

**FABRICATION AND CHARACTERISATION OF BRIQUETTES MADE FROM CORN
STOVERS AND GROUND NUT HUSKS**

BY

NABUTSALE ESTHER

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A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF PHYSICS IN PARTIAL
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Declaration

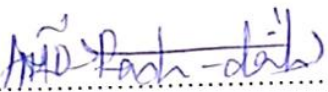
I Nabutsale Esther hereby declare that this project report titled “Fabrication and characterization of briquettes made from corn stovers and ground nut husks” was my original work and has never been published or submitted for any other degree to any other university before.

Signature..........

Date.....16th October, 2024.....

Approval

This project report titled “Fabrication and characterization of briquettes made from corn stovers and ground nut husks” submitted by Nabutsale Esther under my approval for examination to the physics department of Busitema university faculty of science and education.

Signature: 

Date: 1st October, 2024

Supervisor:

Dr. Akoba Rashidah

Department of Physics.

Faculty of science and education.

Busitema University.

Dedication

This project work is dedicated to my dear parents; Mr. Nalali John and Mrs. Namakoye Aidah for entirely supporting me physically, spiritually and financially throughout this course. To all my siblings; Namutosi Grace, Majeme Julius, Nabololi Beatrice and the rest for their prayers and being the source of courage that keeps me moving forward especially throughout my academic journey. My heartfelt prayer for you is that the Almighty God blesses and increases you in all that you do.

Acknowledgement

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Abbreviations

BHT Butylated hydroxy toluene

Abstract

This study involved the fabrication and characterization of briquettes from corn stovers and ground nut husks. It involved production of uncarbonized briquettes from agricultural biomass materials such as corn stovers and ground nut husks as alternative fuel for cooking. The study was based in Nagongera town council due to availability of the desired raw materials especially during the peak seasons of harvesting. This does not only substitute the conventional wood fuels for cooking but also provides a sustainable waste management practice that reduces the adverse effects that arise from these biomass wastes. Briquettes were produced using cassava starch binder and molded manually using a hand then placed under the sun to dry. Results indicated that briquettes from corn stovers had least drop strength and bulk density than those of ground nut husks. Generally, cassava starch binder imparted higher drop strength due to its good binding properties and bonding. Results for boiling times show that ground nut husks had the highest boiling time of about 12.3 minutes. Boiling time indicates the time taken for briquettes to boil a known amount of water. The briquettes with low boiling times are desirable for domestic cooking purposes.

CHAPTER ONE: INTRODUCTION

This chapter describes the background information of the project, the problem statement and justification of the study, purpose, objectives and scope of the project. The problem statement describes the problem of the study and identifies potential causes and solution. The justifications describe the importance of the project and specific objectives which guided the study.

1.1 Background of the study

Uganda's energy needs are skewed toward biomass consumption, which accounts for more than 90% of the country's needs (Kyayesimira & Florence, 2021). Wood accounts for 70% of biomass consumption, charcoal 16%, and agricultural waste for 4% (Kammen & Kirubi, 2008). Other energy resources include fossil fuels, which make up 5% and hydroelectricity from two large dams as well as small hydro projects also amounts to 5% (Kamese, 2004).

Fuel for domestic cooking applications in Uganda, like most of the Sub-Saharan Africa is dominated by firewood (31.0% - Urban 85.2% - Rural) and charcoal (58.2% - Urban, 11.8% - Rural) (Openshaw, 2010). This has resulted in a 46% loss in Uganda's forest cover between 1990 and 2013. The effect of this has been a change in the climatic pattern which has affected farming due to either extended droughts or excessive flooding and rainfall (Mutekwa, 2009). Uganda's deforestation rate now stands at a rate of 1.8%. Uganda's population is growing at a rate of 3% per annum (Akinagbe & Irohibe, 2014). Demand for biomass energy is expected to increase in the short term to match this growth (Mutekwa, 2009). Therefore, there is increasing need to source alternative fuels, especially for cooking so as to reduce deforestation as a result of trees being cut for both charcoal production and firewood (Praveen & Sharma, 2019).

Conversely, briquettes have been applauded as environmentally friendly option to wood fuels as an energy source (Aziz et al., 2024). Briquettes also produce fewer toxic emissions into the environment and present less health hazard to humans than conventional energy sources of firewood and charcoal. Furthermore, briquettes are easy to handle, have a longer burning time than wood fuel sources, making them more cost effective to use in cooking (Ngusale, Luo, & Kiplagat, 2014). The by-products of agricultural activities are

usually referred to as "agricultural waste" because they are not the primary products. These wastes chiefly take the form of crop residues (residual stalks, straw, leaves, roots husks, shells etc.) and animal waste. Agricultural wastes are widely available renewable and virtually free, hence they can be an important resource (Jimenez-Lopez et al., 2020). They can be converted into heat, steam, charcoal, ethanol, bio diesel as well as raw materials.

