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Properties of Briquette from Agricultural Waste available in Brunei Darussalam and its Environmental Impact

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Abstract— **Briquettes are composed of the binder and filler. A binder is usually made up from fibrous organic materials such as newspaper, starch flour etc. in order to hold the briquettes together. The filler is used to enhance the combusting performance.**

To make briquette, two wastes such as saw dust and rice husks was used as the filler material. Those were obtained from saw mills and rice fields respectively. Newspaper was used as the binder material. The newspapers were first soaked in hot water for 3 hours until it reaches porridge-like consistency. The briquettes was made with a Caulk Gun, and dried in an incubator at 50 degree Celsius for 2 days. Eight different types of briquettes were made with different combination of the above mentioned filler and binder materials. Calorific value, elemental analysis and burning tests were performed for the manufactured briquettes. These manufactured briquettes were compared with a commercially available briquette and were ranked based on the basis of experimental properties. From the above tests, it may be concluded that, there is a great potential for these briquettes in Brunei Darussalam and could possibly serve as an alternative source of energy with less environmental impact.

Keywords— Biomass, Briquettes, Renewable Energy, Calorific Value, Ash Content, Elements, Environmental Impact.

I. INTRODUCTION

Briquettes are a household and institutional fuel resources made up from compressed block of organic waste raw materials compacted into mould which is then dried for a few days before being used for cooking or heating.

Briquettes are composed of the binder and filler. A binding agent or binder is usually made up from fibrous organic materials such as newspaper, starch flour etc. in order to hold the briquettes together. The filler is used in order to enhance the combusting performance of the briquettes which should be made locally available all year round such as saw-dusts or rice-husks.

Brunei Darussalam, located on the North-West part of the island of Borneo, is one of the oldest kingdoms in the South East Asian region. The Sultanate, which has a land mass of 5,769 sq. km, has four districts: Brunei-Muara, Tutong, Belait and Temburong. The capital, Bandar Seri Begawan, is located along the Brunei River in the Brunei-Muara district. Rain and sunshine created one of the largest rain forests in the world. Brunei's gazetted forest reserves, which cover an area of about 235,520 ha, or approximately 40% of the total land area. The forests are managed on an optimal, sustainable and ecologically sound basis. There were two types of saw dusts samples obtained from the saw mills, i.e. hilly and peat swamp. For the hilly samples coarse samples were obtained and similarly to the rice husk samples, experiments were done to the coarse samples and manually grinded finer samples. For the peat swamp, only fine samples were available thus no comparison can be made to its coarse sample.

In Brunei Darussalam, several saw mills are currently disposing their excess saw dusts. Recovery rate of saw dusts were calculated to be approximately 40%-50% and thus with Brunei's quota of 100,000 m^3 area for selective logging activities per year, approximately 40,000 m^3 to 50,000 m^3 worth of the logging done are saw dusts waste [1].

In terms of availability in Brunei Darussalam, rice husks are readily abundant. Excess rice husks were burnt openly to reduce the stockpile of rice husks. Local rice production steadily increased according to statistics from 2002 to 2011 at 372 metric ton to 1,480 metric ton [1]. Taking an approximate of 20% recovery rate of rice husk, in 2011, rice husk available was approximately 296 metric ton, equivalent to 296,000 kg.

Two sets of solid fuel briquettes were produced from rice husk using starch and gum Arabic as binders [2]. The briquetting was carried out manually using a dead weight. Good and strong briquettes were produced. Water boiling tests were carried out which showed that 1kg of rice husk - gum Arabic briquette and rice husk - starch briquette took 15 minutes respectively to boil 2 litres of water where as it took 1.2 kg of firewood 21 minutes to boil the same quantity of water. Flame test also showed a pale yellow throughout and pale yellow to pale blue for rice husk- gum Arabic and rice husk- starch briquettes respectively. These indicate the superiority of briquettes over firewood in terms of combustion characteristics and quantity respectively and also indicate the advantage of briquette in terms of ease of handling and transportation.

Markson et al. [3] investigated the optimal compositions of coal, rice husk and palm oil sludge for energy derivation produced at various compression pressures in the range of 20 to 45 Mpa. Their combustion characteristics were tested. Results showed that a 5:3:1 ratio by weight of coal, rice husk at a compression pressure of 35 Mpa produces a minimum power loss.

