrepancies with regard to the study will be reported. Moreover, if future researchers decide to acquire any information found in the study, they shall contact the authors of the paper for consent.

Moving forward, this investigatory project identifies fire as a hazard not only to the researchers but also to the area (school grounds), thus, a risk likelihood has been performed using the hazard matrix taken from Bui, D., et al. (2017).

Figure 1. Hazard Matrix (Bui, D., et al., 2017)

		Hazard Effect/Consequences			
		1 (Minor)	2 (Moderate)	3 (Major)	4 (Maximal)
		First aid case; exposure to minor health risk; little to no economic costs incurred.	Medical treatment; lost time injury; reversible impact on health; exposure to major health risk; economic costs are low.	Loss of quality of life; irreversible health impact; economic costs are moderate.	Single/Multiple fatalities; health impact is ultimately fatal; economic costs are high.
Likelihood		Risk Ranking			
4 (Almost Certain)	The incident occurs with regularity and will continue to occur (>75% likelihood)	7 (M)	11 (H)	14 (EX)	16 (EX)
3 (Likely)	The incident has occurred frequently, and is expected to occur (30-75% likelihood)	4 (L)	8 (M)	12 (H)	15 (EX)
2 (Possible)	The incident has happened at some time (infrequently), and will occur under some circumstances (10-30% likelihood)	2 (L)	5 (M)	9 (M)	13 (H)
1 (Unlikely)	The incident has happened in the past (rarely), and may occur in exceptional circumstances (<10% likelihood)	1 (L)	3 (L)	6 (M)	10 (H)

Upon deliberation, it has been agreed on that the risk ranking for this project, once the biomass briquettes are ignited, is 1 (low). Thus, the ethics of doing no harm (as much as possible), is satisfied in this study.

CHAPTER 3
Results and Discussion

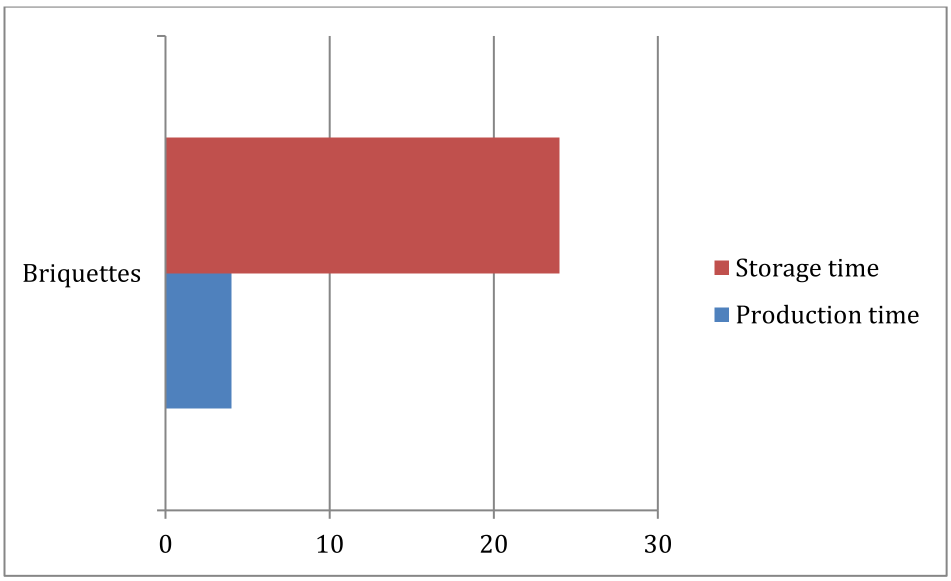
The experiment was conducted on February 24. The gathered data will be summarized into tables and figures which will be used to support the claims of the study. The study has chosen to make use of the following statistics: mean, standard deviation, and t-test to interpret these data into relevant information and correlate it with the review of related literature in the discussion part of this chapter.