In Uganda, maize is cultivated country wide, produced by over 3 million farmers (Daly, Hamrick, Gereffi, & Guinn, 2016) and is one of the staple foods depended on by many households (Epule, 2021). Ground nuts are majorly grown Eastern and northern parts and consumed widely in the country. According to Komakeck et al., the collected waste in Kampala comprised 88.5 % organics, with an average gross energy content of 17.3MJ/kg (Muzhingi, 2016). Uganda's crop energy potential is relatively high compared to that of Ethiopia and South Africa. (Adhikari et-al, 2015)

The consumption of several agricultural products has frequently resulted into waste disposal of the tree stems, leaves, and peels (Alalwan, Kadhom, & Alminshid, 2020). However, the disposal of these agricultural residues generated results into atmospheric pollution and pose serious health problems. The most common method of disposal is burning in open fields which have negative ecological impacts. Therefore, the utilization of corn stovers and ground nut husks in the development of an alternative domestic cooking fuel will reduce on the rate of deforestation for charcoal production and also enhance waste management (Alalwan et al., 2020). These advantages in combination enhance climate change mitigation and reduce environmental degradation and pollution.

The current study involves the production of briquettes from corn stovers and ground nut husks. The effect of different biomass combinations on physical and fuel properties were investigated to determine the optimum combination for briquette production. The objective of this study is to test the suitability of corn stovers and ground nut husks as sources of energy for domestic consumption.

1.2 Statement of the problem

The potential threat posed by climate change, due to high emission levels of greenhouse gases has become a major stimulus for renewable energy sources in general. When produced by sustainable means, biomass emits roughly the same amount of carbon dioxide as is taken up during plant growth. The use of biomass therefore does not contribute to buildup of carbon dioxide in the atmosphere. For biomass to make a significant impact as fuel for rural communities, it is imperative that an efficient, cost effective and easy to duplicate technology is developed specifically for rural communities. This study therefore aims at development and characterization of briquettes from corn stovers and ground nut husks as alternative fuel for cooking.

1.3 OBJECTIVES OF THE STUDY

1.3.1 Aim of the study

To fabricate and characterize briquettes from corn stovers and ground nut husks.

1.3.2 Specific Objectives

The study was guided by the following objectives;

- i) To make briquettes from corn stovers and ground nut husks.
- ii) To calculate the mechanical properties; Bulk Density and Drop Strength of the briquette samples.
- iii) To determine the efficiency of the developed briquettes using water boiling test.

1.4 Significance of the study

This study creates awareness to the people that agricultural wastes for example plant leaves, stalks, peelings and animal remains especially corn stovers and rice husks which are produced in large quantities especially in peak seasons can be used as an alternative energy source for cooking purposes both in rural and urban areas and can be used as a mitigative measure for climate change that arises due to pollution caused by burning these wastes or leaving them in the garden as manure. By turning these wastes into fuel, this will reduce on deforestation as the briquettes formed will substitute firewood and charcoal

which have occasionally been used for domestic cooking purposes especially in rural areas. The study aids people who would like to make briquettes for either small scale consumption or for business which enables to boost their standard of living.

1.5 Scope of the study

This research was based in the community of Nagongera sub county in Tororo District because of the availability of corn stovers and ground nut husks and a steady growing population and the increasing demand for fuel (power) for cooking.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This chapter reviews the existing literature on the production and characterization of briquettes from agricultural waste materials, with a specific focus on corn stovers and groundnut shells. It contains various briquetting technologies and techniques used for agricultural waste materials and the current state of knowledge on the mechanical and the thermal properties of briquettes.

2.1 Briquetting from solid waste

Briquetting is a process of compacting low density and loose combustible materials that are inefficient into high -density solid fuel of convenient shapes. Briquetting improves the physical, chemical and combustion properties of the raw materials (Olaoye & Kudabo, 2017). The briquetting of agro- residues improves material handling it increases the volumetric calorific value, reduces transportation costs and makes them useful for a variety of applications. The shape and size of briquettes are dependent on the mold, while the appearance and calorific values are dependent on the type of feedstock and level of compactness (Akhaton & Bazuaye, 2023).

Briquetting technologies are generally categorized into three: namely high, medium and low compaction technologies and can either be formed with or without binders (Kpalo, Zainuddin, Manaf, & Roslan, 2020b). (Olaoye & Kudabo, 2017) reported that agricultural residues such as straws, tree leaves, maize husks, grass, rice and ground nut husks, banana leaves, sawdust and castor stovers can be used for briquettes production and that though some materials have better calorific value than others, the selection of feedstock is usually dependent on what is readily available. There are several types of briquetting machines available for densification and compaction of biomass and their mode of operation vary from one principle to another (Eling, Okot, Menya, & Atim, 2024). These types of briquetting machines include screw press, manual piston press, hydraulic piston press and pellet press. Briquettes are low tech, environmentally friendly, and energy efficient alternatives to wood fuels, which are frequently associated with indoor pollution and its related health issues. Lubwama and Yoga developed carbonized Briquettes from

agricultural residues including mango waste, rice husks, coffee husks, sugar cane bagasse, and groundnut shells(Lubwama, Yiga, Muhairwe, & Kihedu, 2020). The results were positive in terms of moisture content (4.6- 13%), volatile matter content (16-65%), and calorific value (15-24 MJ/kg), hence providing an alternative to using charcoal and firewood(Thabane, 2020).Recent research was done in Makerere by Micheal Lubwama was done on characterization of Briquettes developed from rice husks and husks using clay and cassava starch binders. Results for boiling times showed that briquettes made from coffee husks had the lowest boiling time than those made from rice husks(Lubwama, Yiga, & Lubwama, 2022).

Adoption of briquette technology will not only create a safe and hygienic way of disposing of the waste but turn into a cash rich venture by converting waste into energy and also contributing towards a safer environment. Based on aforementioned, agro- biomass briquettes can be used as substitutes for conventional fuels and wood fuel(Chen, Xing, & Han, 2009).

