International Journal of Thesis Projects and Dissertations (IJTPD)
Vol. 4, Issue 3, pp: (135-158), Month: July - September 2016, Available at: www.researchpublish.com

A Study of Combustion Characteristics of Fuel Briquettes from a Blend of Banana Peelings and Saw Dust in Malawi

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Abstract: **The study was undertaken to assess the combustion characteristics of briquettes produced from mixed Banana Peelings and Saw-dust as binder. Combustion characteristics investigated were volatile matter, ash content, dry matter base, moisture content, ignition time, burning rate, and water boiling time. The combustion characteristics of banana peelings fuel briquettes was compared with waste paper fuel briquettes due to its only presence on Malawian market though available in small scale. The combustion characteristic of the briquettes produced from these densification (briquetting) variables competed favourably with firewood which is a main cooking energy means in Malawi and account for 96 % in the rural areas and 42% in the urban (Census Main Report, 2008 pp 18). Furthermore, for banana peelings with saw dust and waste paper with saw dust, the volatile matter of was 90±0.5% and 88.3±2.6% respectively and there was no significance difference (P-Value=0.426). The ash content both parameters were 10.1±0.4% and 10.3 ±2.8% respectively and there was no significance difference (P-Value=0.170). Also the dry matter base for both parameters were 90±0.3% and 86.3±6.1% respectively and there was no significance difference (P-Value=0.609). In addition the moisture content for both parameters were 10±0.3% and 13.2±6.1% respectively and there was no significance difference (P-Value=0.609). The ignition time for both parameters were 57.1±0.4 seconds and 39.7±0.4 seconds respectively and there was a significance difference (P-Value=0.000). It was observed that the burning rate for both parameters was 2.5±0.5grams/minute and 2.4±0.6gram per minute respectively and there was no significance difference (P-Value=0.084). Lastly the ash water boiling time for 100cm3 both parameters were 12.6±0.4 minutes and 16.6±0.51 minutes respectively and there was a significance difference (P-Value=0.000). The results confirm the possibility of utilizing banana peelings as fuel briquette of good source that support combustion. Thus banana peelings briquettes possess the high material strength as well as high value combustible fuel; hence they can be a compliment energy source to the firewood in Malawi.**

Keywords: **Ash Content (AC), Boiling Test (BT), Burning rate (BR), Calorific Value (CV), Dry Matter (DM), Fuel Briquette, Ignition time (IT) and Moisture Content (MC).**

1. INTRODUCTION

Energy is a core prerequisite for everyday life. Its application ranges from cooking, local industrial and food processes, warming of the body and complex industrial and commercial applications. The household sector is the dominant energy user, accounting for about 84% of total consumption in Malawi. The remaining 16% is used in the agricultural and natural resources sector (8%), transport (4%), industry and mining (2%), and other social services (2%). Biomass, principally firewood and charcoal, is its source and accounts for an estimated 93% of demand (Gregory et al, 2013). Liquid fuels, electricity, coal and other renewables contribute, respectively, 3.5%, 2.3%, 1.0% and 0.2% to the total demand. Rural households account for 58% of woodfuel consumption, urban households use 12%. Of commercial energy, that is, liquid fuels, electricity and coal, transport is the chief consumer (43%), followed by industry and mining (19%), other services (18%), agriculture (12%) and households (8%) ((E.I.U), 2008b). The transport sector is also the largest consumer of liquid fuels. Paraffin(kerosene) and LPG are important cooking fuels in many developing countries, but they are rarely used in Malawi principally because of their relatively high price. Mainly households without electricity use paraffin and candles for lighting (Zeller, 2012). The biomass resources of Malawi can be identified as wood forage, grasses, shrubs, animal wastes, wastes arising from agricultural, municipal, as well as industrial activities, etc. (Gondwe, 2007). The potential for the use of biomass as energy source in Malawi is very high because about 80% of Malawians are rural and semi-urban dwellers and they solely depend on biomass for their energy needs ((E.I.U)., 2008b). Particularly, fuel wood accounts for about 90% of the total wood demand from the forest and the demand is still on the increase due to population increase and lack of alternative energy source (Williams, 2009). The result of this is a gradual depletion of the total forest cover of the country owing to the fact that the deforestation rate is higher than the afforestation efforts in the country. Biomass energy is derived from plant-based material and residues where solar energy has been converted into organic matter. One of the most challenging tasks facing Malawi, just like other developing countries, is finding a means of expanding its energy services especially to the rural households and at the same time addressing the health and environmental consequences of over dependence on firewood for cooking. “Briquetting of biomass process simply means compressing the material to increase its density and to enhance its handling characteristics and fuel characteristics” (Kantimaleka, 2009, pp. 104).

The process of making charcoal briquettes from agricultural waste is not new. Many institutions have experimented on different agricultural residues to find out which raw materials are possible for charcoal making. The Legacy Foundation and its partners have tested the briquette making process in urban and rural areas such as Malawi, Peru, Mali, Uganda, Haiti, Kenya, Zimbabwe, Nicaragua, Nicaragua and the United States. It is now being used in many places, such as Europe, Haiti and India and even in the Philippines (Environment, 2012). Biomass briquettes are a bio-fuel substitute to a firewood and charcoal. They are mostly made of green waste and organic materials. Gondwe (2009) argues that, environmentally, the use of biomass briquettes produces much fewer greenhouse gases, specifically 13.8% to 14.7% CO_2 and 11.1% to 38.5% in SO_2 emission when compared to coal and charcoal. Even when there is co-firing (use of briquettes together with charcoal or coal) emission of pollution is lowered. The overall bio-briquetting process from production to end-use offers solution to the disposal of harmful waste, results in a cheaper form of energy, creates new employment/business opportunities and is very eco-friendly (Wilaipon P, 2013).

1.2. Problem Statement

Malawi as a country is by far experience a catastrophic deforestation (at the rate of 2.5% per annum) due to firewood and charcoal production (accounting for 93% domestic energy source) which has contributed to climate changes, soil erosion, floods and siltation among others. Furthermore, there is a lot of depositing and littering around of waste, creating an eye-saw (land pollution) in our homes, towns and cities in this country. On the contrary, Malawi has a population of 16,777,547 (Malawi Demographics Profile, 2013) where only 7% of this population has access to electricity for domestic use. There is little affordable option to biomass energy currently available on the Malawian markets despite them being cheaper in production and less emission of CO_2 (Bona., 2001) .Thus, firewood and charcoal characterized by low efficient end-use devices will continue to dominate the energy balance in the country. Environmental degradation would be accelerated unless something is done to balance the effect. Is it possible whether to marry the waste (banana peelings and saw-dust) and energy production while preserving the environment? Thus in long term, minimize environmental degradation and climatic change, reduce utilization of wood fuels as energy sources, improve human health and lead into greater afforestation in Malawi.

1.2.1. Sub-problems

1. What are the resulting combustion characteristics properties of the different samples of briquettes in terms of;

A. Ash content and volatile matter

B. Moisture content and dry matter

C. Ignition time and burning rate

D. Water boiling time.

2. Is there a significance difference in the physical properties of the briquettes?

1.3. Objectives

1.3.1. Main objective

This project aimed at evaluating the combustion characteristics of fuel briquettes from a blend banana peelings and saw dust, by determining the burning time, ash content, moisture content, volatile matter, water boiling time and gas emitted. Then compared with standard values of other briquettes and wood, a commonly used fuel

1.3.2. Specific Objectives

I. To come up with a blend of banana peelings and saw-dust briquettes.

II. To test the usability of the blend of banana-saw dust briquette.

III. To compare the combustion characteristics of briquettes from a blend of banana peelings and saw-dust to the blend of waste paper and saw-dust.

1.4. Justification

Energy is a necessary requirement for everyday life. The banana production occurs in many countries, and Malawi is not an exceptional. Research has shown that dry banana peelings possess 7.7-8.8 MJ/kg of DM (University of Liège, 2008), as such, Bananas have more kilojoules of energy as compared to paper (3.5-4.5MJ/kg of DM) and saw-dust. It is in this line that this project projected at evaluating the viability of biomass briquettes from a blend of banana peelings plus saw-dust as a sustainable alternative energy source to firewood and charcoal for households in Malawi. This might help to break the vicious cycle of charcoal dependence as prime source of energy especially as house hold revel. Furthermore this might raise the living standard of the poor, improve the socio-economic status and empowerment of women, develop and promote sustainable and renewable energy technologies; and Strengthen institutional and household capacity for the management of sustainable and renewable energy.

1.5. Hypothesis of the Study

There is no significance difference in the burning time, ash content, moisture content, dry matter, volatile matter, water boiling time and ignition time of different kinds of briquettes.