Three different types of biomass viz. bagasse, rice straw, and water hyacinth were carbonized, crushed and sieved through screens to obtain the particle size of 150-750 µm [4]. Each sieved bio-coal was then well mixed with the rice husk charcoal at the mixing ratios between the rice husk charcoal and the other charcoal of 80:20, 60:40, 40:60, and 20:80. The mixtures were densified, using cassava starch as binding agent, via the cold extrusion process. The densified charcoals were finally sun dried. Physical and mechanical properties i.e., density, ultimate stress, and toughness of the mixed biocoal briquettes produced were examined and it was found that the mixing ratio had a significant effect on the physical and mechanical properties of the briquettes. Density, ultimate stress and toughness increased with increasing mixing ratio (rice husk charcoal quantity). The rice husk-bagasse charcoal briquette was found to possess the maximum density, ultimate stress and toughness followed by the rice husk-rice straw and the rice husk-water hyacinth charcoals briquettes. Flue gas temperature and, CO and NO contents were monitored and recorded during the combustion tests. The experimental results revealed that the flue gas temperature was maximized at the greatest proportion of the rice husk charcoal. The rice husk-bagasse briquette provided flue gas with maximum temperature followed by the rice husk-rice straw and the rice husk-water hyacinth briquettes. Investigation on CO and NO contents exhausted showed that they were not significantly affected by the mixing ratio.

An agricultural waste, rice husk, in briquette form was used as an alternative fuel to fire crucible furnace to melt lead, zinc and aluminium [5]. Results showed that lead and zinc melted and reached their pouring temperatures of 384 ^{o}C and 530 ^{o}C in 70 minutes and 75 minutes respectively. Aluminium was raised to a maximum temperature of 520 ^{o}C in 75 and 100 minutes. The average concentration of the pollutants (CO, $S0_2$ and NO_X) were found to be below the tolerance limit and that of TSP (Total Suspended Particulates) was found to be within the tolerance limit stipulated by Federal Environmental Protection Agency (FEPA) in Nigeria.

A project undertaken on the development of briquettes from the waste wood (sawdust) resulting from the main waste from timber companies located in the Piura region of Peru [6]. This waste wood currently lacks a useful purpose, and its indiscriminate burning generates CO and CO_2 emissions.

Through a drying and compression process, sawdust briquettes were obtained with the following features: 19.8 MJ/kg, 10% of humidity, 894 kg/m^3, 1.3% of ashes, 15.29% of fixed carbon, and 83.41% of volatile matter.

The results achieved show that sawdust briquettes are a perfect substitute for the fuels coming from illegal logging of the dry forest reserve in Piura that are currently used in domestic stoves (e.g. charcoal, firewood) by 55.81% of families in the region.

In order to investigate the acceptance of the substitute product, eleven communication and awareness workshops were conducted reaching over 600 families, in addition to product testing for 127 families in five low-income areas of the Piura region.

The sawdust of a major hardwood species, Albizia zygia, Ethiopia, is collected and densified into briquettes at a pressure of 2000 MPa at 450 °C and heat intensity of 300% [7]. The results obtained showed that the briquettes produced using 100% sawdust of Albizia zygia had a lower moisture content of 7.10% than the solid wood (23.76%) of the some species. Also, the heat value and the percentage dry matter of the briquettes were 4.723 Kcal and 92.90% respectively which were much higher than the values obtained for the heat value (4.014 Kcal) and percentage dry matter (76.24%) of the solid wood of the same species. It was concluded that stable briquettes with higher calorific value can be produced from the sawdust of Albizia zygia.

Briquettes were produced out of the mixtures of sawdust from Teak, Masonia, Iroko and Afara woods [8]. This mixture of sawdust was sieved into three different grain sizes; A (1.2 mm), B (1.15 mm) and C (0.75 mm). To these were added two grain sizes (1.18 mm and 1.70 mm) of palm kernel shell and paper pastes in various ratios. Sixteen samples were produced from each grain size of the sawdust; hence there are forty-eight different ratios of sawdust: palm kernel shell; paper paste. Five each of the samples were tested and average values recorded. The experimental results show that, as the percentage by weight of paper paste increases, both percentage fixed carbon and ash content reduce. Also both the volatile matters and the calorific values increase with increase percentage paper paste. However, it was noted that as the paper paste exceeded 25% there was a decrease in the calorific value. Hence for optimum performance and calorific value, the appropriate percentage paper paste should range between 20% and 25%.

Rice husk coffee husk, saw dust, ground nutshell and cotton stalks etc. were densified into briquettes at high temperature and pressure using different technologies [9]. The various advantages, factors affecting the biomass briquetting were discussed and comparison drawn between coal and biomass briquetting.