2.2 Composition of Briquettes

2.2.1 Biomass material

This refers to the organic matter from plants, animals, or microorganisms, used as the primary component of briquettes. There are various types of biomass materials that can be used in briquette production, for example; agricultural wastes, forestry residues, municipal waste, energy crops, and industrial wastes.

2.2.2 Binding agent

This refers to the substance added to biomass materials to hold them together and form a compact briquette. Binding agents can be natural like, starch-based, lignin-based, natural polymers, among others or synthetic like, petrochemical-based, polymer-based, among others.

2.2.3 Moisture content

This refers to the amount of water present in a briquette, typically expressed as a percentage of the total weight. For most briquettes, the optimal moisture content is typically between 8-12% (Marreiro et-al, 2021). Moisture content affects combustion efficiency and the burn rate, impacts the storage and handling stability of the briquettes

2.2.4 Additives

This refers to the substance added to briquettes to enhance their properties and performance. These can be ignition aids (e.g., silica, gel, calcium chloride) to regulate moisture content, fillers (e.g., sand, silica) to improve density and strength, Anti-oxidants (e.g. vitamin E, BHT) to prevent degradation, among others.

2.3 Mechanical properties of Briquettes

2.3.1 Compressive strength

This refers to the ability of briquettes to withstand compressive forces without breaking or deforming (Obi et-al, 2022). Compressive strength affects briquette durability and resistance to handling and storage stresses. It also influences the combustion efficiency and burn rate and impacts briquette quality and overall performance.

2.3.2 Bulk Density

This refers to the mass of the briquettes per unit volume, including pores and voids. Bulk density affects energy density and the combustion efficiency of the briquettes. It also influences handling, storage, and transportation costs and impacts briquette quality and overall performance.

2.3.3 Durability

This refers to the ability of briquettes to withstand handling, storage, and transportation without breaking or degrading. Durability influences handling and storage costs, impacts combustion efficiency and the burn rate of the briquettes.

2.3.4 Tensile Strength

This refers to the ability of the briquettes to withstand the tensile forces without breaking or deforming (Obi et-al, 2022). Tensile strength affects briquette durability and resistance to handling and storage stresses. It also influences combustion efficiency and burn rate and the overall performance of the briquettes.

2.3.5 Drop strength

This refers to the ability of briquettes to withstand impact forces from dropping without breaking or deforming. Drop strength affects the briquette durability and resistance to handling and storage stresses, influences combustion efficiency, burn rate and the overall performance of the briquettes. Drop strength is affected by a number of factors like briquette composition, bulk density, moisture content, compaction pressure, particle size and distribution, binding agent type and amount.

2.3.6 Hardness

This refers to the resistance of the briquettes to indentation, scratching, or wear. Hardness of the briquettes affects their durability and resistance to handling and storage stresses, influences combustion efficiency and burn rate. Hardness of the briquettes is tested using methods like shore hardness test, Brinell hardness test, among others.

2.3.7 Young's Modulus

Young's modulus refers to the measure of stiffness or resistance to deformation under stress. It is tested using several methods like Uniaxial compression test, three-point bending test, four-point bending test, and dynamic mechanical analysis. Young's Modulus affects the briquette durability and resistance to the handling and storage stresses, impacts the briquette quality and the overall performance of the briquettes.

2.4 Thermal properties of Briquettes

2.4.1 Ash content

This refers to the amount of ash left after briquettes are burned. It is typically measured as a percentage of the briquette's dry weight (Sunna et-al, 2023). Ash Content is affected by factors like briquette composition (feedstock, binding agents, and additives), moisture content, particle size and distribution, compaction pressure, combustion conditions, among others.

2.4.2 Calorific value

The calorific value also known as the value of the briquettes is the amount of energy released when a unit mass of briquettes is completely burned (Antwi-boasiako, C & Acheampong,B.B, 2016). It is a measure of the energy density of the briquettes. Calorific value is an important property of briquettes since it affects combustion efficiency and the burn rate, influences the boiler or furnace design and operation. It determines the energy value of the briquettes.

2.4.3 Volatile matter

This refers to the amount of volatile gases released during combustion (Chaney, J 2010). The volatile matter of the briquettes influences furnace design and operation, impacts environmental emissions and pollution. It also determines the reactivity of the briquettes.

2.4.4 Ignition temperature

This refers to the lowest temperature at which briquettes will ignite and sustain combustion. The ignition temperature determines the ease of ignition and combustion, impacts environmental emissions and pollution. It is affected by factors like briquette composition, moisture content, particle size and distribution, combustion conditions (air flow, oxygen levels, etc.).

2.4.5 Specific Heat Capacity

This refers to the amount of heat energy required to raise the temperature of a unit mass of briquettes by one degree Celsius. The specific heat capacity determines the energy required for heating and combustion, and impacts environmental emissions and pollution.

2.5 Determination of Efficiency of Briquettes using water boiling test

The water boiling test measures the efficiency of briquettes by boiling water using the heat generated from burning briquettes using the steps below;

Step 1. Measure the initial temperature of the water

Step 2. Burn a known quantity of briquettes in a controlled environment.

Step 3. Measure the temperature of the water at regular intervals.

Step 4. Record the time taken to reach a predetermined temperature

Step 5. Calculate the efficiency using the following formula:

$$\text{Efficiency} = \frac{\text{Energy Output}}{\text{Energy Input}} \times 100\%$$

Where;

Energy-output = *Mass of water* × *specific heat capacity of water* × *Temperature rise*.