1.6. Scope and the Study boundaries

The study was limited to the utilization of the banana peelings and waste paper with sawdust as components in briquettes. For the determination of the combustion characteristics of the briquettes, the study was limited to the determination of the burning time, ash content, moisture content, dry mater, volatile matter, water boiling time and ignition time. The experimentation was done during the school year 2014-2015.

1.7. Significance of the Project

Some of the benefits of using agricultural wastes, such as sugarcane trash, grass, and saw dust and so on, as an

alternative cooking fuel can be described as follows: Unlike firewood, briquettes are a low smoke producing fuel. The smoke produced by wood fires in an indoor cooking environment can lead to multiple respiratory illnesses (Kammen, 2009). Biomass briquetting is viewed as an advanced fuel because of its clean-burning nature and the fact that it can be stored for long periods of time without degradation. Therefore, a micro- enterprise can be formed around the production of energy derived from agricultural waste (banana peelings). By turning something that was previously little used into a means by which to produce income, the wealth of individual entrepreneurs and the country in general is increased (Akinbami, 2001).

2. LITERATURE REVIEW

2.1. Households and Energy

Malawi's Population Census of 2008(Main report, page 100) counted 243,716 households, each of which averaged 5.3 people. Eighty four percent of these households are in rural areas, the remaining 16% are urban. Biomass supplies satisfy about 88% of household energy demand (used by 11,054,103 heads). The remaining 2% comes from electricity (for lighting and, to a lesser extent, cooking, which supports 292,678 heads), paraffin and candles (for lighting). The biomass is principally firewood (80%), charcoal (8.8%) and crop and industrial residues (11.2%). Although it is available, Malawian households do not use coal, principally because of the lack of appropriate end-use appliances and its high cost (Initiative., 2013). Dependence on traditional primary energy sources on this scale is, on the one hand, an indication of abject poverty and, on the other, an extremely high incidence of low-cost traditional biomass conversion technologies, end-use cook-stoves and appliances (Baruah, 2013).

2.2. Dependency on Firewood and Charcoal

Energy problems are never rare in Malawi; ranging from persistent blackouts, to low power production whose lasting solution is yet to be traced. In Malawi 2.5% of the forest disappears each year (Gregory et al, 2013). The use of firewood and charcoal, deriving from forest resources, accounts for about 93% of the household energy demand in Malawi and is a cause to the deforestation. The Government of Malawi launched a programme called Promotion of Alternative Energy Sources Programme (PAESP) with the aim to reduce the use of firewood and charcoal. One of the fuels included in the programme is the biomass briquette (Zana, 2010). Zingwangwa Briquettes Project implementation in May 2012 followed the successful implementation of Chemusa Briquettes Project, in Blantyre Central in 2012.

Like their counterparts in rural areas, urban households in Malawi depend on firewood (50%) and charcoal (43%). Other important sources of energy in urban households are paraffin, candles and electricity (0.7%, 0.1%, and 13.6%, respectively). LPG is used by 1% of urban households and 4% use paraffin for cooking (half use paraffin only occasionally). Some paraffin is used as starter fuel to light charcoal fires ((E.I.U)., 2008b). Similarly, LPG is used infrequently as a backup for cooking and illumination. Firewood is used mainly for cooking (76%), water heating (22%) and space heating (2%). Charcoal is used for cooking (48%), ironing (24%), space heating (16%) and water heating (12%) (Initiative., 2013). Seventy-nine percent (79%) of urban fuelwood users collect some wood themselves which results in more lopped branches. Forty three percent buy some, and 24% buy all, of their fuelwood. While almost all fuelwood used by rural households is collected free of charge, that used by urban households is purchased. In 2011, the wood consumed by urban households was estimated at 1.241 million tonnes, of which 844,550 tonnes (68%) was in the form of charcoal (Zeller, 2012). Because most urban dwellers live in the four major towns, 86% of the wood was used in them. Most of it (85%) was purchased in local markets, the other 15% was obtained free of charge from local sources (Sengar S.H., 2012).

2.3. Related Studies on Briquettes

The fuel consumption efficiency, calorific values, boiling time, burning rate, specific fuel consumption and ignition time of traditional fuel sources utilized in Africa have also been investigated. For example, the approximate ash content of papaya peelings + sawdust and mango peelings are 10.14% and 10.48% respectively and their approximate moisture contents are 69.00% and 74.00% respectively, whereas the calorific values are 14,150 kJ/kg and 15,000 kJ/kg, respectively (Michelle et al, 2012). The fuel utilization efficiency of the water hyacinth briquette is (28.17±0.88%), charcoal is (43.29 ± 0.19%), red mangrove wood is (23.55±0.56%) and firewood is (21.31±0.28%) in Africa. The fuel utilization values differed significantly between the variables ($P<0.001$). Furthermore, the fuel efficiency of charcoal is (43.29 ± 0.19%) was the highest, followed closely by fuel briquette which is (28.17±0.88%). However, the produced fuel briquettes complied with the standard regulations for the protection of the environment, particularly in area of low emissions of harmful substances such as SO2 and NO2 to the atmosphere. Produced briquettes were found to be safer than charcoal due to emission of dangerous gases to the environment. The results were compared to the commercial sawdust briquettes and to the minimum requirements of DIN 51731(Purohit et al., 2006).

The calorific values of the energy sources ranged from 4166.68±4.3kcal/kg (firewood) to 6552±4.7kcal/kg (charcoal). The disparity of the caloric values of the fuel types was significantly different ($P<0.001$). The calorific value of water hyacinth briquette was found to be higher than calorific values of firewood and mangrove but lower than charcoal. This is an indication that more heat during combustion may be generated from briquette than firewood and mangrove but lesser than that of charcoal (Kuti 2007 and Aina et al.2009).

The recorded boiling time values were found to be 11.43±0.43min (briquette), 14.94±0.22 min (charcoal), 9.25±0.42min (firewood) and 8.99±0.2 min (mangrove). The values of the boiling time of the energy sources were significantly different ($P<0.001$). Among the energy sources mangrove had the shortest boiling time while charcoal had the longest duration of water boiling time. It could be inferred that biomass having highest calorific value does not guarantee shortest water boiling time (Michelle et al, 2012).

The burning rate values of the energy sources ranged between 0.97±0.01g/min (charcoal) and 2.49±0.01g/min (firewood). The variation of the burning rate values of fuel types was significantly different ($P<0.001$). Charcoal recorded the lowest burning rate than other energy sources. This observation could be due adduced to porosity exhibited between inter and intra–particles which enable easy infiltration of oxygen and out flow of combustion briquettes (Michelle et al, 2012). Onuegbu et al. (2011) reported factors that could be responsible for burning rate of biomass (briquettes) such as chemical composition, volatile matter content and geometry (bulk and packing orientation) of the biomass.

The specific fuel consumption of the four fuel sources were 217.00±0.58g (briquette), 228.00±2.52g (charcoal), 264.00±2.08g (firewood) and 253.33±1.86g (mangrove). The variation of the specific fuel consumption values of the studied energy sources was significantly different ($P<0.001$). Hence, biomass of higher ash content tends to consume more fuel for cooking than biomass of lower ash content. According to Onuegbu et al. (2011) reported that percentage ash content is one of the factors that affect specific fuel consumption of fuel briquettes negatively. The percentage ash content as reported by Onuegbu et al. (2011) for 18.23% for coal while the present result recorded ash content ranged from 5.3 to 6.7% for mixture of water hyacinth with binder. The ash content values for some agricultural wastes namely palm oil effluent (10.97%), corn cob (4.85%), yam peels (4.56%), mango peels (4.33%), black walnut hull (4.10%), cherry (3.80%), coconut shell (3.47%) and orange peels (2.66%) (Jekayinfa, 2005).

The ignition time of the studied fuel types varied between 84.33±0.28 seconds (firewood) and 138.29±0.19 seconds (charcoal). There was significant difference in variation of the ignition time of the energy sources. The observed values on ignition time showed that charcoal took a longest time for it to start burning and stress as compared to other energy sources. This could be adduced its low volatile matter as compared to other biomass and high ash content. Dermirbas and Sahin (1998) recommended that briquettes for domestic use must be easily ignitable, but with low porosity index, low volatile content and low ash content. Onuegbu et al. (2010) improved the suitability of charcoal for domestic use by blending the elephant and spear grass at different concentration of 10 -50% with coal thereby reduced ignition time from 186 seconds to 33 seconds.

