TO WHAT EXTENT CAN BRIQUETTES SUBSTITUTE THE USE OF CHARCOAL AND WOOD FUEL IN KENYA

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Abstract

In Kenya, there is over reliance on wood fuel and charcoal as source of energy, which has been~~ing~~ found to have some impacts on health due to indoor pollution. The overall total energy dependence in Kenya is as follows: 68% on biomass (wood fuel and charcoal), 20% on petroleum, 10% electricity and 2% from other sources. This has resulted to the ~~re~~search for an alternative source to substitute the over reliance of traditional biomass which has~~ve~~ some impacts on~~to~~ women and children who most of the time are in the kitchen. This paper aims to provide an understanding ~~on~~ on how densification of biomass to briquettes that are clean and they can substitute the use of traditional fuel in households. Experiments to determine the Time of combustion, calorific value and ash content of briquettes will be determined. In addition the impacts of wood fuel and charcoal have on health will be discussed to justify that briquettes can be used as a clean fuel. Further experiments to determine calorific value of different raw materials used for making briquettes shall be determined to find out how high quality briquettes can be produced. This information will be very vital to briquettes manufactures in improving the quality of their briquettes.

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Keywords: Briquettes, Indoor pollution, Calorific value, Ash content, Densification, Biomass

Introduction

The main objective of making briquettes is to improve biomass properties. According to Kaliyay,et al (2009) and Kong et,al (2012). Biomass have low density, low calorific value in a unit value and high moisture content, unstable combustion problems and high cost of bulk transportation ,difficult in storage and high particles emission during combustion. It was found that the process of briquetting is one way of solving these challenges as it results to compaction of the waste.

Composition of biomass

The elemental composition of biomass is very important when using ~~as~~ biomass as a source of energy. This determines which conversion technology is to be implemented, defines the energy content and determines how clean and efficient use of a given type of biomass. A study showed this will have a significance in determining the heat value, since when some chemical composition is not ~~be~~ known an approximate value is used by determining the chemical composition of the biomass by use of proximate analysis and ultimate analysis (Jigisha Parikh, Channiwala, & Ghosal, 2007). Mainly biomass ~~will~~ consists of ; cellulose, hemicellulose, Lignin, lipids, water, hydro carbon, organic acids and other compounds in small quantities. The concentration of these elements ~~will~~ vary from one plant to another depending on; species, type of plant tissue, stage of growth and growing conditions: weather conditions, the nature of the soil and fertilizers applied. In comparison to fossil fuels 30% to 40% of biomass is oxygen and the rest is dry matter depending on the amount of ash content. Of all the other organic components found in biomass hydrogen is third approximately 5% of the total composition of biomass. (Jenkins, Baxter, Jr, & Miles, 1998)

Impact of cooking using wood fuel to health

The bulk nature of the solid fuels has a significant impact on human health particularly to women and children. It has been found that human being are exposed to the impacts during the following activities, which involves four stages illustrated in flow diagram figure 1.1 they are: Searching and gathering: It involves the actual looking of biomass in the field which are very far from where the residents are living. Collection: Preparing the biomass together so as to transport it to the user place. It was found that different methods are used to transport it but the most common was women and children carrying it on~~using~~ their backs and sometimes using animals like donkey. Processing: This involves the actual splitting of bigger biomass into smaller pieces by cutting using a panga and an ~~pang,~~ axe so that it can be used with the small improved cooking stoves or in three stone fire place which is very common in many rural areas. But in some cases it involves the drying of biomass to reduce the moisture content. Cooking: the actual use of the biomass in the fire place and it is at these stage women and children are exposed to emissions.

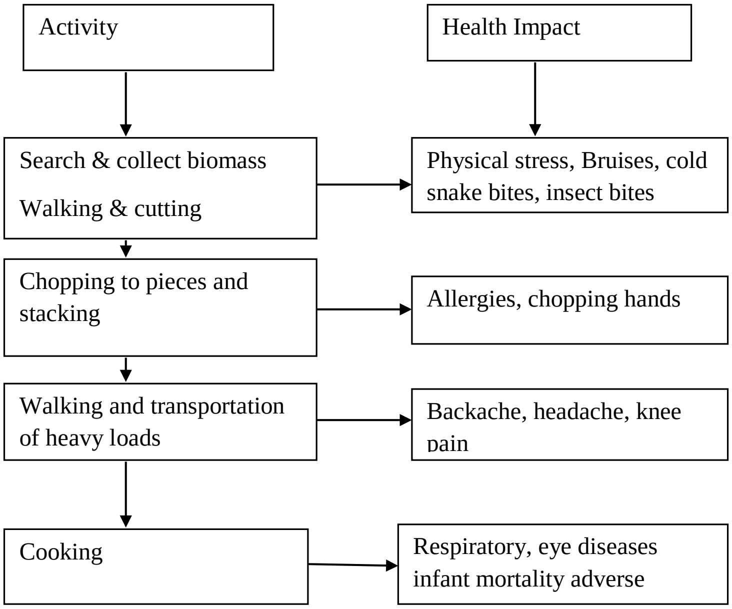

Figure 1.1: The effect of wood fuel harvesting and its impact to health Source (Parikh, 2011)