Table 1. Average weight (in grams) of 12 briquettes and corresponding standard deviation

BRIQUETTE	WEIGHT (g)
1	8g
2	6g
3	8g
4	6g
5	8g
6	6g
7	6g
8	6g
9	7g
10	7g
11	5g
12	5g
MEAN WEIGHT	**6.5g**
STANDARD DEVIATION	**1.09**

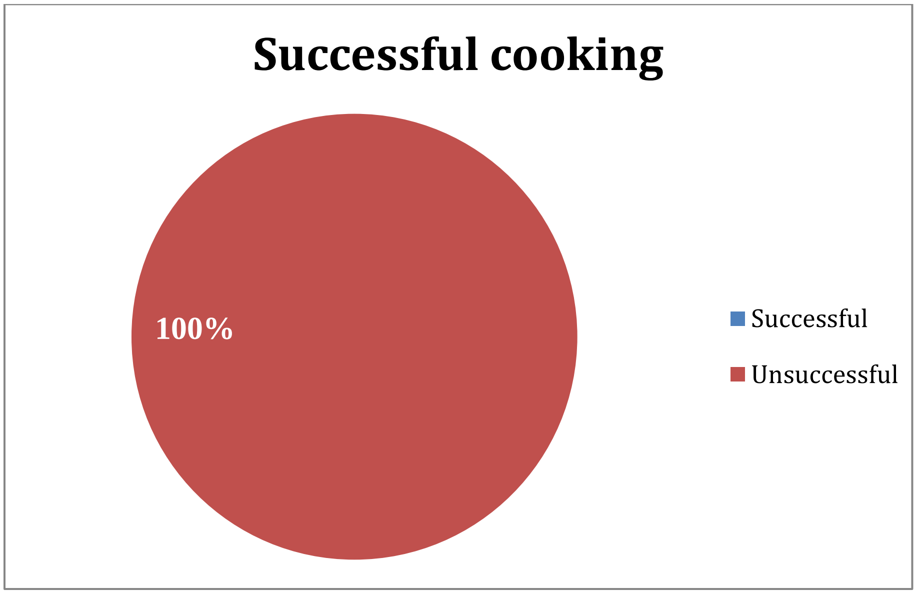
Upon weighing the 12 briquettes individually, the average weight in grams turned out to be 6.5g, with a standard deviation of 1.09. It may be assumed that the variation, although insignificant in difference, may be tracked back to the drying process.

Figure 1. Storage and production time (in days)



The production of all briquettes took exactly 4 days (January 28-31), following the manual discontinuous procedure (refer to conceptual framework). Since the briquettes were tested on February 24 and all successfully ignited, the storage time reached 24 days.

Figure 2. Percentage of trials with successful cooking attempt



Checking for the success of cooking attempt may act as a confounder for the study since it is not the experiment's direct objective, but it is a factor that is important to be noted since it forms part of the study's purpose. This graph shows that all trials failed in cooking the egg during the experiment.

Table 2. Mean burning time of 3 trials and corresponding standard deviation

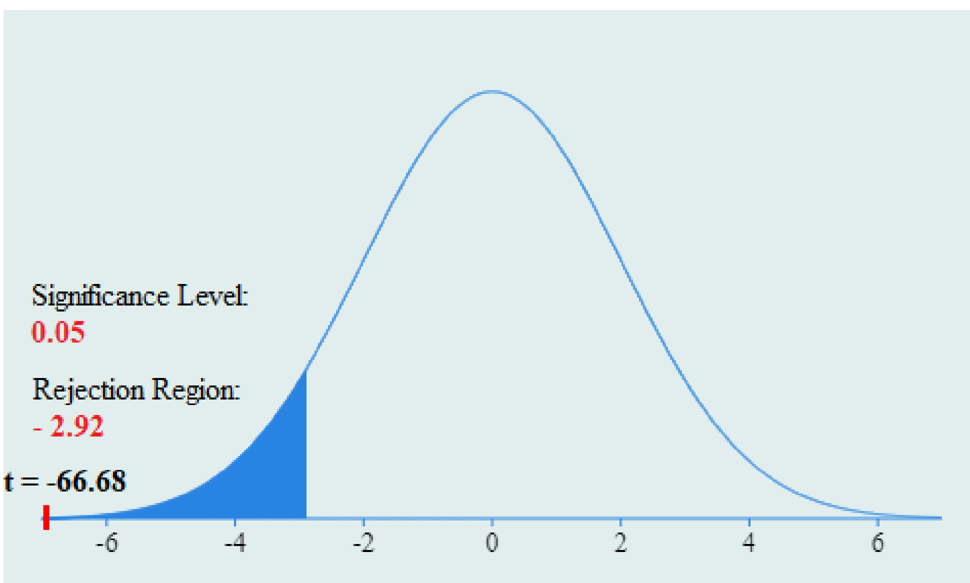
TRIAL	BURNING TIME
1	17m 21s ≈ 17m
2	17m 54s ≈ 18m
3	18m 36s ≈ 18m
Mean Burning Time	**17.67 min**
Standard Deviation Burning Time	**0.58**

Table 2.1 T-test One Sampling on Burning Time

T-test One Sampling	*Burning Time(min)*
Mean	17.66666667
Variance	0.333333333
Observations	3
Hypothesized Mean Difference	0
df	2
t Stat	53
P(T<=t) one-tail	0.000177904
t Critical one-tail	2.91998558
P(T<=t) two-tail	0.000355809
t Critical two-tail	4.30265273

The average burning time from the 3 trials is approximately 17.67 minutes with a standard deviation of 0.58, thus reassuring that the data is homogenous and valid.