Energy input = *Mass of briquettes* × *calorific value of briquettes*.

2.6 Carbonization, Crushing, Sieving, Mixing, Binding, Briquetting, Drying and curing

Once the materials are sufficiently dry, they are carbonized to produce charcoal. A traditional kiln can be used for this purpose (Rodrigues & Junior, 2019). The kiln is constructed by digging a pit and covering it with a layer of soil, except for a small opening for air circulation (Norsker, 1987). The dried materials are then placed inside the pit, and a fire is lit through the opening. The kiln is covered with soil or a metal sheet to minimize oxygen supply and promote carbonization (Maneechot, Thanarak, & El Sharkawi, 2020). The materials are left to burn slowly for several hours until they turn into charcoal.

Once the charcoal has cooled down, it is removed from the kiln and crushed manually or using a simple grinding machine to reduce it into small pieces (Manual, 2018). This step helps in achieving uniformity in the final briquettes.

The sieved material is mixed with a binder material to facilitate briquette formation. Locally available binders such as cassava starch, corn starch, or clay can be used (Medashe & Abolarin). The binder is added gradually to the charcoal while continuously mixing until a homogeneous mixture is obtained (Skoczko & Guminski, 2020). The proportions of charcoal to binder can vary depending on the desired quality and consistency of the briquettes.

The mixture of materials and binder is then manually fed into a simple, hand-operated briquetting machine (Somorin, Gitau, Agbefu, & Gebrezgabher, 2023). This machine consists of a mold or a piston that compresses the mixture under pressure to form briquettes (Miah, 2017). The briquetting machine may be made from locally available materials or improvised using basic tools. The operator manually applies pressure on the lever or handle to compress the mixture and form the briquettes (Kpalo, Zainuddin, Manaf, & Roslan, 2020a).

The freshly made briquettes are laid out in a well-ventilated area to dry naturally (Ngusale et al., 2014). This process can take several days to a week, depending on the weather conditions. It is important to ensure that the briquettes are completely dry to enhance their combustion efficiency and prevent spoilage (Prihatin, Pratama, Kustanto, Pambudi, & Widodo, 2023). They should be turned periodically during the drying process to ensure uniform drying.

CHAPTER THREE: MATERIALS AND METHODS

3.0 Introduction

In this chapter, the steps used and the steps that were taken in the making of the briquettes and how the measurements were done in line with the objectives that will be discussed briefly.

3.1 Process of briquetting

3.1.1 Collection and drying of materials

The corn stovers and ground nut husks were sourced from local farmers in Nagongera town council in Tororo District. The roots of corn stovers were cut off and the materials were chopped into small pieces and then placed under the sun to dry to reduce moisture content. After drying the materials were grounded using manual grinding machine and then stored for further operations. The ground nut husks were sundried and grounded into smaller particles and then stored.

3.1.2 Preparation of the starch binder

To prepare the starch binder, a paste was produced using 400g of cassava flour, mixed with 3 liters of hot water with continuous mixing. Cassava is a good binding agent due to its chemical properties. It imparts higher drop strength onto the briquettes than clay binder material. Cassava starch is also available locally at low prices.

3.1.3 The preparation of the briquettes

The briquettes were produced using a manually and shaped using a hand. Briquettes of corn stovers and ground nut husks of different compositions were produced by adding one small cup of cassava starch binder. Water was added to the blend and mixed properly until a paste was formed. The briquettes were molded manually using a hand. The briquettes were dried under the sun for 7 days before analysis. After drying, the briquettes were taken to the laboratory for experimentation and data collection.

3.2 Determination of mechanical properties of the briquette samples

3.2.1 Calculation of Bulk density

The mass and diameter of the prepared samples were measured using a digital weighing scale and a Vernier caliper respectively. The bulk density of the briquettes was calculated from the ratio of mass to volume of the briquettes. The measured diameter of the samples was used to calculate the final volume of the briquette using the formula for determining the volume of a sphere given in the equation (Swetz, 1995).

$$Volume = \frac{4}{3}\pi r^3 \dots\dots\dots 3.1, \text{ where } r \text{ is the radius of the briquette.}$$

Then the bulk density was calculated using the following equation (Bhagwanrao & Singaravelu, 2014).

$$Bulk\ density = \frac{mass\ of\ the\ briquette}{volume\ of\ the\ briquette} \dots\dots\dots 3.2$$

3.3.2 Determination of the Drop strength

To determine the drop strength of the briquette using the drop test method, the briquette samples were elevated up to 1m and then dropped onto a cemented floor. The ratio of the weight after dropping to the weight before dropping was recorded as the drop strength. Drop strength is an indicator as to whether packaging, storage and transportation (Fengmin and Mingquan, 2011; Finney et al., 2009).

3.3.3 Determination of the efficiency of the samples using the water boiling test

In order to determine the efficiency of the developed briquettes using a water boiling test, the total time taken to ignite and boil 1litre of water using different briquette samples was determined (Chen et al., 2016; Lubwama and Yoga; Tumutegyereize). The briquette samples were placed in a charcoal stove and the briquettes were ignited using paraffin because it is easily combustible. Instantaneously a saucepan containing one cup of water was placed and the stop clock was started. The total time taken to ignite the briquettes and boil the water was noted and recorded as the boiling time of the samples.