Due to the inefficient ways of utilizing biomass it results to incomplete combustion of biomass fuel (BMF) wood fuel and Charcoal in the traditional cooking stoves. It willwill also results to high fuel consumption and emissions of pollutants which include: pParticulate matter (PM), as well as carbon monoxide, hydro carbons and oxygenated organics, this result indoor pollution. The PM of smoke is classified according to the to its size and with inhalable material ≤µm in aerodynamic diameter referred as (PM_{10}) (Fullerton, Bruce, & Gordon, 2008).From a study carried in the rural Kenya it was found that the peak indoor concentration of PM_{10} often exceeds the recommended levels set by world health organization (WHO) as data collected showed many residents are exposed to 1000-2000µg/m^3 since there is high exposure of indoor pollution during cooking. A case study of a woman cooking using the three stones fire in a sSmokey kitchen which is a replica in many rural villages in Kenya and developing nations (Ezzati & Kammen, 2001). Furthermore, there is evidence that a lot of people are now suffering from chronic obstructive pulmonary diseases (COPD) for instancelike, in the year 1997 and 1999 there was an increase of 3.5% to 4.0% of acute lower respiratory infection (ALRI) (Ezzati & Kammen, 2001). This is as a result of the deposition of soot in form of poly aromatic hydrocarbons (PAH) on the lungs, stroke eye diseases, tuberculosis (TB),and cancer related complications as shown in figure 1.2 by a study by (Roden et al., 2009), (Ezzati & Kammen, 2001) , (Ngui et al., 2011)(Kim, Jahan, & Kabir, 2011) ,(Kim Oanh, Albina, Ping, & Wang, 2005) and (Jyoti Parikh, 2011)

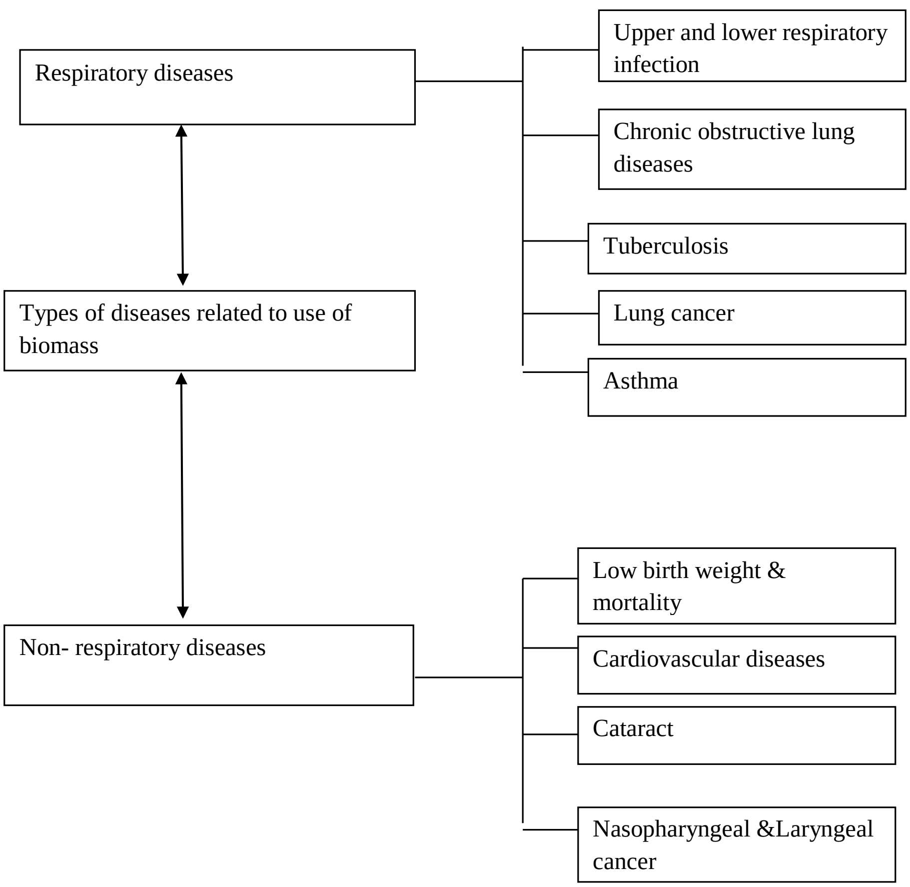

Figure 1.2: The impact of biomass fuel smoke and other diseases: Source (Kim et al., 2011)

According to (WHO) statistics annually there are 2 million deaths among women and children as a result of indoor pollution. Moreover, statistics by (Fullerton et al., 2008) shows that 76% of all global particulate matter occurs in- doors and it occurs in industrialised countries as result of over reliance of biomass whereas it is only 9% of indoor pollution that comes from developed countries as shown in figure 1.3. Furthermore it has been found pneumonia is leading global killer to children as a result of indoor pollution. A projection by (WHO, 2010) & (IEA, 2010) indicate that by 2030 premature deaths caused by wood fuel and charcoal will ~~are~~ ~~increasing~~ increase whereas those due to HIV/AIDS will reduce~~are reducing~~ as shown in figure 1.3. T~~t~~herefore, death by pneumonia will exceed death caused by HIV/AIDS. It is very important to come up with a way of reducing the indoor pollution by embracing use of briquette technology which will lower the infant mortality rate.