The mean moisture contents of cassava and yam peels residues were 10.19% and 9.27% respectively, while those of relaxed briquettes were 8.76% and 7.95% respectively (Che Zhanbin, 2011). The initial, maximum and relaxed densities were 251.50 kg/m3; 741.13 kg/m3 and 386.4 kg/m3 respectively for briquettes produced from cassava peel, while the corresponding values for briquettes produced from yam peel were 283.40 kg/m3; 911.45 kg/m3 and 512.54 kg/m3 respectively. The compaction ratio of 2.94 and 3.21 were obtained for briquettes produced from cassava and yam peels respectively (Che Zhanbin, 2011). The higher heating value of briquettes from cassava peel was found to be 12,765kJ/kg (SD 30), while the corresponding value for yam peel was 17,348kJ/kg (SD 20). The results of this work indicate that briquettes produced from the two biomass residues would make good biomass fuels. However, findings show that yam peel briquette has more positive attributes of biomass fuel than its cassava peel counterpart. It has a moderate moisture content of 10.95 %, higher density of 911.45 kg/m3 and lower relaxation ratio of 1.78. Other positive attributes of yam peel briquette over cassava peel are long after glow time of 375 seconds and slow propagation rate of 0.16 cm/s. It also has higher heating value of 17,348 kJ/kg and compressive strength of 1.76 kN/m2 compared to cassava peel, which are 12,765 kJ/kg and 1.53 kN/m2 respectively (Purohit et al., 2006).

The average energy values of the briquettes produced using cassava peel as binder from rice husk, maize cob, groundnut shell and sugarcane baggasse were found to be 26.612MJ/Kg, 28.255MJ/Kg, 33.703MJ/Kg and 32.762MJ/Kg, respectively (Oladeji J.T., 2011). The results indicate that briquettes produced from groundnut shell using cassava peel gave the highest energy value of 33.70 MJ/kg while those obtained from rice husk using cassava peel gave the lowest calorific value of 26.61MJ/kg and these were significantly different ($P\leq 0.05$). The briquettes from these by-products in terms of energy values are ranked as follows: groundnut shell > sugar cane baggasse > maize cob > rice husk. The effective utilization of these agricultural by-products as high grade solid fuel can reduce environmental pollution resulting from the wastes and also help in minimizing the energy crisis resulting from non- renewable energy sources like petroleum products as domestic fuel (Oladeji J.T., 2011).

2.4. Population Growth and Energy.

Malawi is one of the poorest countries in the world, with 55 % of the population living on less than US$1 a day (MEP, 2011). The industrial sector in Malawi is small and the country's energy is almost solely used in households. Hence a situation where the forest is disappearing mainly affects the ability for households to meet their energy needs, which is most commonly spent on cooking. Unfortunately the handling of forests in Malawi is not sustainable today. Every year 2.5 % of the total forest in Malawi disappears according to government statistics (MASEDA, 2009). The reasons are various, but the extensive use of forest as resource for providing firewood and charcoal, is one of them. Malawi’s forest resources are being harvested at unsustainable rates. Much of this deforestation is caused by the country's demand for charcoal and wood to meet its daily energy requirements. Firewood is the most important among biomass sources, contributing to about 88% of total domestic energy in SNNPRS Distribution of households by type of fuel they use for cooking purpose (2008 SNNPRS Main Report, pp 18)

As population grows, consumption of firewood and charcoal is likely to increase since the supply of alternative sources of energy are limited in Malawi. This phenomena will in turn aggravate deforestation; thus calling for alternative sources of energy. One of those is fuel briquette which could be made available cheaply for low income households (Zeller, 2012).

Low income households are assumed to consume, on average, 2.5 kg of firewood per day. On this assumption, total annual consumption by all urban households in a year would amount 216,310 tones. Assuming that about 10% of the demand will be covered by fuel briquette, effective demand for fuel briquette in the region is estimated at 21,631 tons. The future demand for fuel briquette is projected on the basis of the urban population growth rate of 4%; and the result ranges from 12,320 tons by the year 2005 to 22,510 tons by the year 2019 (Climate, 2012).

In 2008, this amounted to a forest consumption rate of 15,000 hectares every year. Charcoal made from wood is often transported distances in excess of 40 miles on a bicycle for purchase by consumers. This raises the price of charcoal and creates the opportunity for alternative fuels to become more economically feasible (Malawi climate, 2010).

The use of fuel wood in the large scale without replenishing poses serious environmental consequences in any country, desertification being the most significant one. Also population increase in countries like Malawi calls for more demands on energy to light and heat homes, to cook food, to drive transport, and communication devices and provide power for industries (Baruah, 2013). According to the world's energy topics, it is widely accepted that fossil fuel shortage, fuel increasing price, global warming including other environmental problems are critical issues that need immediate solutions. Therefore, biomass energy has been attracting attention as an energy source since less net carbon dioxide accumulation in the atmosphere from biomass production and utilization can be achieved. The carbon dioxide released during combustion process is compensated by the carbon dioxide consumption in photosynthesis (Baruah, 2013). Akinbami (2001) reported that the increasing pressure on forest resources for energy has led to what is called "Other Energy Crisis of wood Fuel". This has led to environmental degradation, deforestation and misuse of soil forests and water resources. The uncontrolled level of cutting of wood for firewood and charcoal for combustion, and for other domestic and industrial uses, is now a serious problem in Malawi. To address the various energy challenges related with non-renewable fuels, many countries have committed to biofuel production that are renewable, sustainable, cheap, efficient and geographically diversified where research on briquettes is mostly encouraged (Southern Centre, 2012). The main advantage of biofuel are its domestic origin, potential for reducing total dependence on oil and gas economy, energy security and waste management, jobs creation and source of revenues to the government and rural farmers, it also offers benefits of regional development, and social structure, especially to developing countries like Malawi (Zeller, 2012).

2.5. Briquettes in Malawi

The production of briquettes from banana peelings might exemplify the potential of appropriate technology for banana waist utilization (Sheikh, 2012). It might save trees thereby preventing soil erosion and desertification by providing an alternative to burning wood for domestic and industrial heating and cooking. Also, it might substitute banana-peelings as a waste in the environment for a valuable resource. Biomass briquetting improves health by providing a cleaner burning fuel and also provides a better alternative to firewood (40% more efficient, longer burning and better) as well as helping to protect the environment by reducing the number of trees cut for firewood. In addition, briquetting in Malawi might engenders many micro enterprise opportunities that include the production of the presses from locally available materials, using materials like agricultural waste and sawdust, briquette production enterprise, packaging and selling of the briquette. These can be burnt clean and therefore are eco-friendly arid also those advantages that are associated with the use of biomass are present in the briquettes (Sheikh, 2012).

As written in Ndirande Nkhuni briquette, "Introducing briquettes in rural households can decrease the time women spend on collecting firewood, thereby freeing time for other economic activities and reducing the risk of rape" (Bona., 2001).

Briquette making has the potential to meet the additional energy demands of urban and industrial sectors, thereby making a significant contribution to the economic advancement of developing countries. Besides, briquettes have advantages over fuel wood in terms of greater heat intensity, cleanliness, convenience in use, and relatively smaller space requirement for storage. However, in order to make a significant impact as a fuel source, there is the need to improve and promote its production technology (Zana, 2010).

Malawi is number 28 in the world ranking with a world share of 0.4% in-terms of banana production (FAO, 2012). See table 1 below

DATA SET	RANK	VALUE	DATE
Bananas production quantity (tons)	28	380.000	2012
Bananas area harvested (hectare)	40	14.000	2012
Bananas yield (hectogram per hectare)	28	271.429	2012

Companies have also come up with banana plantation in Salima district, from 2013 for agro-industry. This mean the production of bananas in Malawi is expected to rise rapidly (Malawi Nation, June 04 2014).

3. MATERIALS AND METHODS

3.1. Research Design

The approximate burning time, ash content, moisture content, dry mater, volatile matter, water boiling time and ignition time were determined. The briquettes were produced from waste paper and banana peelings with sawdust. The study utilized the randomized complete block design (RCBD) since there were two different treatments that were grouped into blocks. The treatments were varied so the results may be compared. There were two treatments and in each treatment there were three samples. The research determined if there was a significant difference in burning time, ash content, moisture content, dry mater, volatile matter, water boiling time, ignition time and gas emitted. The study used a T-test for testing the difference between two means with small independent samples.

3.2. Methodology

This project embarked on quantitative approach because burning time, ash content, moisture content, dry mater, volatile matter, water boiling time and ignition time were analysed.

3.3. Materials and Equipment

Chopping Board, Knife / Kitchen Scissors, Measuring Cups, Waste paper, Banana peelings, Sawdust (binder), Blender, Analytical Balance, Brazier (Chitetezo Mbawula), Stop Watch, Gas Analyzer, Briquette Making Machine, Blender, Analytical Balance, moisture dishes, desiccators, oven , 2 sliver pots, thermometers, crucibles, crucible tongs.