CHAPTER FOUR: PRESENTATION AND DISCUSSION OF RESULTS

4.1 Sample of molded briquettes from corn stovers and ground nut shells



Figure 4.1: Showing the samples made briquettes

Figure 4.1 shows 30 uncarbonized briquette samples that were made with varying composition of raw materials. The briquettes made had a spherical shape with relatively small size. It can be seen that the briquettes made were so compact with minimal breaking and wearing and this could be due to the influence of the binder which was properly proportioned during the production.

4.2 Determination of the Mechanical properties of the prepared samples

4.2.1 Calculated Bulk density of Briquette samples

Table 4.1: Experimental values and calculated bulk density values

Ratio	$M(g)$	$m(kg)$	$d(mm)$	$r(m)$	r^3	$v(m^3)$	$d(kgm^{-3})$
5:0	28.48	0.02848	60.44	0.03022	2.76×10^{-5}	1.16×10^{-4}	246.260
3:2	36.29	0.03629	59.81	0.02991	2.67×10^{-5}	1.12×10^{-4}	323.811
2:3	37.96	0.03796	60.77	0.03039	2.81×10^{-5}	1.16×10^{-4}	322.913
4:1	34.85	0.03485	56.56	0.02828	2.26×10^{-5}	9.48×10^{-5}	367.706
0:5	49.56	0.04956	61.6	0.03080	2.92×10^{-5}	1.22×10^{-4}	404.777
1:4	38.71	0.03871	50.32	0.02516	3.48×10^{-6}	1.46×10^{-5}	580.000

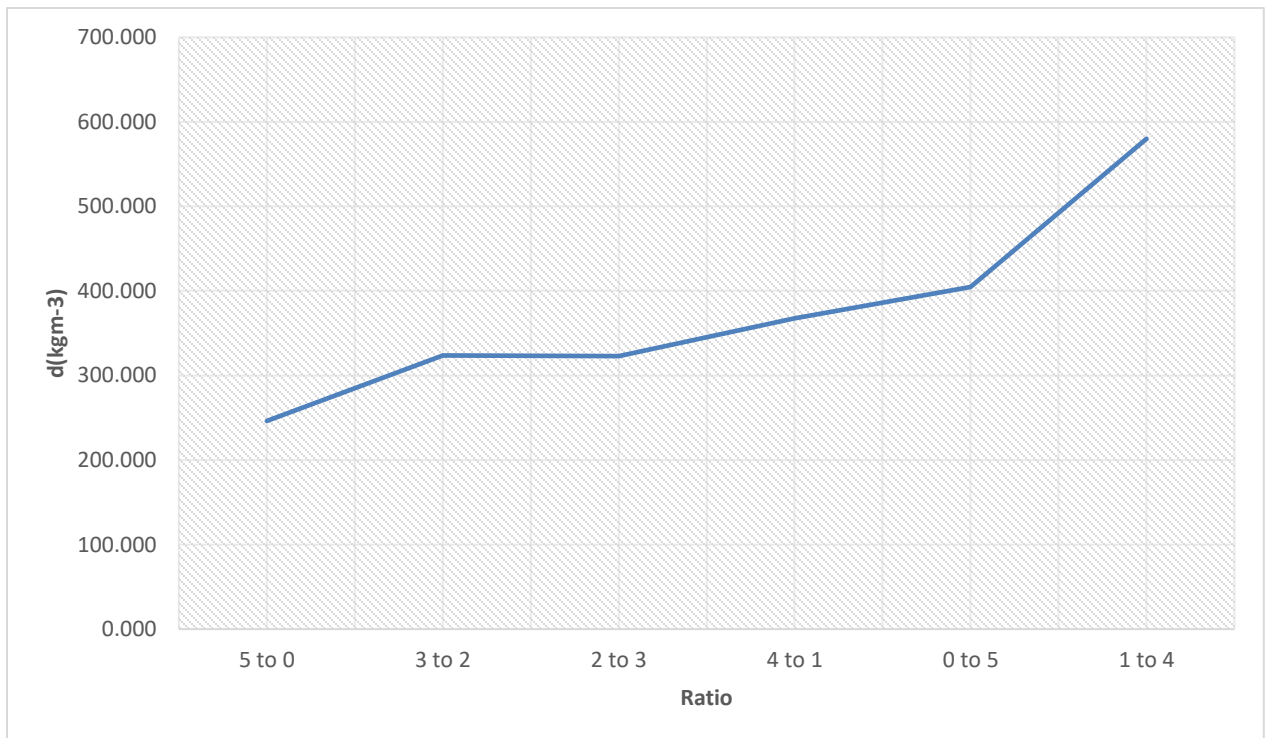


Figure 4.2: Showing variation of bulk density with different briquette types

From figure 4.2 above, briquettes from ground nut husks had the highest bulk density compared to other briquettes. Bulk density expresses the amount of material per unit volume. Therefore, briquettes with high drop strength are desirable.