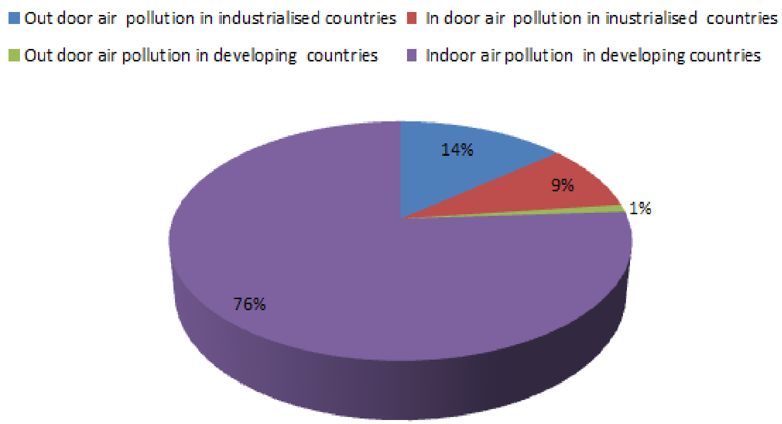

Figure1.3: Pie chart showing total global exposure to particulate matter air pollution source (smith, 1993)

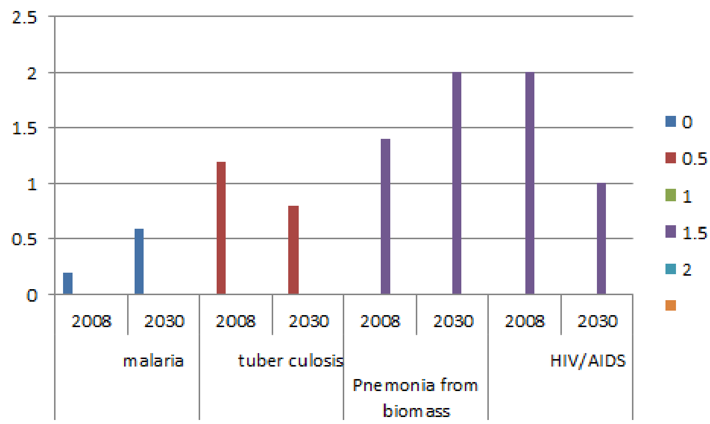

Figure 1.4: Projected annual deaths from house hold air pollution in comparison to other diseases Source (IEA, 2010)

The technology of briquetting

Studies by researchers showed that there were limited ways of making use of waste as fuel because fossil fuel was the main source of energy. In early 1950 in Europe during the world war several methods were developed to use waste paper, this was the first to be used as a raw material for making briquettes to substitute the reliance of fossil fuel. Compaction of papers using a simple machine was the main method used to make briquettes which resulted to low quality briquettes as they did not have the centre hole which has been found to have a comparative advantage when it comes to combustion of briquettes and they were smoking a lot. Use of hands and containers as a mould was used in most of the developing countries and parts of Asia (Khas & Delhi, 1998).

Improvement in the technology of producing briquette

Recent research by Nyakeru (2012) found that fuel briquettes have emerged as a significant business enterprise in the 20th century because they are substituting the use of fossil fuels; moreover they contribute to environmental conservation due to the greenhouse emissions caused by fossil fuels. Today there are some improvements on ways of making briquettes without a binder and in some cases a binder must be used. This has been made possible by using larger efficient machines (piston presses, screw presses, roller press pelletizing manual press and low pressure and high pressure). In addition to development of the machinery used, carbonization of waste before using it to make briquettes has also improved the quality of briquettes. The improvements of this technology are because there is plenty of bio waste material which can be used for making briquettes and the increased demand for briquettes. In many European countries people are used to make their own briquettes by use of soaked papers and a simple machine which is very common even today in many households where there are trying to go green.

According to Guo et al. 2009), Amaya et al. 2007) and oden et al. 2009) bBiomass briquetting has been defined as the "densification or compaction of biomass material by applying pressure. Most of the biomass waste will have a length of 5mm to 30mm which result to them having a low bulk density while briquettes will range from 30mm to 200mm in diameter and 50mm to 400mm in length"

Densification of biomass is a form of promoted agglomeration by using pressure to compact biomass waste together. There are two convectional process for biomass densification; extrusion roll briquetting, and pelletizing Bbriquette technology has been developed in two methods. Europe and US has pursued and perfected the reciprocating ram/piston press while Japan independently invented and developed screw press technology in 1945. At present two main high pressure technology ram and piston press and screw extrusion machines are used for briquetting. Briquettes can be produced with density of 1.2g/cm^3 from loose biomass of bulk density of between 0.1-0.2g/cm^3 (Granada, López González, Míguez, & Moran, 2002).