The effect on environment by agricultural and other industrial wastes is on the increase and is causing a lot of problem. Adequate means of disposing these wastes are lacking, hence, converting them to other useful products such as briquettes for domestic fuel is desirable. In this work [10], the energy values of briquettes made from some of these agricultural by-products using two binders were assessed. Wastes from rice husk, maize cob, groundnut shell and sugarcane bagasse were turned to briquettes using two different types of agricultural byproduct binders (banana peel and cassava peel gel). The briquettes were subjected to energy evaluation test using the Fulton XRY-1B Oxygen Bomb Calorimeter. The mean bulk densities of the briquettes produced from rice husk, maize cob, groundnut shell and sugar cane bagasse were 0.75 g/cm^3, 0.69 g/cm^3, 0.81 g/cm^3 and 0.65 g/cm^3 respectively. The results obtained showed that the average energy values of the briquettes produced using cassava peel as binder from rice husk, maize cob, groundnut shell and sugarcane bagasse were 26.612 MJ/Kg, 28.255 MJ/Kg, 33.703 MJ/Kg and 32.762 MJ/Kg, respectively. The corresponding average values for those produced using banana peel as binders were 29.980 MJ/kg, 28.981 MJ/kg, 32.432 MJ/kg, 31.508 MJ/kg for rice husk, maize cob, groundnut shell and sugarcane bagasse, respectively. 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 26.61 MJ/kg and these were significantly different ($p < 0.05$). The briquette from groundnut shell is therefore more suitable for starting and maintaining fire for cooking and other domestic heating. The briquettes from these by-products in terms of energy values are ranked as follows: groundnut shell > sugar cane bagasse > 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.

Providing biomass as an alternative to wood charcoal using in Ghana is discussed by Ebo Tawiah Quartey [11] article aims at. Using agricultural wastes converted into charcoal briquettes to provide much needed source of cheap fuel that is cleaner in burning. It is also intended to create awareness of agricultural wastes briquettes technology in Ghana and to make use of the technology by small scale entrepreneurs. This paper also seeks to explore benefits Ghana can achieve by using agricultural residue as a substitute for wood fuel burning. Agricultural residue includes all leaves, straw and husks left in the field after harvest, hulls and shells removed during processing of crop at the mills.

Current energy shortage and environmental issues have led to exploitation of renewable energy resources especially in Kenya that includes agricultural residues. These residues are available, indigenous and are environmental friendly but some cannot directly in combustion process due high moisture content and low volumetric energy unless by briquetting. A research was focused on evaluating the physical and combustion characteristics of rice husk-bagasse-charcoal dust composite briquettes [12]. Rice husk and bagasse were carbonized in a muffle furnace at 450 ^{o}C, grounded, sieved and mixed with charcoal dust at different mixture ratios. The mixtures were bonded with different types of binder at varying amount before briquetting at 5 MPa using hydraulic press into different sizes. Physical and combustion tests were conducted according to standard procedures. The binder types and ratios had effect on the density, calorific values, ignition and burning time that could be attributed to the incombustibles matter. It was concluded that briquettes bonded by molasses binder had better combustion characteristics. There is need to study the use of other binder materials.

Ikelle and Joseph [13] based their work on production and study of the properties of smokeless briquettes of various compositions with coal and rice husk. Different briquettes were produced with starch, bitumen and $CaSO_4$ as the binders while $Ca(OH_2)$ was the desulphurizing agent. The proximate analysis of the raw coal sample showed ash content 19.12%, moisture content 6.25%, volatile matter 41.12%, fixed carbon 33.51% and calorific value 117 KJ/g, the rice husk had the following values ash content 7.53%, moisture content 10.48%, volatile matter 68.74%, fixed carbon 13.25% and calorific value 65.24 KJ/g. The briquettes produced are in the following ratio of mixtures of coal and rice husk 100:0, 80:20, 60:40, 40:60, 20:80 and 0:100 respectively. The prepared briquettes were sun dried for seven days, subjected to various tests to assess their fuel quality. The briquettes produced with starch as the binder had better results for faster ignition time, lower amounts of sulphur emissions during burning, highest calorific values and longer burning time for all the different compositions.