4.3 Determined drop strength values of the Briquette Samples

Table 4.2: Experimental results for the drop strength of the briquette insamples

<i>Ratio</i>	$m_b(g)$	$m_a(g)$	$\frac{W_a}{W_b} \times 100\%$
2:3	37.69	37.69	98.06
5:0	30.09	30.05	99.87
4:1	34.85	34.83	99.94
1:4	38.46	38.45	99.97
3:2	36.31	36.31	100.00
0:5	49.56	49.56	100.00

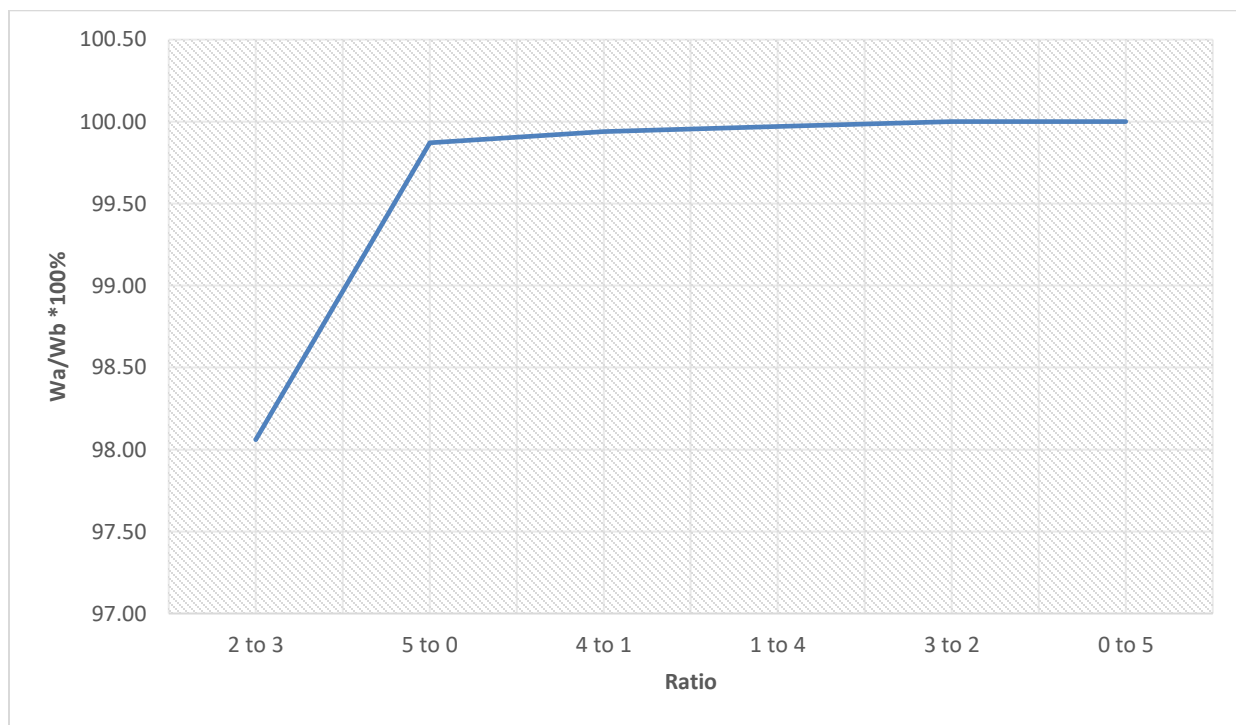


Figure 4.3: Showing the variation of the Drop Strength for the different briquette types

From figure 4:3 above, it can be seen that briquettes from groundnut husks had the highest drop strength and results showed that their drop strength is higher than that of briquettes from corn stovers.

Composite briquettes had higher drop strength compared to single substrate briquettes. The results for drop strength ranged between 98% and 100% which is slightly higher than those obtained in previous studies. Research done by Lubwama indicated that the drop strength of briquettes made from coffee husks and rice husks using starch binder had higher drop strength of about 94% developed using cassava starch as binder. This could have been as a result of variation environmental conditions during the drying process.

4.4 Boiling time

Table 4.3: Experimental results for boiling time for each briquette type.