Extrusion involves forcing materials through a heated die by typical pressure exerted on the product by tapered screw. Research carried in Kenya showed that most of the machines are of this kind (simple press machine) and are been operated by applying force using hand or leg. This process will employ a roll press to compress the material between the rolls removing water. Briquettes will be formed depending on the geometry of the rolls, various shapes and sizes of compact material can be produced (Granada et al. 2002.A survey carried out in rural areas and in the slums many residents are still using their hands to roll ball briquettes hence making briquettes by using cow dung or soil as a binder with charcoal dust figure as shown on 1.6.

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Figure 1.5 Briquettes made from charcoal dust and soil by use of hands source (photo taken in Kenya in Kibera, 2011

(Granada et al., 2002). Found that the piston press is very common in Kenya as many NGOS have provided them too many local residents and are offering training on how to fabricate them. It is recommended because of its superior strength, can produce many briquettes at a time and it produces briquette of high quality best suited for use by customers since they have better combustion characteristics.

Process of briquetting

According to (Khas & Delhi, 1998)the process of making briquettes involves five major steps shown in figure 1.6 which include: Sorting, shredding biomass into small pieces, Mixing, Adding a binder, Compaction and drying.

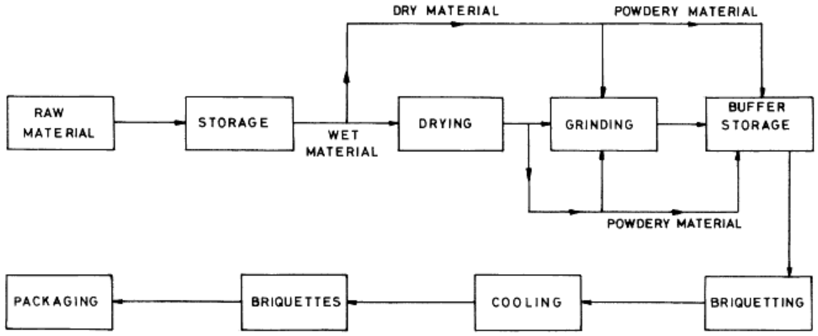

Figure 1.6: Flow diagram of briquette production process source (Khas & Delhi, 1998)

Advantages of briquetting

Recent research by (Rousset, Caldeira-Pires, Sablowski, & Rodrigues, 2011) & (Khas & Delhi, 1998) has shown that briquettes have numerous advantages which include: ~~Densities~~ densities of fuel are easy to handle, transport and store, b~~B~~riquettes have no sulphur, have no fly ash found when wood fuel is burnt, have a consistent quality in terms of high calorific value, cheaper in comparison with other forms of biomass, have uniform size and quality which will enhance complete combustion not like wood fuel charcoal, solves residue disposal process because it enhances the utilization of the waste in an eco-friendly way scale, they can provide additional income to the farmers who can sell their agro waste to briquette manufacturing companies thus offering a very good substitute for wood fuel, charcoal coal and lignite.

Disadvantages of briquettes

Though briquettes have a higher potential of substituting charcoal and wood fuel it experiences the following challenges (Khas & Delhi, 1998) which include: t~~T~~hey will have undesirable combustion characteristics like smoking if they are not given enough time to dry, there is a tendency of briquettes to loosen when exposed to water or high humidity weather conditions which is as a result of poor compaction.

Experiments

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Proximate analysis

This refers to an analysis of finding the quantity and physical characteristics of biomass, which will have an impact on its combustion properties. This analysis is done by considering that biomass consists of four major components which include; moisture content, volatile matter, ash and carbon and determining the quantity of each in a given biomass.

Aim: To determine the ash content of different samples of biomass used as raw materials for making briquettes

In these experiment samples of raw materials used to make briquettes were collected locally they included: sawdust, soaked papers, bagasse which was in form of sugar cane remains, charcoal dust, Rice husks, coconut husks and a mixture of carbonised waste.

The test method was carried to determine the ash content of different raw materials used for making briquettes. (Charcoal dust, soaked papers, sawdust, coconut shells, carbonised waste and rice husks)

Apparatus

Aluminium weighing pans, Crucible 50ml, Analytical balance sensitive to 0.1mg, Desiccator, Thermometer, Bunsen burner

Procedure

1) Weigh the weight of the crucible without the lid and mark it W_1.
2) Place the sample material in the crucible mark the level on the crucible using a porcelain marker and weigh the content and the crucible and mark it $W_{2.}$
3) Burn the samples in a closed crucible and keep on checking to ensure that there combustion until you get a white substance left which is ash.
4) After combustion is complete place the crucible and the ash in a desiccator to cool at room temperature and avoid exposure of any moisture. Silica gel was used in this case which work well in moderate to high humidity and moderate temperatures ≤ 125°F.
5) Weigh the contents in the crucible to the nearest 0.1 mg. In the experiment analytical balance mettle AJ 100 was used. After weighing burn the contents again on the Bunsen burner and reweigh. step 4 &5 are repeated until the weight of the crucible varies by less than 0.3mg

For this experiment is very important to ensure that combustion takes place completely to get accurate results and that why steps 4 & 5 are repeated and an accuracy of 0.3mg is considered as it will give accurate results in the experiment.