3.4. Collection of Raw Materials

The raw materials (banana peelings) were gathered from various fruit vendors at Kamba Market, Queen Elisabeth and around Polytechnic campus. Personal consumption of banana fruits also contributed to the quantity of the raw materials. The banana peels were sun dried as shown in figure 1. Sawdust was collected from Technical Education Lab. The old idle news papers were used as waste paper and they were collected from the Physics Department.

3.5. Experimental Briquette Design Set-Up

Brandon (2012) of California State Science Fair, determined which ratio of waste paper to sawdust burns the best and fund out that the optimal viable fuel source briquette is that of 70% paper and 30% sawdust, which after 10 minutes of burning, the pot of water reached a normalized temperature of 52 degrees centigrade and the briquette burns better than white pine, the same as poplar, but less efficiently than red oak. The research also concluded that materials like maize husk, rice husk, dry grass, sugarcane husk, cassava peelings, mango peelings, dry leaves, sweat potato peelings, pine apple peelings, avocado pairs and orange peelings, gave the optimal viable fuel source when blended with saw dust at the ratio of 70% (agricultural waste) and 30% sawdust. After 10 minutes of burning, the pot of water reached a normalized temperature of 52,±7 degrees centigrade. It is from this reason that the project based on the same ratio as depicted in Table 2 below.

COMPONENT	TREATMENT A	TREATMENT B
Banana Peelings (g)	70%	0%
Waste Paper (g)	0%	70%
Sawdust (g)	30%	30%

3.6. Raw Materials Preparation

3.6.1. Banana Peelings and Sawdust

Banana peelings were partially sun dried then chopped into small pieces, soaked for two days. Then the banana peelings and sawdust were mixed at a mass ratio of 7:3. Then the mixture was put in a local motor and then pounded using a pest. This also ensured that saw dust had excellently mingled with the banana peelings as depicted in Figure 2.

3.6.2. Waste Paper and Sawdust

Waste paper (news papers) were chopped into small bits and then, soaked for about two days and then mixed at a ratio of 7:3. Then the paste of waste paper and sawdust were mixed at a mass ratio of 7:3. Then the mixture was put in a local motor and then pounded using a pest. This also ensured that saw dust had excellently mingled with the waste paper.

3.7. Briquette production

A screw briquette machine was used (see Figure 3). The mixed paste was weighed in a plastic cup ranging from 400-500 grams (by using a beam balance) which was then pooled in a cylinder of the briquette making machine. Each cylinder was accommodating three paste (pulp) segments separated by circular discs as depicted if Figure 3.

Then the pulp was compressed by a plunger (passing through the centre along the central axis) up to a specified pressure so that constant briquette densities were achieved. Practically this was done by counting the remaining threads of a plunger. Ten threads were left above the horizontal beam as depicted in Figure 4.

Then the final products now called the briquettes were softly pushed out of the cylinders to avoid breakages due to their high softness. The height was measured in four positions 90° to each other around the briquette, the external diameter of the briquette was measured in three positions, at the top, middle and bottom, the diameter of the internal hole was measured twice at each end in perpendicular directions. The volume of the nearest geometrical shape was then calculated and hence the density were determined.

The drying briquettes were placed in a carton which was kept in a closed dry room temperature so as to prevent them from absorbing moisture.

3.8 Population size

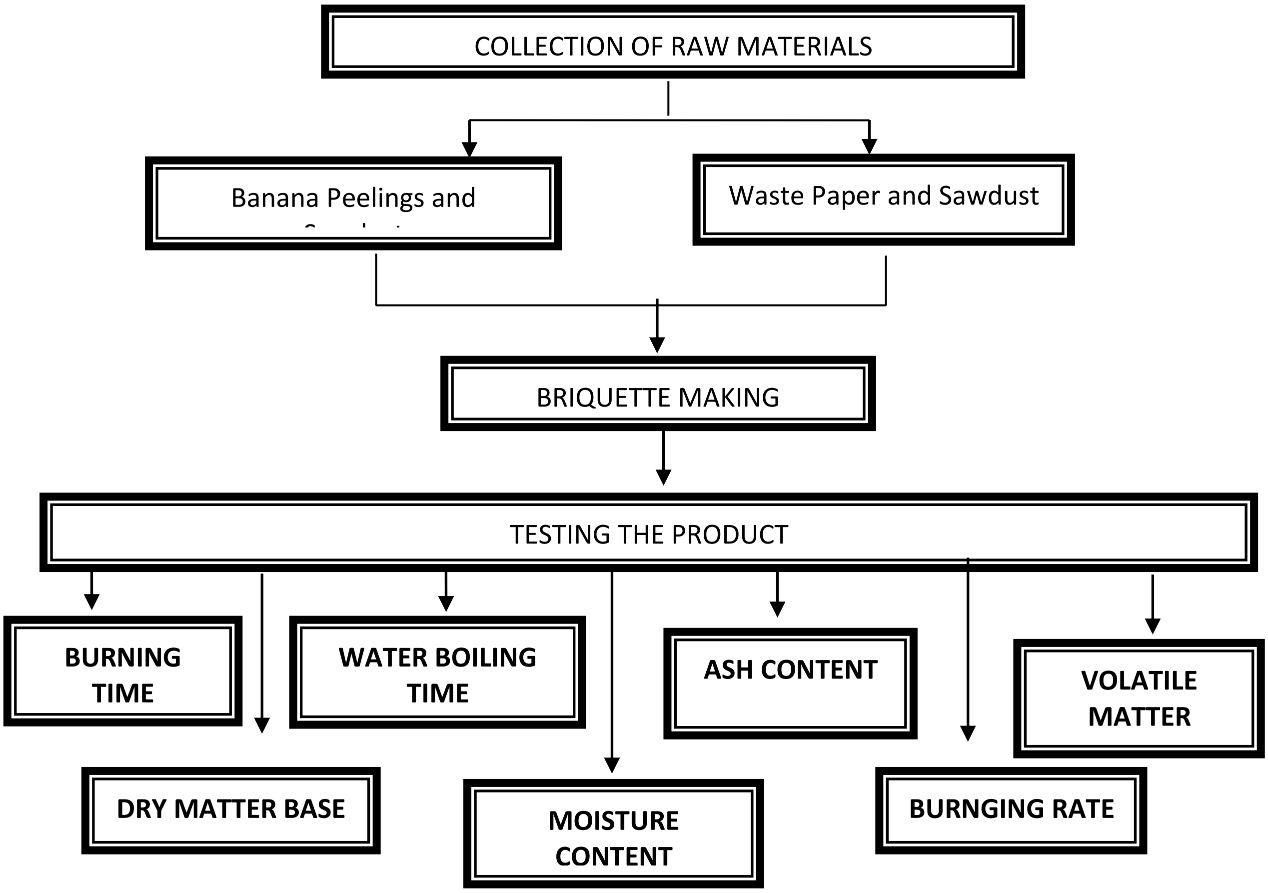
A total 45 waste paper briquettes and 45 banana peelings briquettes were produced. This was a good number to conduct all the analysis parameters such that burning time, ash content, moisture content, dry mater, volatile matter, water boiling time and ignition time as shown in table 3.3 below.

Table 3.3. Project Population size

PARAMETER	NUMBER OF BRIQUETTE FROM EACH
Ash Content (%)	**5**
Moisture Content (%)	5
Volatile Matter (%)	5
Dry Matter Base (%)	5
Ignition Time (seconds)	5
Burning Rate (grams/minutes)	5
Water Boiling Test (min)	15

3.9. Chart overview

Figure 5: Chart in Preparation of banana Peelings as a Fuel Briquette



3.10. Testing the briquettes

Briquettes from each blend were subjected under the analysis of burning rate, ignition time, ash content, dry matter, moisture content, volatile matter, water boiling time and gas emitted

3.10.1. Ash content

This is an organic residue resulting from the inclination of organic matter (Onuegbu TU, 2011). Equipment used; balance, crucibles, crucible tongs, desiccators and the muffle furnace. The procedure followed the Gravimetric Muffle Furnace Method (AOAC, 2005)

3.10.1.1. Procedure

The labelled crucibles were washed, and then placed in a muffle furnace which was turned to a temperature of 550^0 C for a period of 15-20 minutes. Then the crucibles were cooled in desiccators and their weights were recorded using a balance.

The dried briquettes were grinded into tiny bits (dust) through the use of an electric grinder. This sample was weighed in the prepared crucibles from the range of 3-5 grams. The crucibles together with the samples were then incinerated in a muffle furnace at a temperature of 550^0 C for 2 hours 30 minutes until the samples became white or grey as show in figure 7.

The crucibles from the muffle furnace were then cooled in desiccators and weighed again. The gain in weight of the dishes represented ash content.