Figure 3. One-sample t-test of burning time



Interpretation:

As per checking the mean burning time against Estiaty, et al.'s (2018) mean which is a range of 40-60 minutes, the population mean was decided to be 40; nonetheless, upon computation of the test statistic, it showed that the data are not within the 95% critical value accepted range. The t-value that was obtain from the computation is -66.68. With this, the t-value fell inside the rejection region which show that the briquette does not qualify with high quality in terms of its density

Table 3. Mean ash weight of 3 trials and corresponding standard deviation

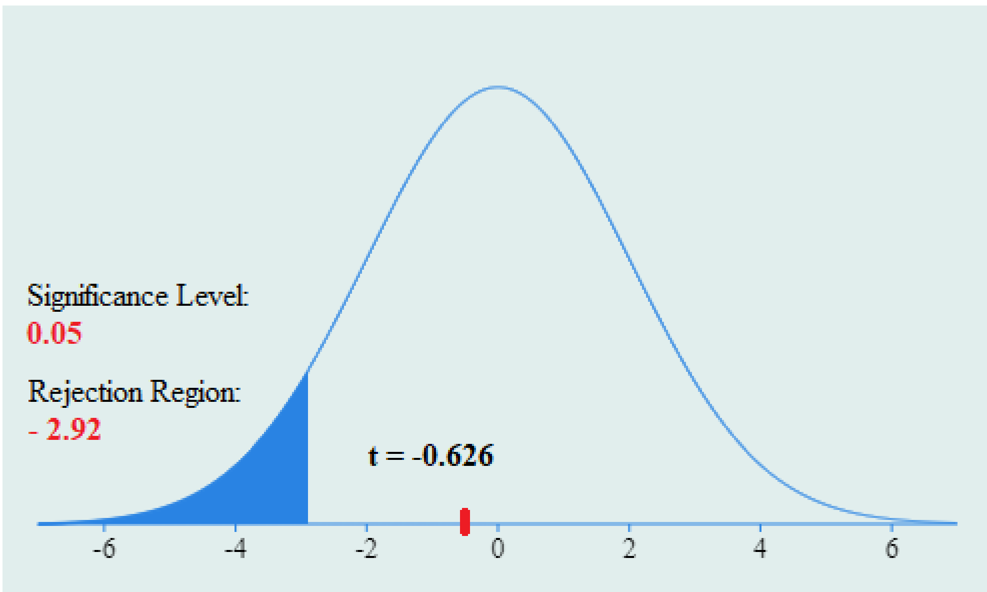
TRIAL	ASH WEIGHT (g)
1	<0
2	<0
3	3
Mean Ash Weight	**1**
Standard Deviation Ash Weight	**1.73**

Table 3.1 T-test One Sampling on Ash Weight

T-test One Sampling	*Ash Weight (g)*
Mean	1
Variance	3
Observations	3
Hypothesized Mean Difference	0
df	2
t Stat	1
P(T<=t) one-tail	0.211324865
t Critical one-tail	2.91998558
P(T<=t) two-tail	0.422649731
t Critical two-tail	4.30265273

The average ash or "crumbled pieces" weight was noted to be 1g with a standard deviation of 1.73, which is still relatively homogenous since the set SD value is ±2; however, it may be noticed that the data is recorded as less than 0. It was assumed that the ashes still weighed a certain amount but that the scale had no longer seen it as relevant, thus why it was recorded in such a manner.

Figure 4. One-sample t-test of ash weight



As per checking the mean ash weight against Estiaty, et al.'s (2018) mean which is a range 25% of the original briquette, which is calculated to be 1.625g, it was shown via one-sample t-testing that the ash weight or density of the briquettes, with a test statistic value of -0.626, fall within the 95% critical value accepted range. With this, the t value fell outside the rejection region. Therefore, at the 5% significance level, there is sufficient evidence that the briquettes show resistance to humidity.