Calculations of ash content for dried materials

Weight of the sample (w_1) = ($W2$- W_1) mg

Weight of ash (w_2) = (W_3 - W_1) mg

Ash content $= \frac{w2}{w1} \text{ x } 100\%$ Equation 3(Ehrman, 1994)

Where: W_1 = Weight of the crucible.

W_2 = Weight of the sample plus crucible before combustion.

W_3 = Weight of ash and crucible after combustion.

Experiment 2: Determination of calorific value

Ultimate analysis

This is an analysis of the chemical composition what makes up biomass; carbon, hydrogen, oxygen, nitrogen and sulphur which will have an impact on the heating values of biomass. During combustion process carbon and hydrogen are the main heating.

Laidrel& Meiser (2003) defined heat capacity "as the amount of heat required to raise the temperature of any substance by 1K it unit is JK^{-1}. Heat capacity is key in this experiment especially when calibrating the calorimeter and calculating the calorific value. In addition they pointed out that heat evolved in a combustion process is determined in bomb calorimeters. There are two types of calorimeter which include; convectional calorimeter and adiabatic calorimeter. In this experiment a convectional calorimeter will be used.

According to Pahari & Chauhan (2008) calorific value can be defined as" the amount of heat produced when one unit mass of a fuel is completely burnt and the products are allowed to escape in the air".it can be expressed into as: Gross calorific value (GCV), Higher heating value (HHV): is the total amount of heat generated when a mass fuel is burnt and cooled down at room temperature 25°C. Net calorific value (NCV), lower heating value (LHV) is the net heat produced when one unit mass of fuel is completely burnt and the products allowed to escape can be calculated by subtracting the latent heat of vaporisation of water from GCV

It was also found that bomb calorimeters and other types of calorimeters can be working, at a constant pressure therefore giving as ΔH or working at constant volume giving internal energy as Δu.Which can be expressed in form of equations as shown below by equation 5 & 6 (Laidrel& Meiser ,2003)

$Q_V = \Delta u$ (Constant volume) Equation 5

$Q_p = \Delta H$ (constant pressure) Equation 6

$Q_{p=} \Delta u = \Delta nRT$

Where $\Delta n =$ number of moles

R = 8.314$KJ^{-1}Mol^{-1}$

T = Temperature in K

Aim: To determine the calorific value of different samples used as raw materials for making briquettes and calorific value of different samples of briquettes obtained from Kenya.

Apparatus Bomb calorimeter, Analytical balance sensitive of 0.1mg, Cotton string, Benzoic acid for calibration, Oxygen gas, weighing crucible

Procedure

1) Weigh the sample (sawdust, coconut husk, soaked papers, rice husks, charcoal dust) using the Analytical balance sensitive to the nearest 0.1mg.Use at least about o.5mg of every sample.
2) Place the sample in the crucible and insert it on the support pillar in the bomb calorimeter.
3) Tie one end of a single 8cm strand of cotton to the ignition coil and insert the other end under the tablet.
4) Check the rubber sealing is in its groove then carefully lower the bomb body into position and hand tighten the locking ring. At this step leaking of the calorimeter is checked because the experiment is carried under constant pressure and excess oxygen. Also when tightening the lock ring one needs to be careful not to destroy the coil.
5) Insert the probe of the digital thermometer into the hole on top of the bomb close the bomb release valve and open the oxygen cylinder valve. Gradually open the oxygen valve on the front panel of the apparatus and let the pressure rise to 25bar, then close the valve. In this step precaution should be taken not to over tighten valve as this may seriously damage the valve seat.
6) Allow time for the temperature to settle and record this value as (T_1). Press and release the firing button and record the maximum temperature reached (T_f). Successful ignition is

accompanied by a large initial rise in pressure- in case of failure first check that the apparatus is switched on.

7) Release the gases from the bomb then remove the body of the bomb by unscrewing the locking ring. Immerse the bomb in cold water to bring the temperature back, approximately, to its initial value. Dry the bomb.
8) Repeat the procedure using the test samples recording the temperature in a table. Calibration of the bomb calorimeter

When calibrating the bomb calorimeter we use compounds of known heat value like iron benzoic acid or naphthalene. In this experiment the procedure in experiment above will be repeated using benzoic acid as the sample who heat value is -3225 $kJmol^{-1}$.

For accuracy three samples were used in both experiments and the average was considered for temperature difference and mass

Table 1: Calculation for benzoic acid

Mass(g)	T_1	T_f	ΔT℃	q/kj
0.4258	32.1℃	23.4℃	8.7℃	
0.4813	34.5℃	25.7℃	8.8℃	
0.4148	35.8℃	27.2℃	8.6℃	

For benzoic acid ΔU (comb) = - 3225$kjmol^{-1}$

ΔT℃ $= \frac{8.7+8.8+8.6}{3} = 8.7$℃

Mass of benzoic acid used $= \frac{0.4258+0.4813+0.4158}{3} = 0\ .4258$g

Relative molecular mass (RMM) for benzoic acid C_6H_5COOH = 122

Moles = $\frac{0\ .4258g}{122} = 3.49 \times 10^{-1}$ moles

Heat released on combustion = $\Delta U \times$ number of moles

$= 3225 \times 3.49 \times 10^{-1}$ moles.