Calculation

%AS CONTENT=B/(initial wgt ofsample)×100

Where B is the weight of the sample after incarnation

3.10.2. Volatile matter

This is the carbon content that has gone under combustion. In other terms, it's the % left escaped after analysis of Ash content. Gravimetric Muffle Furnace Method (AOAC, 2005) was used.

3.10.2.1. Procedure

The labelled crucibles were washed, and then placed in a muffle furnace which was turned to a temperature of 550^0 C for a period of 15-20 minutes. Then the crucibles were cooled in desiccators and their weights were recorded using a balance.

The dried briquettes were grinded into tiny bits (dust) through the use of an electric grinder. This sample was weighed in the prepared crucibles from the range of 3-5 grams. The crucibles together with the samples were then incinerated in a muffle furnace at a temperature of 550^0 C for 2 hours 30 minutes until the samples became white or gray.

The crucibles from the muffle furnace were then cooled in desiccators and weighed again. The loss in weight of the dishes represented ash content.

Calculation

%VOLATILE MATTER=(A-B)/(initial sample wgt)×100

Where A is the Weight of sample & crucibles before incarnation and B is the weight of A after incarnation

3.10.3. Moisture content

This is a small quantity of water or other liquid diffused as vapour, within a solid. It is important to determine the moisture content (MC) before carrying out any analysis because the results of analyses are more reliable when reported on a dry-matter basis (DMB), using the MC to convert "as is" result to DMB figures. Sample were weighed and then heated to remove the moisture at temperature of 130^0 C for 2 hours, 30 minutes. Oven Drying Gravimetric Method (AOAC,2007) was followed.

3.10.3.1. Procedure

Moisture dishes were labelled and then dried in the oven at 130^0 C for 30 minutes. The dishes were then cooled in desiccators. The briquettes were grind in a motor so as to obtain small particles. Then ≅2g of the milled sample was put into each dish and thereafter, the dishes were placed in the Oven which was tuned to a temperature of 130^0 C for 2 hours, 30 minutes as depicted in figure 8. The dishes were then moved from the oven to the desiccators, using tongs again, and allowed to cool. The dishes were then weighed and the difference between the initial & final weights was equal to moisture in the sample.

Calculations

%MOISTER CONTENT=(B-A)/(initial weight of sample)×100

where B is the intial weight of dish+sample and A is thefinal weight of B

3.10.4. DRY MATTER BASIS

This is the physical substance or material that occupies space and possesses mass, especially as distinct from energy. It is the dry matter that the combustion characteristics of this project were profound on. The test also followed Oven Drying Gravimetric Method (AOAC,2007) protocol.

3.10.4.1. Procedure

Moisture dishes labelled and then dried in the oven at 130^0 C for 30 minutes. The dishes were then cooled in desiccators. The briquettes were grinded in a motor so as to obtain small particles. Then ≅2g of the milled sample was put into each dish and thereafter, the dishes were placed in the Oven which was tuned to a temperature of 130^0 C for 2hours, 30 minutes. The dishes were then moved from the oven to the desiccators, using tongs again, and allowed to cool. The dishes were then weighed and the remaining weights were equal to the dry matter basis in the sample.

%DRY MATTER=B/(initial weight of sample)×100

Where B is the final weight of dish+sample

3.10.5. Water boiling test

The Water Boiling Test (WBT) is a simplified simulation of the cooking process (Senger et al, 2012). It is intended to help energy designers measure how efficiently a means of energy developed is in stove if used as a fuel to heat water in a cooking pot and the quantity of harmful emissions produced while cooking. This was carried out to compare the cooking efficiency of the briquettes. It measured the time taken for each set of briquettes to boil an equal volume of water under similar conditions.

3.10.5.1. Procedure

300g of each briquette sample was put in a Brazier (chitetezo mbawula). This was used to boil 1000 〖cm〗^3 (1 litter) of water in aluminium pots (due to its high conductivity) of a diameter of 18cm. A stop watch was used to record the time it took to boil the water in minutes. The mercury dry bulb thermometers were used to pin point the exact boiling temperature of water, which is 100^0 C. The time it took to boil the given amount of water was equal to the boiling time in that sample as depicted in figure 9a and 9bDuring WBT test, ignition time, burning rate and specific fuel consumption were also determined. 3.10.6. The ignition time To determine the ignition time, each briquette sample was ignited at the base in a drought free corner by using Leopard Matches. The time required for the flame to ignite the briquette, in seconds, was recorded as the ignition time and a used stop watch.

3.10.7. Burning Rate (BR)

As stated by Chaegba et al (2011), Burning rate is the ratio of the mass of the fuel burnt (in grams) to the total time taken (in minute). This is the time from ignition up to when the fire flame goes out.300 grams of briquettes from each blend will be burnt and the initial time (ignition time) to final time of burning (flame extermination) will be recorded using a stop watch. Burning Rate helps to how much fuel briquette mass a person should require to burn under normal conditions in a specific given time.

Burning rate = mass of fuel consumed (g)

Total time taken (min)

3.11. Limitations

There was also a limitation in the methods of determining the calorific value due to lack of an oxygen boom calorimeter in this country. Furthermore, the levels of smoke released during the burning of the briquettes were not determined due to malfunctioning of the Gas Monitor at the Polytechnic. The heat of the sun was enough to completely absorb the moisture of the briquettes, and the use of an oven drying did not take place, thus conserving energy. But it was taking many days of about 7 fully sunny days and 13 cloudy days to sundry a sizable briquette. Though it was discovered that a better way of improving sun drying was to maximise the briquette surface by hung through the use lops via the briquette central hole.

4. RESULTS AND DISCUSSION

In this study, the researcher compared the burning rate, ash content, moisture content, dry mater, volatile matter, water boiling time and ignition time.

4.1. Physical properties of briquettes

The physical properties of briquetted fuel after eight days of sun drying were recorded. The result obtain was depicted in Table 4.3 as shown below.

Table 4.3: Physical properties of briquettes

Properties of briquettes	Banana peeling + Saw-dust	Waste Paper + saw-dust
Average length (cm)	2.0±0.4	2.5±0.8
Average diameter (cm)	9.5±0.6	10.5±0.3
Average weight (g)	206.7±27	174.0±34
Average volume (cm^3)	131.9±13	216.6±9
Average density (g/ cm^3)	1.6	0.8

These results were compared with the combustion characteristics of biomass briquettes international standard values given by ISO (the International Organization for Standardization) 17225-1:2014(E). Tabular form and appropriate graph were plotted to show the results of the samples under different conditions of treatment for the various combustion parameters investigated.

4.2. Combustion Experimental Characteristics Results

Table 4.4. Mean Values of Characteristics of Briquette Samples

PARAMETER	BANANA PEELINGS + SAWDUST	WASTE PAPER + SAWDUST	STANDARD VALUES
Ash Content (%)	10.1±0.4	10.45±2.75	3.3-11.7
Volatile Matter (%)	90±0.5	88.3±2.61	75.8-94.7
Moisture Content (%)	10±0.23	13.2±6.1	2.2 - 15.9
Dry Matter Base (%)	90±0.3	86.3±6.1	80.3-97.4
Ignition Time (seconds)	57.1±0.4	39.7±0.4	15-120
Burning Rate (grams/minutes)	2.5±0.5	2.4±0.6	2.3-5.8
Water Boiling Test (minutes)	12.6±0.4	16.6±0.5	8.3-20.7

Table 4.4 shows that the approximate burning rate, ash content, moisture content, dry mater, volatile matter, water boiling time, ignition time of Treatment A (banana peeling + sawdust) and Treatment B (waste paper + sawdust) both fall in the standard values . The standard values of wood were used in this table since it is a very common fuel in Malawi. The volatile and dry matter base value can thus be used to calculate the competitiveness of a processed fuel in a given market situation. The standard volatile matter and dry matter base value of wood is 75.8 and 94.7 and 75.8 and 94.7 respectively. Although the mean percentages of volatile and dry matter for both Treatment A (banana peeling + sawdust) and Treatment B (waste paper + sawdust), fall in the standard range, Treatment A (banana peeling + sawdust) has better potential as fuel briquette over Treatment B (waste paper + sawdust). The ash content of both briquettes in the two treatments was also comparable to the typical ash content of wood which ranges from 3.3% to 11.7%. The same comparison was applied to standard moisture content and ignition time which range from 2.2% and 15.9% as depicted in Figure 11.