A comparative performance of composite sawdust briquette with kerosene fuel during domestic cooking conditions was discussed by Kuti and Adegoke [14]. Controlled cooking test was carried out on three food items namely white yam, rice and white beans, respectively using composite sawdust briquette fuel and kerosene. Yam has the lowest specific fuel consumption (SFC) value of 0.12 kg/kg when sawdust briquette was used, 0.0635 kg/kg when kerosene was used. Rice had SFC of 0.195 kg/kg when composite sawdust briquette was used and 0.0795 kg/kg when kerosene was used Beans had the highest SFC value of 0.32 kg/kg and 0.1425 kg/kg for composite sawdust briquette and kerosene respectively. On the other hand from the time spent to cook food items, yam has the lowest time spent in cooking per kg of 40.34 min/kg for briquette fuel and 36.36 min/kg for kerosene fuel. Rice has a cooking time of 40.38 min/kg for composite sawdust briquette and 31.1 min/kg for kerosene fuel. Beans had the highest cooking time of 75.83 min/kg for composite sawdust briquette and 74.7 min/kg for kerosene. From the result of carried out, the effect of the type of cooked food item on the SFC as well as the time spent in cooking 1 kg of food item is highly significant at 0.05 and 0.01 levels of significance. On the other hand, the effect of the type of fuel used for cooking on the SFC and the time spent in cooking per kg is not significant at any level of significance. There is no interaction between the type of cooked food item and the type of fuel used as levels of significance is low.

Yazdani et al. [15] experimented with seven varieties of wood saw dust has been taken into consideration with regard to fuel value and its environmental impact. Among the seven variety of variety of wood investigated, one is soft, two are light and four are hard type. Properties, such as wood density, ash content and elemental composition of plants were determined and correlated with the calorific value and evaluated in relation to their properties and environmental impact when burned. It was revealed that the sawdust with the highest calorific value does not necessarily constitute the best option as fuel, if elemental composition is taken into account. The variation of the wood density, calorific value, ash contains and elemental composition C, N, and S, and their indirect impact on the environment were discussed.

A fuel switching project was implemented for using the sawdust as an energy source replacing fossil fuels in the district heating systems [16]. The above was introduced in five medium sized towns in Romania.

Fuel briquettes generated by the low-pressure compaction of paper, sawdust, agricultural or yard waste, etc. currently serve as an alternative to firewood, wood pellets and charcoal in developing countries in Africa, Asia and South America [17]. Research at Boise State University in Idaho, explored both the calorific content and shape to optimize the burn efficiency of the bio-briquettes. The energy content of briquettes ranged from 4.48 to 5.95 kilojoules per gram (kJ/g) depending on composition, whereas the energy content of sawdust, charcoal and wood pellets ranged from 7.24 to 8.25 kJ/g. Bio-briquettes molded into a hollow-core cylindrical form exhibited energy output comparable to that of traditional fuels. The study demonstrates that low-energy content feedstock can be composted, pressed and combusted to produce heat output commensurate with higher energy content fuels.

A study was undertaken to assess the calorific value of briquettes produced from mixed sawdust of three tropical hardwood species (Afzeliaafricana, Terminaliasuperba, Meliciaelcelsa) bonded with different binding agents (starch, cow dung and wood ash) [18]. Sawdust from each of the species was mixed with the binder in ratio of 70:30 cow dung and wood ash and 70:15 of starch. The sawdust where mixed in a ratio 50:50 for each briquette combination produced. Combustion related properties namely percentage volatile matter, percentage ash content, percentage fixed carbon and calorific value of the briquettes where determined. All processing variables assessed in this study were not significantly different except for percentage fixed carbon at five percent level of probability. The result shows that briquette produced from sample of Afzeliaafricana and Terminaliasuperba combination bonded with starch had the highest calorific value of 33,116 kcal/kg while briquette produced from sample of Afzelia Africana and Terminaliasuperba bonded with ash had the least calorific value of 23,991 kcal/kg. Since the aim of briquetting is to produce briquette that will serve as good source of fuel and support combustion, the best briquette was produced when sawdust was mixed with starch. This study shows that the use of mixed wood residue from the selected species and other hardwood species for briquette production will provide an alternative cheap energy source to firewood for household heating application.

Elemental analysis can be used to describe biomass fuels, determine their calorific values [19] and their expected impact on the environment. This investigation is aiming to determine the best fuelwood by evaluating energy content and elemental composition for seven different available species. In this study, the wood density, ash content, calorific value and the elemental composition of the sawdust samples were determined. A simple credit system is developed that could help consumers to decide on the best option of fuel wood for heating purpose.

Some experiments have been carried out to investigate the best briquette dimension [20]. Briquettes are formed cylindrical with a diameter of 13 mm and made from 75% of wooden saw dust added with 25% of lignite in order to improve its heating value and combustibility. Additionally they are mixed with 40% natural binder. In order to obtain the same initial weight of the briquette group, the following amount of bio-briquettes are selected: 20 pieces of 3 gram briquette, 15 pieces of 4 gram briquette, and 12 pieces of 5 gram briquette. Combustion air are supplied with three different velocities (i.e. 0.3 m/s, 0.4 m/s, and 0.5 m/s), meanwhile its temperature is held constant at 70 ºC. Those bio-briquettes are placed onto a 11.7 cm diameter perforated plate which is located within a cylindrical combustion furnace where combustion air flows upward. The plate is suspended by a wire which hangs down from a constantly measuring electronic scale. As expected, it is concluded that smaller bio-briquettes produce better combustion characteristics (especially combustion rate) due to larger specific surface area available for reaction.