11.26 KJK^{-1}

Heat capacity (Cv) = $\frac{\text{Heat released on combustion}}{\Delta T°C}$

$= \frac{11.26}{8.7}$

$= 1.29KjK^{-1}$

Combustion testing

After determination of the calorific value it important to determine the how briquette burn in air to show their performance and quality. Previous researchers used water boiling test to ascertain the length of burn of the briquettes which was found to be less accurate as they used different stoves .In this experiment briquettes will be burnt in free air and time taken for complete burning will be recorded.

Aim: To determine the combustion rate of different briquettes.

Apparatus

Stop watch, Insulating bricks, Mesh grid

Procedure

1. Place the briquette on top of the mesh above the two bricks to allow free movement of the air
2. Ignite the each briquette by placing a fire lighter beneath the platform as shown in the figure 1.7 ensuring there is free air to have accurate results

Figure1.7: Combustion of briquettes in free air

3. Record the time taken from the stop watch for the complete combustion of the three kinds of briquettes.

Results and analysis

Calculations of ash content for dried materials

The ash content of the samples was be calculated using equation 1

Weight of the sample (w_1) = (X2- X_1) mg

Weight of ash (w_2) = (X_3 - X_1) mg

Ash content = $\frac{w2}{w1}$ x 100% Equation 1 (Ehrman, 1994)

Where: W_1= Weight of the sample

W_2 = Weight of the ash after combustion

X_1 = Weight of the crucible.

X_2 = Weight of the sample plus crucible before combustion.

X_3 = Weight of ash and crucible after combustion.

Ash content for sawdust $= \frac{0.0980}{1.520}$ x $100\% = 6.4\%$

Ash content for soaked papers $= \frac{0.080}{1.078} \times 100\% = 7.61\%$

Ash content for bagasse $= \frac{0.1700}{1.430} \times 100\% = 12.09\%$

Ash content for carbonized waste $= \frac{0.1530}{1.840} \times 100\% = 8.31\ \%$

Ash content of charcoal dust $= \frac{0.0860}{2.280} \times 100\% = 3.7\%$

Ash content of rice husks $= \frac{0.900}{5.600} \times 100\% = 16.07\%$

Ash content for coconuts $= \frac{0.076}{1.360} \times 100\% = 5.8\%$

Table 2: Ash content for different biomass samples

Name of the sample	Weight before combustion	Weight after combustion	%ash content
Soaked papers	0.080	1.784	7.61%
Bagasse	1.434	0.1700	12.09%
Carbonised waste	1.840	0.153	8.31%
Charcoal dust	2.290	0.086	3.7%
Rice husks	5.600	0.900	16.07%
Coconut husks	1.360	0.076	5.8%
Sawdust	2.520	0.0507	6.4%

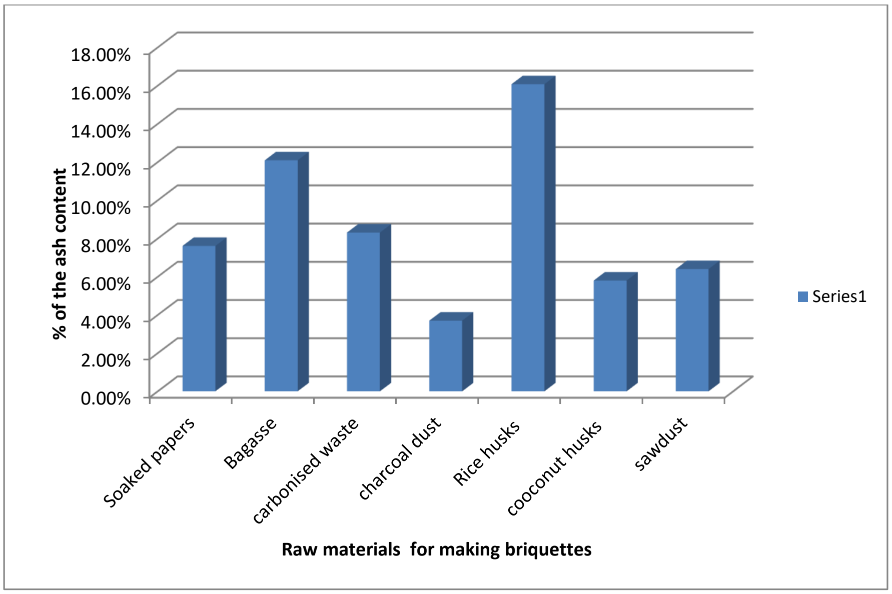

Figure 1.8: Bar graph showing the ash content of different raw materials for making briquettes

From figure 1.8 charcoal dust has the highest calorific value followed by carbonised waste this is because the carbonization has already been done which increases the char yield therefore making it to have a higher heating value in comparison to other waste.