A bar Graph 1

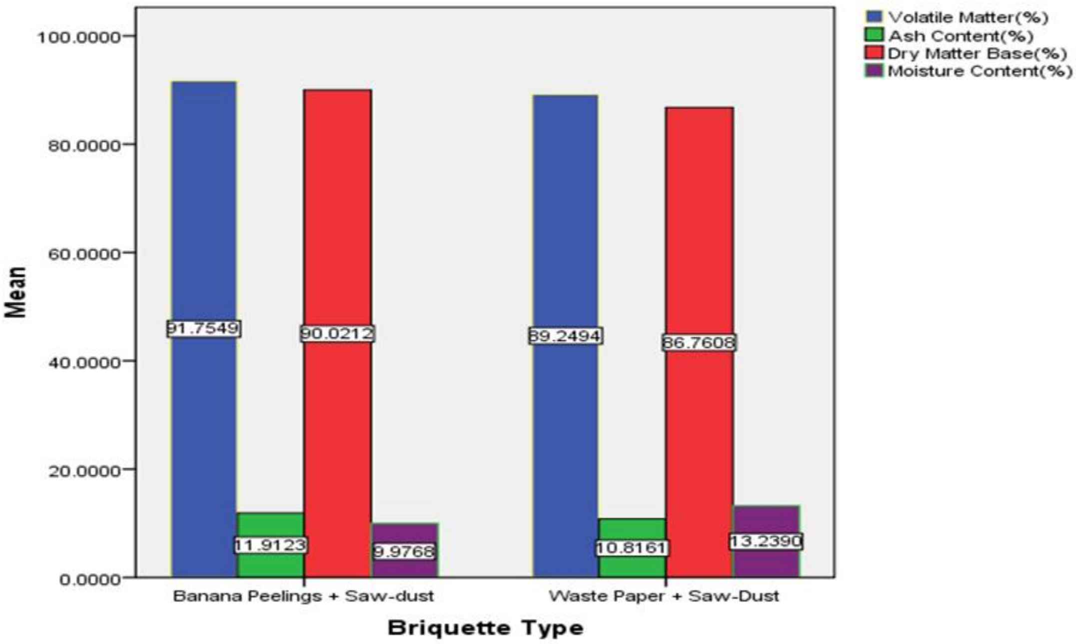


Figure 11: A bar graph showing % mean values of VM, AC, DM and MC of both treatments

In additional, Treatment A boiled a given specific volume of water faster than Treatment B under the same conditions. This is also due to the fact that Treatment A had higher burning rate (2.52g/min) than Treatment B (2.38g/min). The results for both treatments are depicted in Figure 13 below.

Pie chart 1

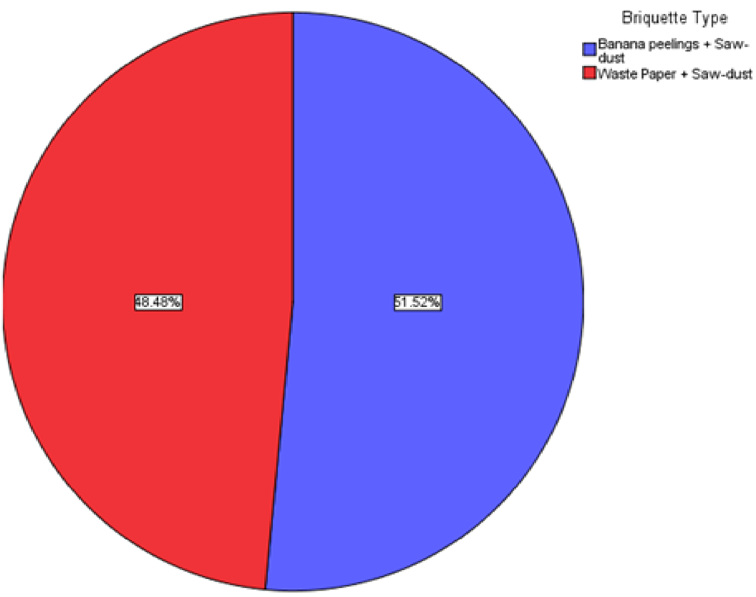


Figure 13: A pie chart showing BR mean treatments

However, it was noted that if heating was in smaller amounts but for longer time for Treatment B (waste paper + sawdust) hence low burning rate as compared to Treatment A (banana peelings + sawdust).

A bar Graph 2

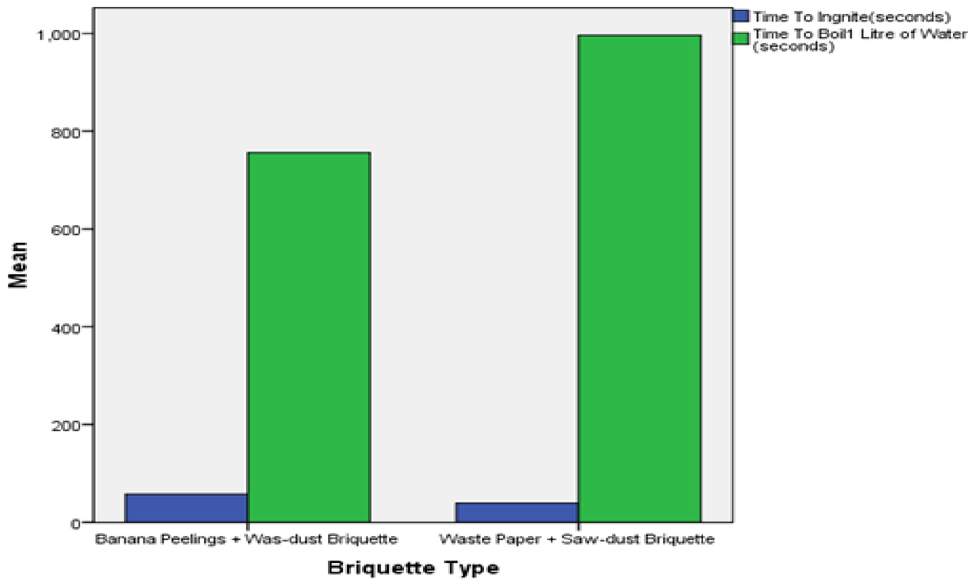


Figure 12: A bar graph showing of both mean IT and BT values of both treatments.

The maximum burning rate was obtained from banana peeling briquette was 2.52grams per minute, where as waste paper was 2.38grams per minute. Treatment B (waste paper + sawdust) had also less ignition mean time (39.71min) as compared to Treatment A (banana peelings +saw-dust) which had an ignition time of (57.14min) and the ignition time of about 15 and120 seconds respectively as depicted in Figure 12 above.

4.4. Discussion {Statistical Analysis Overview}

The Independent-samples t-test, was used because the research compared the mean scores of two different groups of briquettes. The data was then subjected to two-way analysis of variance at 0.05 probability level. If the value in the P-value (2-tailed) column was found to be equal or less than 0.05 (for example. 0.03, 0.01, 0.001), there is a significant difference in the mean scores on the dependent variable for each of the two groups then the hypothesis was "Rejected". Where the value was above 0.05 (for example. 0.06, 0.10), there is no significant difference between the two group, the hypothesis was "Failed to Reject" based on the statistical significant difference of the variables. All the analyses were done with the Statistical Package for Social Science (SPSS) software.

4.4.1. Comparison of volatile matter

Table: 4.5. Statistical Test for Results in VOLATILE MATTER

TYPE OF BRIQUETTE	BANANA PEELING +SAWDUST	WASTE PAPER + SAWDUST
Mean	90.01%	88.31%
St. Dev.	3.31	8.14
Hypothesized Difference	0	
Difference	0.00831	
P-value (two-tailed at α=0.05)	0.426	

Table 4.5 shows the result of the t-test performed on the mean values of volatile matter of fuel briquettes for each treatment. The statistical data gathered shows that there is no significant difference between the two treatments since P-value (0.426) is greater than the level of significance (0.05) hence null hypothesis is not rejected. This implies that the volatile matter of Treatment A (banana peelings + sawdust) and Treatment B (waste paper + sawdust) fuel briquettes are statistically the same.

4.4.2. Comparison of volatile matter

Table 4.6. Statistical Test for Results in ASH CONTENT

TYPE OF BRIQUETTE	BANANA PEELING +SAWDUST	WASTE PAPER + SAWDUST
Mean	10.05%	14.28%
St. Dev.	3.28	5.74
Hypothesized Difference	0	
Difference	0.0000278	
P-value (two-tailed at α=0.05)	0.170	

Table 4.6 shows the result of the t-test performed on the mean values of Ash Content of fuel briquettes for each treatment. The statistical data gathered shows that there is no significant difference between the two treatments since P-value (0.170) is greater than the level of significance (0.05) hence null hypothesis is not rejected. This implies that the Ash Content of Treatment A (banana peelings + sawdust) and Treatment B (waste paper + sawdust) fuel briquettes are statistically the same.