CS:GH	Time (minutes)
5:0	4.5
4:1	5.1
3:2	6.8
2:3	7.5
1:4	10.2
0:5	12.3

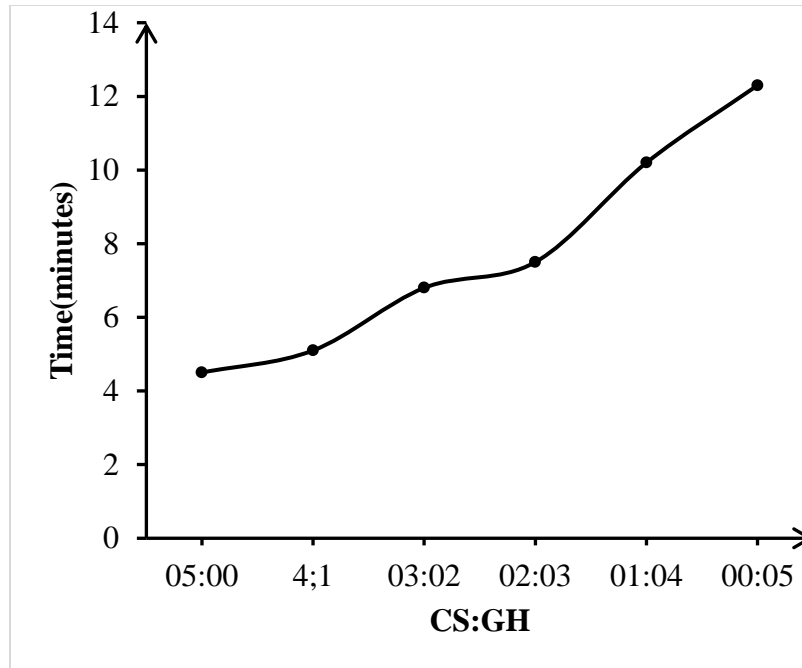


Figure 4.4: Showing the boiling time of 1/by the briquette sample

The total ignition and boiling time of one cup of water of the briquettes are shown in figure 4.4 above the tests were performed using a charcoal stove because they are used by majority of the population in Uganda for cooking purposes. Briquettes from Corn stovers had the lowest boiling times of about 4.5 minutes while those from pure ground nut husks had the highest boiling times of 12.3 minutes. Composite briquettes had higher boiling time than that of corn stovers. The boiling times of the briquette samples increased with increase in proportion of ground nut husks. The results obtained in the water boiling tests were influenced by the size and shape of the briquettes used that were less than what is described in other studies for example research conducted by Tumutegyereize showed that the boiling times ranged between 31.5 to 52.5 minutes to boil 8 to 10 liters of water using briquettes developed from matooke peels (Tumutegyereize P et-al, 2016). There results may be relatively less due to the size of briquettes and the amount of water used in the tests. The use of a cooking stove in order to align the study with what consumers actually use also affected the results because there is heat loss to the environment due to conduction, radiation and convection. However, the results for total time for ignition and water boiling highlight the possibility of applying less amounts of briquettes for cooking which saves energy for domestic use (Kpalo et-al, 2021).

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study investigated the suitability of agricultural waste for domestic cooking purposes as a substitute for wood and charcoal. Mechanical properties of the briquettes such as drop strength and bulk density and thermal properties such as boiling time of uncarbonized briquettes made from corn stovers and ground nut husks using cassava starch binder were investigated. The results showed that composite briquettes had the highest drop strength and briquettes from corn stovers had the least drop strength. The bulk density of the briquettes increased with increase in proportion of ground nut husks. Briquettes from ground nut husks had the highest boiling time and the boiling time decreased with increase in proportion of corn stovers.

5.2 Recommendations

To ensure sustainable energy use, agricultural wastes such as corn stovers and ground nut husks should be used for domestic cooking purposes especially for rural households. This will not only act as alternative fuel source but also mitigate climate change that arises as a result of over dependence on wood fuel. Although corn stovers and groundnut husks can be used for briquette production, composite briquettes have been reported to have better drop strength than single substrate briquettes. Results also show that briquettes from ground nut husks have greater bulk density thus easy to handle compared to that of corn stovers. I therefore recommend the next researcher in this area to investigate more on the physical and burning characteristics of briquettes developed from other agricultural wastes using various binders.

References

1. Adhikari, U., Nejadhashemi, A. P., & Woznicki, S. A. (2015). Climate change and eastern Africa: a review of impact on major crops. *Food and energy security*, 4(2), 110-132.
2. Akhator, P. E., & Bazuaye, L. (2023). Characterization of Fuel Briquettes Produced from Pet Plastics and Sawdust. *Journal of Energy Technology and Environment*, 5(2).
3. Akinnagbe, O. M., & Irohibe, I. J. (2014). Agricultural adaptation strategies to climate change impacts in Africa: A review.
4. Alalwan, H. A., Kadhom, M. A., & Alminshid, A. H. (2020). Removal of heavy metals from wastewater using agricultural byproducts. *Journal of Water Supply: Research and Technology—AQUA*, 69(2), 99-112.
5. Antwi-Boasiako, C., & Acheampong, B. B. (2016). Strength properties and calorific values of sawdust-briquettes as wood-residue energy generation source from tropical hardwoods of different densities. *Biomass and Bioenergy*, 85, 144-152.
6. Aziz, N. A. M., Mohamed, H., Kania, D., Ong, H. C., Zainal, B. S., Junoh, H., . . . Silitonga, A. (2024). Bioenergy production by integrated microwave-assisted torrefaction and pyrolysis. *Renewable and Sustainable Energy Reviews*, 191, 114097.
7. Belonio, A. T. (2005). Rice husk gas stove handbook. In: Central Philippine University.
8. Bhagwanrao, S. V., & Singaravelu, M. (2014). Bulk density of biomass and particle density of their briquettes.
9. Chaney, J. (2010). *Combustion characteristics of biomass briquettes* (Doctoral dissertation, University of Nottingham).
10. Chen, L., Xing, L., & Han, L. (2009). Renewable energy from agro-residues in China: Solid biofuels and biomass briquetting technology. *Renewable and Sustainable Energy Reviews*, 13(9), 2689-2695.
11. Daly, J., Hamrick, D., Gereffi, G., & Guinn, A. (2016). Maize value chains in East Africa. *Center on globalization, governance & competitiveness, Duke University*, 1-49.
12. Devi, M. K., Manikandan, S., Oviyapriya, M., Selvaraj, M., Assiri, M. A., Vickram, S., . . . Chang, S. (2022). Recent advances in biogas production using Agro-Industrial Waste: A comprehensive review outlook of Techno-Economic analysis. *Bioresource Technology*, 363, 127871.