Discussion and Findings

1. Upon careful deliberation of the feasibility of the briquettes to be applied in common households, it was determined that:

   a. the amount of waste paper needed to create 1 briquette is approximately 3.25g, which may be attainable considering the amount of waste paper produced in Metro Manila alone, as per the reports in the related literature,

   b. the amount of maize straw needed to create 1 briquette is approximately 3.25g, which may be attainable considering the amount of maize straw refuse is produced per year in the agricultural sector of the country, as per the reports in the related literature, and;

   c. the length of production, which is 5 days, may be longer than expected for some households who may only have "free time" during the weekends; however, significant testing must yet ensue to prove such claim; nonetheless,

   albeit the amount of raw materials needed per briquette may be feasible for most since it only requires a small quantity, the time of production and its effect and significance on the feasibility of creating briquettes in common households may still need to be tested further.

2. After computing the test statistic for the burning time of the briquettes, it was shown that the burning time is outside the designated critical value; thus, the burning time of the briquettes in the experiment did not meet the assigned burning time of 40 minutes as mentioned in the related literature. This result suggests that there is insufficient data to support that the briquettes produced were not of sufficient density, since the density of briquettes is measured via their burning time. All in all, the t-test shows that the null

hypothesis must NOT be rejected. Several factors may have affected this result; however, these are beyond the scope of the study. On the other hand, it is notable to mention that the data are homogenous, thus suggesting that the variables in all trials were consistent and no outliers are present.

3. In terms of the briquettes' resistance to humidity, the test statistic shows that the weight of the ashes are within the critical range, therefore suggesting that under the parameter of resistance to humidity, the briquettes produced are of quality by successfully attaining the ≤25% (or 1.625g) ash weight after 15 minutes of burning. This thereby directs the experiment to reject the null hypothesis. It is important to mention that the data are satisfactorily homogenous and therefore valid for assessment (or are devoid of outliers).

CHAPTER 4

Summary, Conclusion, and Recommendation

Summary

In totality, the following characteristics may be derived from the briquettes:

1. It has an attainable amount of raw material requirement.

   As per the reports in the review of related literature, wastepaper is attainable considering the amount of the Metro Manila that produces wastepaper. Alongside with the maize straws, It may be feasible given the amount of maize straw produced annually in the country's agricultural sector

2. Shows feasibility in terms of viability

   For certain households that only have "free time" on weekends, the length of production, which is four days, may be longer than expected; nevertheless, considerable testing is required to substantiate such a claim; yet, Although the amount of raw materials required per briquette may be feasible for most because only a small quantity is required, the time required for production, as well as its effect and significance on the feasibility of making briquettes in everyday households, may still need to be investigated further.

3. Demonstrates poor density

   The burning time of the briquettes was demonstrated to be outside the defined critical value after computing the test statistic; hence, the burning time of the briquettes in the experiment did not satisfy the allotted burning time of 40 minutes as indicated in the associated literature. Because the density of briquettes is assessed by their burning duration, this result shows that there is insufficient evidence to support that the briquettes created were not of appropriate density.

4. Demonstrates significant resistance to humidity

The test statistic for the briquettes' resistance to humidity reveals that the weight of the ashes is within the necessary range, implying that the briquettes generated are of good quality by successfully achieving the 25% (or 1.625g) ash weight after 15 minutes of burning

Conclusion

Corollary to the discussion of findings, it may be suggested to not reject the null hypothesis, thereby suggesting that with the current data and methodology, the paper concludes that the use of maize straw and wastepaper cannot produce biomass briquettes with satisfactory density and resistance to humidity that can act as sufficient and efficient fuel for cooking. This is the decision upon finding that only one of the two computed test statistics for the two vital briquette quality parameters, density, and resistance to humidity, fell within the critical range, whilst the other did not.

This is the decision based on the premises gathered from the related literature and studies, suggesting that all tested parameters must meet the specified standard criteria in order to qualify a briquette as one of good quality or otherwise. Going back to one of the purposes and goals of the study, this experiment seeks to produce briquettes that can be used as alternatives to commercial cooking fuel, hence why its main objective is to produce quality briquettes that can fulfil such goal and purpose. Since only one of two parameters was satisfied, it may be said that the study failed in producing quality briquettes that can serve as alternative cooking fuel; however, they may be insufficient data to prove this claim otherwise, especially since there are plenty of variables that were not covered by this experiment.

In summary, the conclusion met is consistent with the requirements of the related literature – one of the probable reasons why the briquettes failed to cook the egg is its below average quality, as computed and correlated with the briquette quality parameters.