4.4.3. Comparison of moisture content

Table 4.7. Statistical Test for Results in MOISTURE CONTENT

TYPE OF BRIQUETTE	BANANA PEELING +SAWDUST	WASTE PAPER + SAWDUST
Mean	9.97%	13.24%
St. Dev.	0.56	13.68
Hypothesized Difference	0	
Difference	0.00000276	
P-value (two-tailed at α=0.05)	0.609	

Table 4.7 shows the result of the t-test performed on the mean values of Moisture Content of fuel briquettes for each treatment. The statistical data gathered shows that there is no significant difference between the two treatments since P-value (0.609) is greater than the level of significance (0.05) hence null hypothesis is not rejected. This implies that the Moisture Content of Treatment A (banana peelings + sawdust) and Treatment B (waste paper + sawdust) fuel briquettes are statistically the same.

4.4.4. Comparison of dry matter base

Table 4.8. Statistical Test for Results in DRY MATTER

TYPE OF BRIQUETTE	BANANA PEELING +SAWDUST	WASTE PAPER + SAWDUST
Mean	90.021%	86.7%
St. Dev.	0.5593	13.681
Hypothesized Difference	0	
Difference	0.008367	
P-value (two-tailed at α=0.05)	0.609	

Table 4.8 shows the result of the t-test performed on the mean values of Dry Matter of fuel briquettes for each treatment. The statistical data gathered shows that there is no significant difference between the two treatments since P-value (0.609) is greater than the level of significance (0.05) hence null hypothesis is not rejected. This implies that the Dry Matter of Treatment A (banana peelings + sawdust) and Treatment B (waste paper + sawdust) fuel briquettes are statistically the same.

4.4.5. Comparison of ignition time

Table 4.9. Statistical Test for Results in IGNITION TIME

TYPE OF BRIQUETTE	BANANA PEELING +SAWDUST	WASTE PAPER + SAWDUST
Mean	57.14 seconds	39.17 seconds
St. Dev.	2.116	2.563
Hypothesized Difference	0	
Difference	0.000004532	
P-value (two-tailed at α=0.05)	0.00	

Table 4.9 shows the result of the t-test performed on the mean values of Ignition Time of fuel briquettes for each treatment. The statistical data gathered shows that there is no significant difference between the two treatments since P-value (0.00) is greater than the level of significance (0.05) hence null hypothesis is rejected. This implies that the Dry Matter of Treatment A (banana peelings + sawdust) and Treatment B (waste paper + sawdust) fuel briquettes are not statistically the same.

4.4.6. Comparison of burning rate

Table: 4.10. Statistical Test for Results in BURNING RATE

TYPE OF BRIQUETTE	BANANA PEELING +SAWDUST	WASTE PAPER + SAWDUST
Mean	2.52(grams/minute)	2.38(grams/minute)
St. Dev.	0.104	0.132
Hypothesized Difference	0	
Difference	0.0000273	
P-value (two-tailed at α=0.05)	0.084	

Table 4.10 shows the result of the t-test performed on the mean values of Burning Rate of fuel briquettes for each treatment. The statistical data gathered shows that there is no significant difference between the two treatments since P-value (0.084) is greater than the level of significance (0.05) hence null hypothesis is not rejected. This implies that the

Burning Rate of Treatment A (banana peelings + sawdust) and Treatment B (waste paper + sawdust) fuel briquettes are statistically the same.

4.4.7. Comparison of water boiling time

Table 4.11. Statistical Test for Results in WATER BOIL TIME

TYPE OF BRIQUETTE	BANANA PEELING +SAWDUST	WASTE PAPER + SAWDUST
Mean	12.6 minutes	16.6 minutes
St. Dev.	0.844	1.140
Hypothesized Difference	0	
Difference	0.0000652	
P-value (two-tailed at α=0.05)	0.000	

Table 4.11 shows the result of the t-test performed on the mean values of Water Boil Time of fuel briquettes for each treatment. The statistical data gathered shows that there is no significant difference between the two treatments since P-value (0.00) is less than the level of significance (0.05) hence null hypothesis is rejected. This implies that the Water Boil Time of Treatment A (banana peelings + sawdust) and Treatment B (waste paper + sawdust) fuel briquettes are not statistically the same.

5. CONCLUSION AND RECOMMENDATION

5.1. Summary

This study demonstrated that briquettes can be utilized instead of other traditional fuel energy sources for domestic and industrial application in Malawi. The results confirm the possibility of utilizing banana peeling as fuel briquette of good source that support combustion. The banana peelings possess the high dry matter base and volatile matter as well as high value combustible fuel, which qualify it as alternative to firewood and charcoal for domestic and industrial energy in Malawi.

Furthermore, the research found out that the mean burning rate, ash content, moisture content, dry mater, volatile matter, water boiling time, and ignition time and approximate ash content of banana peeling + sawdust fall in the standard values. The standard combustion values of wood were used since it is a very common fuel source in Malawi.

5.2. Conclusion

The mean volatile matter of Treatment A (banana peelings + sawdust) and Treatment B (waste paper + sawdust) are 90 % and 88.3%, respectively. The approximate moisture content was 10% and 13.2%, respectively. The approximate ash content was 10.1% and 10.5%, respectively. Furthermore the approximate ignition time is 57.1 seconds and 39.7 seconds respectively. In addition the approximate burning rate is 2.5 grams per minute and 2.4 grams per minute respectively. The approximate dry matter base are 90% and 86.3%, respectively .While the mean water boiling time for 100cm^3 (1 litre) is 12.6 minutes and 16.6 minutes respectively.

There is no significant difference in the burning rate, ash content, moisture content, dry mater and volatile matter between treatments. However there is significant difference in water boiling test and ignition time between the treatments.

The banana peelings fuel briquettes produced are environmental friendly, provide a means to reduce desertification and its environmental implication and reduce health hazard associated with the use of fuel wood and charcoal. Therefore, combination of banana peelings and saw dust might be very suitable for briquette production for domestic and industrial uses in Malawi because the project has found that it is usable.

5.3. Recommendation

1. Apart from the combustion characteristics captured above, there is need of further studies on calorific value and levels of gas pollution from these briquettes
2. There are briquettes making machines for agricultural waste briquettes here in Malawi already. It's really more of the marketing, distribution, and cultural acceptance that will make briquettes successful, so there is need of coming up with an excellent dissemination plan to create the demand and usage is what may lead to success.

3. Fundamentally, any future research needs to figure the economics of biomass fuels to determine what is cost-competitive and an analysis of production processes to anticipate production costs, likely revenues, and thus likely payback time for local use in homes. Moreover, because agricultural waste briquettes require better cultural acceptance, future research must explore effective methods of shifting perceptions through promotional images, video, and other means of cultural communication for briquettes themselves.

4. Consumer testing is a critical requirement of any product. Banana peelings briquettes and other briquettes from agricultural by products need their trial by fire. Future researchers could share these and similar agricultural waste briquettes with urban and rural cooks in Malawi, observe their cooking behaviour, and elicit their feedback. For instance, asking women to determine how big a bag of briquettes they'd accept to give up a bag of charcoal.

ACKNOWLEDGEMENTS

Authors would like to thank the University of Malawi for financially supporting the study.

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APPENDIX – A

Documentation:

Figure 1: Banana Peelings Collected Around the Polytechnic Campus

Figure 2: Pounding banana peelings mixed with sawdust

Figure 3: Screw Briquette making machine and its componets

Figure 4: Compressing the mixed sawdust-banana peeling pulp

Figure 5: Briquettes being sun dried

Figure 6: Crucibles with the samples in a muffle furnace ready for incineration

Figure 7: Samples in crucibles been place in an Oven

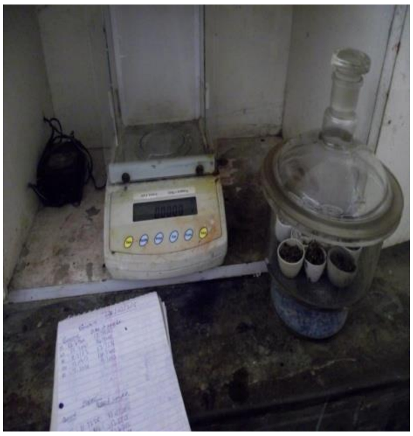
Figure8: Briquettes Before the water boiled

Figure9: Briquettes After the water boiled

Figure 10: Paper and banana blends of Briquettes burning in chitetezo mbawula respectively

Paper blend being weighed

Banana blend being weighed



Samples in crucibles being weighed

APPENDIX - B

Tables and Figures:

Table: B1.