13. Eling, J., Okot, D. K., Menya, E., & Atim, M. R. (2024). Densification of raw and torrefied biomass: A review. *Biomass and Bioenergy*, *184*, 107210.
14. Epule, T. E. (2021). Recent patterns of exposure, sensitivity, and adaptive capacity of selected crops in Cameroon. *Agriculture*, *11*(6), 550.
15. Jimenez-Lopez, C., Fraga-Corral, M., Carpena, M., García-Oliveira, P., Echave, J., Pereira, A., . . . Simal-Gandara, J. (2020). Agriculture waste valorisation as a source of antioxidant phenolic compounds within a circular and sustainable bioeconomy. *Food & function*, *11*(6), 4853-4877.
16. Kamese, G. (2004). Renewable energy technologies in Uganda: The potential for geothermal energy. *A Country Study Report under the AFREPREN/HBF study*.
17. Kammen, D. M., & Kirubi, C. (2008). Poverty, energy, and resource use in developing countries: focus on Africa. *Annals of the New York Academy of Sciences*, *1136*(1), 348-357.
18. Kpalo, S. Y., Zainuddin, M. F., Manaf, L. A., & Roslan, A. M. (2020a). Production and characterization of hybrid briquettes from corncobs and oil palm trunk bark under a low pressure densification technique. *Sustainability*, *12*(6), 2468.
19. Kpalo, S. Y., Zainuddin, M. F., Manaf, L. A., & Roslan, A. M. (2020b). A review of technical and economic aspects of biomass briquetting. *Sustainability*, *12*(11), 4609.
20. Kyayesimira, J., & Florence, M. (2021). Health concerns and use of biomass energy in households: Voices of women from rural communities in Western Uganda. *Energy, Sustainability and Society*, *11*, 1-13.
21. Lubwama, M., Yiga, V. A., & Lubwama, H. N. (2022). Effects and interactions of the agricultural waste residues and binder type on physical properties and calorific values of carbonized briquettes. *Biomass Conversion and Biorefinery*, *12*(11), 4979-4999.
22. Lubwama, M., Yiga, V. A., Muhairwe, F., & Kihedu, J. (2020). Physical and combustion properties of agricultural residue bio-char bio-composite briquettes as sustainable domestic energy sources. *Renewable energy*, *148*, 1002-1016.
23. Maneechot, P., Thanarak, P., & El Sharkawi, H. M. (2020). Carbonization of Wasted Biomass and Carbon Sequestration. *Recycle Based Organic Agriculture in a City*, 33-68.
24. Manual, A. G. T. (2018). Sustainable Woodfuel (charcoal and firewood) Systems in Tanzania.

25. Marreiro, H. M., Peruchi, R. S., Lopes, R. M., Andersen, S. L., Eliziário, S. A., & Rotella Junior, P. (2021). Empirical studies on biomass briquette production: A literature review. *Energies*, *14*(24), 8320.
26. Medashe, M. O., & Abolarin, M. S. Development and Characterisation of Briquettes from Biomass Wastes: A Review.
27. Miah, M. (2017). Effect of additives on rice husk briquette by piston press system.
28. Mutekwa, V. (2009). Climate change impacts and adaptation in the agricultural sector: The case of smallholder farmers in Zimbabwe. *Journal of Sustainable Development in Africa*, *11*(2), 237-256.
29. Muzhingi, A. (2016). *Forward osmosis of stored urine*.
30. Ngusale, G. K., Luo, Y., & Kiplagat, J. K. (2014). Briquette making in Kenya: Nairobi and peri-urban areas. *Renewable and Sustainable Energy Reviews*, *40*, 749-759.
31. Norsker, H. (1987). *The Self-reliant potter: refractories and kilns*: F. Vieweg.
32. Olaoye, J., & Kudabo, E. (2017). Evaluation of constitutive conditions for production of sorghum stovers briquette. *Arid zone journal of Engineering, Technology and Environment*, *13*(3), 400-412.
33. Openshaw, K. (2010). Biomass energy: employment generation and its contribution to poverty alleviation. *Biomass and Bioenergy*, *34*(3), 365-378.
34. Praveen, B., & Sharma, P. (2019). A review of literature on climate change and its impacts on agriculture productivity. *Journal of Public Affairs*, *19*(4), e1960.
35. Prihatin, J. Y., Pratama, G. W., Kustanto, H., Pambudi, S., & Widodo, L. (2023). *The Study Calorific Value of Organic Briquettes for Optimizing Healthy Food Drying as an Alternative to Rainy Weather*. Paper presented at the Proceedings of the 4th Borobudur International Symposium on Science and Technology 2022 (BIS-STE 2022).
36. Rodrigues, T., & Junior, A. B. (2019). Charcoal: A discussion on carbonization kilns. *Journal of analytical and applied pyrolysis*, *143*, 104670.
37. Skoczko, I., & Guminski, R. (2020). Research on the Development of Technologies for the Production of Granulated Activated Carbons Using Various Binders. *Materials*, *13*(22), 5180.
38. Somorin, T., Gitau, J., Agbefu, D., & Gebrezgabher, S. (2023). Biomass briquetting: a training module for trainers and practitioners.

39. Sunnu, A. K., Adu-Poku, K. A., & Ayetor, G. K. (2023). Production and characterization of charred briquettes from various agricultural waste. *Combustion Science and Technology*, 195(5), 1000-1021.
40. Swetz, F. J. (1995). The volume of a sphere: a Chinese derivation. *The mathematics teacher*, 88(2), 142-145.
41. Thabane, K. (2020). *Development of charcoal briquettes using Sehalahala (Seriphium plumosum and Felicia filifolia)*. National University of Lesotho,
42. Tumutegyereize, P., Mugenyi, R., Ketlogetswe, C., & Gandure, J. (2016). A comparative performance analysis of carbonized briquettes and charcoal fuels in Kampala-urban, Uganda. *Energy for Sustainable Development*, 31, 91-96.
43. Obi, O. F., Pecenka, R., & Clifford, M. J. (2022). A review of biomass briquette binders and quality parameters. *Energies*, 15(7), 2426.