Calculation for calorific value

When finding the calorific value the first step is to calculate the heat capacity of the benzoic acid which will be used in the finding the calorific value of the other samples been tested. Results for heat capacity are shown in table 3

Table 3: Calculation for calibration of benzoic acid

Mass(g)	T_1	T_f	ΔT℃
0.4258	32.1℃	23.4℃	8.7℃
0.4813	34.5℃	25.7℃	8.8℃
0.4148	35.8℃	27.2℃	8.6℃

Calculation of heat capacity of benzoic acid

For benzoic acid ΔU (comb) = - 3225kjmol^{-1} (Laidrel & Meiser, 2003)

ΔT℃ $= \frac{8.7+8.8+8.6}{3}$ = 8.7℃

Mass of benzoic acid used = $\frac{0.4258+0.4813+0.4158}{3}$ = 0 .4258g

Relative molecular mass (RMM) for benzoic acid C_6H_5COOH = 122

Moles = $\frac{0\ .4258g}{122}$ = 3.49 $\times 10^{-1}$ moles

Heat released on combustion = ΔU × number of moles

= 3225 ×3.49 $\times 10^{-1}$ mole.

11.26 KJK^{-1}

Heat capacity (Cv) = $\frac{\text{Heat released on combustion}}{\Delta T℃}$

= $\frac{11.26}{8.7}$

= 1.29KjK^{-1}

Determining the calorific value for different samples used for making briquettes will be calculated using equation 2 & 3 (Laidrel & Meiser, 2003)

Δ u = change in temperature × Heat capacity (Cv) Equation 2

Internal energy of combustion per gram (g) $= \frac{\Delta u}{average\ mass\ of\ the\ sample}$ Equation 3

Calorific values for different samples used in making briquettes

Sample	Δ T °C	Cv kj/k^{-1}	Δu	Average mass(g)	$\frac{\Delta u}{Avarage\ mass}\ kj/g$
Coconut husk	7.73	1.29	9.971	0.5385	18.517
Soaked paper	5.4	1.29	6.966	0.5076	13.723
Sawdust	7.15	1.29	9.223	0.4393	20.995
Rice husks	5.8	1.29	7.482	0.4696	16.000
Charcoal dust	11.2	1.29	14.448	0.5292	27.301
Macadamia nuts	5.05	1.29	6.527	0.3148	20.730
Paper briquettes	6.5	1.29	8.3885	0.5397	15.534
Carbonized bagasse	10.1	1.29	12.900	0.4933	26.150
Carbonized briquette (a)	8.3	1.29	10.707	0.5157	20.762
Carbonized briquette (b)	5.8	1.29	10.482	0.4676	22.416

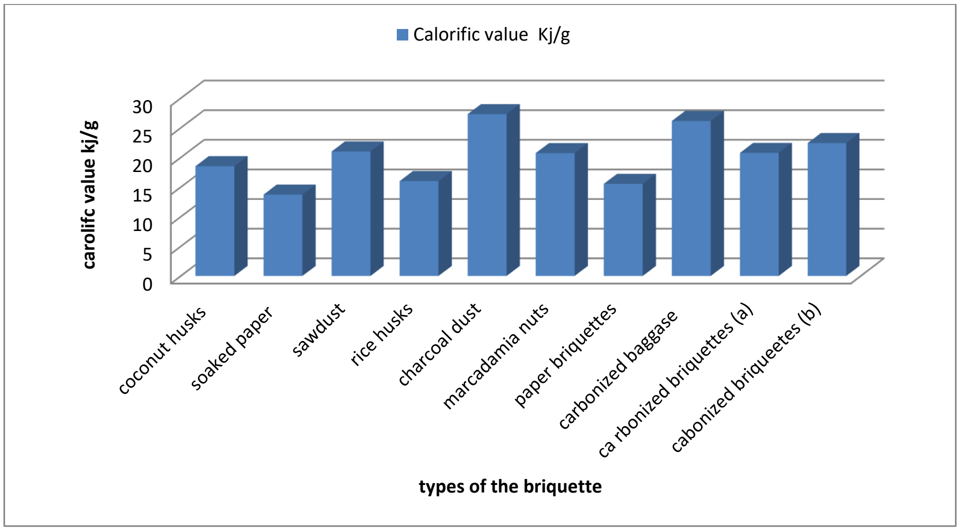

Figure 1.9: Bar graphs showing the calorific value of materials and briquettes

Results for the combustion characteristics

As the combustion of the briquettes takes place the time taken is recorded in the table below

Table 4: Table Combustion time for three kinds of briquettes

Type of briquette	Time taken for combustion
Non carbonized briquette	30 min
Carbonized briquette	47min
Sawdust briquette	28min

From this experiment it was found that carbonized briquettes take a long period in combustion as shown in figure 1.9 whereas the sawdust briquettes took a shorter time in combustion because of high volatile matter in the composition because through carbonization volatile matter is eliminated from the biomass thus increasing the calorific value thus it is possible to have longer heating

Though sawdust briquettes take 28 min to burn it can be used for domestic and small scale purposes where carbonization is not viable. Furthermore 28 min is enough to prepare a meal and they can always be replaced after burning out