MASS OF CRUCIBLES	MASS OF CRUCIBLE + BRIQUETTE SAMPLE BEFOR INCIRATION	INITIAL SAMPLE WEIGHT	MASS OF CRUCIBLE + BRIQUETTE SAMPLE AFTER INCIRATION	WEIGHT DIFFERENCE	% VOLATILE MATTER	% ASH CONTENT
10.822	15.047	4.225	11.62	3.427	81.1124	18.8876
2212.3	15.607	3.307	12.571	3.036	91.8053	8.9470'
10.271	15.019	4.748	10.658	4.361	91.8492	8.1508
112.606	15.841	4.235	11.979	3.862	91.1924	8.8076
1122.5	16.605	5.105	11.931	4.674	91.5573	8.4427
11.01	14.929	3.919	11.367	3.562	92.3705	7.6295
12.035	15.933	3.898	12.967	2.966	76.0903	23.9096
11.707	14.962	3.255	11.993	2.969	91.2135	8.7865
11.681	15.241	3.56	11.983	3.258	91.5169	8.4831
11.718	15.383	3.665	12.05	3.333	90.9413	9.0587

Table: B2.

MASS OF CRUCIBLES	MASS OF CRUCIBLE + BRIQUET SAMPLE BEFORE INCIRATION	INITIAL SAMPLE WEIGHT	MASS OF CRUCIBLE + BRIQUETTE SAMPLE AFTER INCIRATION	DIFFERENCE IN MASS	% VOLATILE MATTER	% ASH CONTENT
16.821	20.473	3.652	16.933	3.54	96.9332	3.0668
19.965	23.087	3.122	20.137	2.95	94.4907	5.5093
20.649	24.117	3.468	20.83	3.287	94.7809	5.2191
10.402	13.172	2.77	11.378	1.986	71.6968	28.3032
16.981	20.257	3.276	17.186	2.897	88.431	11.5690'
15.561	18.083	2.522	16.22	1.863	73.8700'	26.1300'
10.774	13.083	2.309	11.184	1.899	80.6843	19.3157
11.332	14.394	3.062	11.645	2.749	89.7779	10.2221
13.497	16.739	3.242	13.932	2.807	86.5824	13.4176
16.043	18.571	2.528	16.537	2.034	80.4589	19.5411

Table: B3.

WEIGHT OF CRUCIBLES	WEIGHT OF CRUCIBLE + BRIQUET SAMPLE BEFOR OVENING	INITIAL SAMPLE WEIGHT	WEIGHT OF CRUCIBLE + BRIQUET SAMPLE AFTER OVENING	WEIGHT DIFFERENCE	% MOISTURE CONTENT	% DRY MATTER
13.494	15.39	1.896	15.2008	0.1892	9.97	90.021
12.269	14.2291	1.9601	14.0433	0.1858	9.479	90.521
11.7182	13.7776	2.0594	13.5264	0.2512	10.927	89.073
12.0413	14.3401	2.2988	14.1148	0.2253	9.801	90.199
7.1016	9.1063	2.0047	8.9117	0.1946	9.707	90.292

Table: B4.

WEIGHT OF CRUCIBLES	WEIGHT OF CRUCIBLE + BRIQUET SAMPLE BEFOR OVENING	INITIAL SMPLE WEIGH	MASS OF CRUCIBLE + BRIQUET SAMPLE AFTER OVENING	WEIGHT DIFFERENCE	% MOISTURE CONTENT	% DRY MATTER
11.7228	13.0736	1.3508	12.9795	0.0941	6.966	93.033
11.6214	13.5725	1.9511	13.4249	0.1476	7.565	92.435
11.542	13.4702	1.9282	13.3204	0.1498	7.768	92.232
10.2698	12.2258	1.956	12.1044	0.1214	6.206	93.794
11.6871	14.7852	3.0981	13.6175	1.1677	37.69	62.31

Table: B5.

BANANA BRIQUETTE SAMPLE IN GRAMS	BURNING TIME IN MINUTES	BURNING RATE (g/min)
300	123	2.4390'
300	117	2.5641
300	125	2.4000'
300	113	2.6549
300	117	2.5641

Table: B6.

PAPER BRIQUETTE SAMPLE IN GRAMS	BURNING TIME IN MINUTES	BURNING RATE (g/min)
300	129	2.3256
300	131	2.2900'
300	128	2.3438
300	115	2.6087
300	130	2.3077

Table: B7.

WEIGHT OF PAPER BRIQUE IN GRAMS	VOLUME OF H2O(IN Cm3)	TIME TO BOIL IN MIN
300	1000	12
300	1000	13
300	1000	12
300	1000	14
300	1000	12

Table: B8.

WEIGHT OF PAPER BRIQ SAMPLE IN (g)	VOLUME OF WATER(IN Cm3)	TIME TO BOIL IN MINUTES
300	1000	18
300	1000	17
300	1000	17
300	1000	16
300	1000	15

Table: B9.

banana briquette ignition time (sec)	paper briquette ignition time (sec)
59	37
57	42
53	39
59	36
58	40
58	41
56	43

APPENDIX - C

Statistics Analysis:

Table C1. Group Statistics

	Briquette Type	N	Mean	Std. Deviation	Std. Error Mean
Volatile Matter(%)	Banana peelings + Saw-dust Briquette	10	9.196491E1	1.5101489	.4775510
	Waste Paper + Saw-dust Briquette	10	8.477061E1	8.2664208	2.6140718
Ash Content(%)	Banana peelings + Saw-dust Briquette	10	8.310310E0	1.3345210	.4220126
	Waste Paper + Saw-dust Briquette	10	1.432939E1	8.7105622	2.7545216
Dry Matter(%)	Banana peelings + Saw-dust Briquette	5	9.002120E1	.5598725	.2503826
	Waste Paper + Saw-dust Briquette	5	8.676080E1	13.6819095	6.1187359
Moisture Content(%)	Banana peelings + Saw-dust Briquette	5	9.976800E0	.5600064	.2504425
	Waste Paper + Saw-dust Briquette	5	1.323900E1	13.6820241	6.1187872

Table C2: Independent Samples Test

		Leve Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Volatile Matter(%)	Equal variances assumed	1.417E1	.001	2.707E0	2.E1	.014	7.1943030E0	2.6573344E0	1.6114505E0	1.2777155E1
	Equal variances not assumed			2.707E0		.023	7.1943030E0	2.6573344E0	1.2397866E0	1.3148819E1
Ash Content(%)	Equal variances assumed	2.082E1	.000	-2.160E0	2.E1	.045	-6.0190800E0	2.7866618E0	-1.1873639E1	-1.6452081E-1
	Equal variances not assumed			-2.160E0		.058	-6.0190800E0	2.7866618E0	-1.2280143E1	2.4198314E-1
Dry Matter(%)	Equal variances assumed	6.521	.034	.532	8	.609	3.2604000E0	6.1238567E0	-1.0861239E1	1.7382039E1
	Equal variances not assumed			.532		.623	3.2604000E0	6.1238567E0	-1.3719794E1	2.0240594E1
Moisture Content(%)	Equal variances assumed	6.520	.034	-5.327E-1	8	.609	-3.2622000E0	6.1239104E0	-1.7383963E1	1.0859563E1
	Equal variances not assumed			-5.327E-1		.622	-3.2622000E0	6.1239104E0	-2.0242532E1	1.3718132E1

Table C3. Group Statistics

	Briquette Type	N	Mean	Std. Deviation	Std. Error Mean
Burning Rate(g/min)	banana peelings + sawdust	5	2.52	.104	.046
	waste paper + sawdust	5	2.38	.132	.059

Table C4. Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper

Burning Rate(g/min)	Equal variances assumed	.053	.824	1.988E0	8	.082	.149	.075	-.024	.322
	Equal variances not assumed			1.988E0	7.571E0	.084	.149	.075	-.026	.324

Table C5. Group Statistics

	Type of Briquette	N	Mean	Std. Deviation	Std. Error Mean
Time taken to Boil Water	banana peelings +saw-dust	5	12.60	.894	.400
	waste paper +saw-dust	5	16.60	1.140	.510

Table C6. Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Time taken to Boil Water	Equal variances assumed	.264	.621	-6.172E0	8	.000	-4.000	.648	-5.494	-2.506
	Equal variances not assumed			-6.172E0	7.571E0	.000	-4.000	.648	-5.509	-2.491

Table C8: Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Burning Time	Equal variances assumed	.100	.759	-2.072E0	8	.072	-7.600E0	3.669E0	-1.606E1	.860
	Equal variances not assumed			-2.072E0		.075	-7.600E0	3.669E0	-1.618E1	.983
Burning Rate(g/min)	Equal variances assumed	.053	.824	1.988E0	8	.082	.149	.075	-2.387E-2	.322
	Equal variances not assumed			1.988E0		.084	.149	.075	-2.559E-2	.324