Recommendations

Due to the limitations in time and communication caused by the COVID-19 restrictions, the study had potential variables outside its scope; hence, the following recommendations are proposed to expand the scope of the paper:

1. Since the researchers speculate that the possible cause for the insufficient burning time of the briquettes may be because of its size and weight, it may be suggested that future researchers who would like to attempt this paper's process should create bigger briquettes with significantly heavier weight.
2. To further test the quality of biomass briquettes, it may be best to measure other parameters beyond its density and resistance to humidity, particularly its combustion efficiency and carbon dioxide flue gas.
3. Furthermore, for improvement and repeatability of the test results, more trials and number of briquettes may be recommended.

4. For studies with the same purpose, cooking time may be an additional variable that can be measured.
5. Additionally, comparison between biomass briquettes, charcoal briquettes, and/or LPG based on a set of standard parameters may also be suggested in order to test the commercial efficiency and feasibility of biomass briquettes in mass production and the market in general.

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APPENDIX

A.) RAW DATA RECORD:

Batch Experiment	Briquette	Weight (g)	Ignition time	Cooking Time	15 min reach	Additional Burning Time	Total Burning Time	Weight of ash (g)
Batch 1	A1	8grams	71 sec	Failed	Success	2min 21 sec	17min 21 sec	<0g
	A2	6grams	31sec					
	A3	8grams	40sec					
	A4	6grams	30sec					
Batch 2	B1	8grams	29sec	Failed	Success	2min 54 sec	17 min 54 sec	<0g
	B2	6grams	23sec					
	B3	6grams	18sec					
	B4	6grams	29sec					
Batch 3	C1	7grams	22sec	Failed	Success	3min 36 sec	18 min 36 sec	3g
	C2	7grams	28sec					
	C3	5grams	32sec					
	C4	5grams	27sec					
	Total	78g	380 sec				53 mins	3grams
	Mean Ave.	6.5g	31.6 sec				17.67mins	1 gram

B.) COMPUTATION

c.1 Briquette Weight

Mean Average of Briquette Weight	Standard Deviation of Briquette Weight
$\frac{8+6+8+6+8+6+6+6+7+7+5+5}{12}$ $Mean\ Briquette\ Weight = 6.5$	$\sqrt{\frac{(8-6.5)^2+(6-6.5)^2+(8-6.5)^2+(6-6.5)^2+(8-6.5)^2+(6-6.5)^2+(6-6.5)^2+(6-6.5)^2+(7-6.5)^2+(7-6.5)^2+(5-6.5)^2+(5-6.5)^2+}{12-1}}$ $Standard\ Deviation\ of\ briquette\ weight = 1.09$

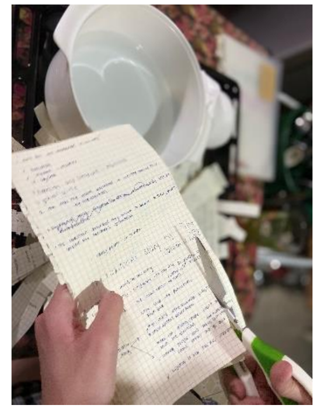
c.2 Burning Time

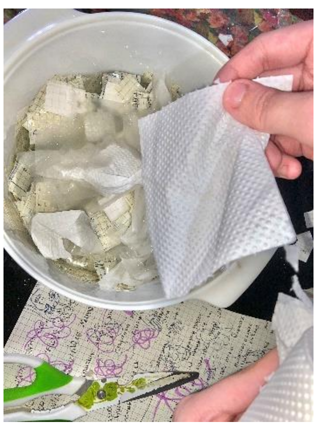
Mean Average of Burning Time	Standard Deviation of Burning Time	T-value Testing
$\frac{17+18+18}{3}$ $Mean\ Burning\ Time = 17.67\ min$	$\sqrt{\frac{(17-17.67)^2+(18-17.67)^2+(18-17.67)^2}{3-1}}$ $Standard\ Deviation\ of\ briquette\ weight$ $= 0.58$	$t = \frac{17.67-40}{\frac{0.58}{\sqrt{3}}}$ $T\ value = -66.68$

c.3 Ash Weight

Mean Average of Burning Time	Standard Deviation of Burning Time	T-value Testing
$\frac{0+0+3}{3}$ $Mean\ Ash\ Weight = 1\ gram$	$\sqrt{\frac{(0-1)^2+(0-1)^2+(0-3)^2}{3-1}}$ $Standard\ Deviation\ of\ briquette\ weight$ $= 1.73$	$t = \frac{1-1.625}{\frac{1.73}{\sqrt{3}}}$ $T\ value = -0.626$

C.) DOCUMENTATION\





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