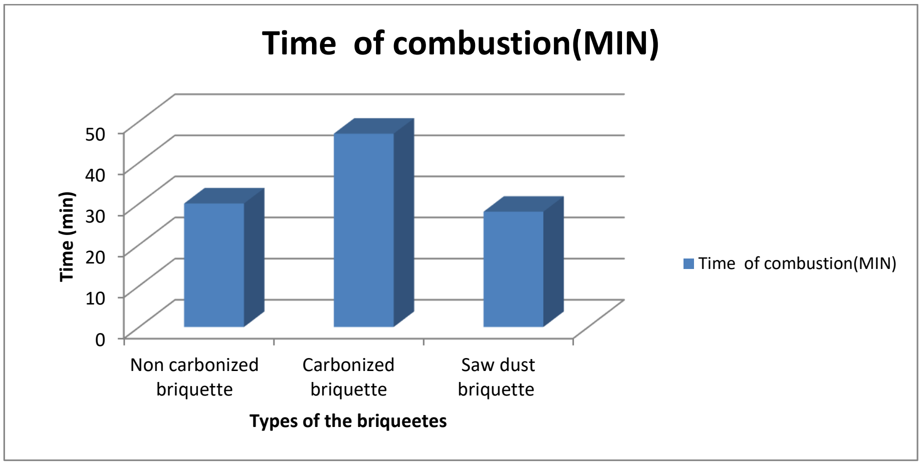

Figure 2 Diagram showing type of briquettes and time of combustion

Discussion and Conclusion

It was found that the elements carbon, hydrogen and sulphur increase the calorific value and this is why carbonisation of waste is recommended when making briquettes. Whereas in those biomass that have high content of nitrogen, oxygen and ash their heating value will be low as this elements suppress it. Therefore it is important to blend the raw materials together for example using the ones with high ash content with those with low ash content or those with a higher heating value with those with a low heating value this will give briquettes with a higher heating value which is a major factor for all fuels.

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Various research and experiments have been carried to determine the ash content of various species of biomass. In order to validate my results I compared my experiment results with those of other researchers as shown in table 5 found that ash content in a particular biomass depends on one of the following factors: Harvesting method, pre-processing method, the thermochemical and bio chemical method used, handling and storage, growing conditions and plant type and species,

Table 5 : Comparison of experimental results from the other researchers

Name of the biomass	% ash from experiment	% ash from researchers
Rice husks	16.07%	13%
Bagasse	12.09%	11%
Soaked papers	7.61%	-
Sawdust	6.4%	
Charcoal dust	3.7%	2%
Coco nut husks	5.8%	7%

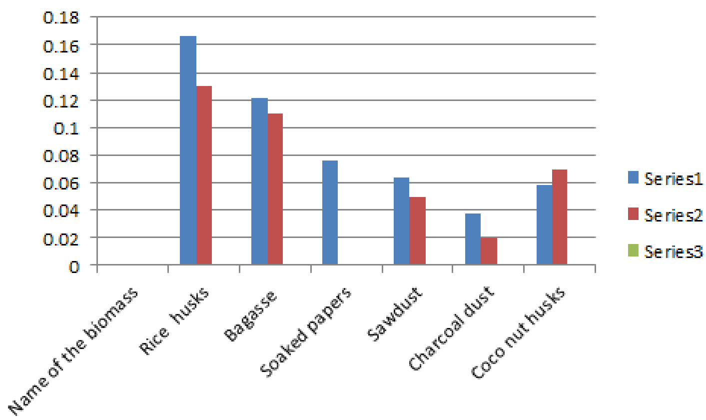

Figure2.1: Bar graph showing comparison between the ash content of other researchers and the experiment results

It is ~~significant~~ important during the production of briquettes at low pressure to soak the biomass materials as it was found in Kenya there are many small scale producers of briquettes who are doing this to soften the materials. Moreover there is another advantage for soaking the raw materials there will be leaching of the alkali elements thus producing briquettes which will burn without producing any smoke thus reducing indoor pollution.

In-door pollution and deforestation is the major problem in Kenya ~~and deforestation~~ and its impact as a result of over reliance ~~of~~ on charcoal and wood fuel. In this paper solutions have been discussed at length how these problems can be solved. By the use of well-designed cooking stoves to reduce PM and CO as it has been found that use of traditional cook stoves result to a lot of emission particulate matter which is has an adverse effect to human. Also the complexity of the stove is a problem in terms of design, lack of maintenance which leads to accumulation of ash in the stove and excess of air in the combustion which result to increased emission in form of smoke and will have low ash content.

In many parts of Kenya a lot of people are living below a dollar in a day which forces them to suffer from energy poverty. This has made them to rely on traditional fuels like (charcoal, wood fuel and dung, agricultural waste etc.). It will be better to introduce clean fuels like briquettes which have the characteristics of a good fuel which are: available in bulk and cheap, have high calorific value in comparison with other traditional solid fuels, low ash and moisture content ,they are smokeless rather than replacing them with other stoves which rely on fossils fuels like LPG, kerosene.

Commented [MM5]: In full

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