Other experiments have been conducted to investigate the influence of particle sizes which come together to form bio-briquettes, however rice husk is used entirely to create the bio-briquettes. There are 5 different particle sizes, i.e. more than 100 mesh, between 70 and 80 mesh, between 60 and 70 mesh, between 50 and 60 mesh, and between 40 and 50 mesh. The investigations revealed that the smaller the particle size, the lesser will be the porosity, and on the contrary, the more will be the density. Briquettes made from coarser rice husks tend to expand more significantly shortly after released from the briquetting machine. Results from the combustion tests show that lower porosities will hinder drying, de-volatilization and char burning processes due to fewer free spaces for mass diffusion. Consequently its combustion rates will be lower. The combustion period will be longer. On the average, briquettes from the largest particle burn only for 19.25 s, while those from the smallest particle react until 28 s. Furthermore more unburned carbon is left at the combustion termination, i.e. only 16% for briquettes from the largest particle compared to 33% for briquettes from the tiniest particles.

It can be concluded from those experiments that briquette dimensions should be as small as possible but their composing particles should be as coarse as possible. Combining those requirements, each briquette should be an impervious single very small unit.

II MATERIAL AND METHODS

A. Briquette Making

To obtain the information we require, several process were carried out. Agricultural waste such as saw dust and rice husks were first obtained from saw mills and rice fields and these samples are then made into briquettes using a Caulk Gun. (Fig. 1)

Figure 1 Caulk Gun

To get the optimum performance we use the paper paste binder at 25% of the total mass of a briquette [8]. To make the biomass briquettes we have measured out 300 g of agricultural waste and 100 g of newspaper which gives a 75% to 25% biomass-binder ratio respectively. The newspapers were first soaked in hot water for 3 hours until it reaches a porridge consistency. This acts as a binder for the briquettes. The agricultural waste was combined with the newspaper in which the mixture will then be inserted to the PVC pipe prepared earlier. The PVC pipe is fixed onto the caulk gun with the washer fitted at the opening end so to prevent the briquettes from flowing out when pressed. (Fig. 2)

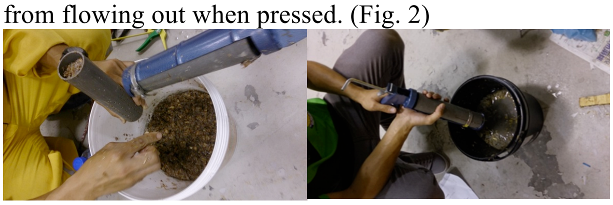

Figure 2 Briquette Making

When ready, the clamp was screwed onto the pipe and the gun was pressed to apply pressure to form the biomass briquettes (Fig. 3). The biomass briquettes were then taken out to be dried in an incubator (Fig. 4) of 50 degree Celsius for 2 days. This procedure is then repeated for all the briquettes with combination of different percentage of agricultural waste. Some of the dried briquettes are shown in Figure 5.

Figure 3. Freshly pressed briquettes

Figure 4 Incubator

Figure 5 Sample of dried briquettes

The manufactured briquettes, its composition and code are given in Table 1. The manufactured briquettes (A to H) are listed in increasing amount of sawdust.

Table1. Material Ratio by Mass for the Preparation of Briquette Samples

Material		Ratio	Code	Remarks
	Coarse Rice Husk	00:75:25	A	
	Fine Rice Husk	00:75:25	B	
Fine Hilly Sawdust	Fine Rice Husk	22.5:52.5:25	C	
Fine Hilly Sawdust	Fine Rice Husk	37.5:37.5:25	D	
Fine Hilly Sawdust	Fine Rice Husk	52.5:22.5:25	E	Incubated at 90^{o}C
Fine Hilly Sawdust		75:00:25	F	
Coarse Sawdust		75:00:25	G	
Peat Swamp Sawdust		75:00:25	H	Incubated 1 day
			I	88 Briquette *

B. *Calorific Value*

For the determination of the calorific value, a sample of the material to be tested was weighted accurately into a suitable crucible. The weight of sample was chosen to give a temperature rise of about 3 K, i.e. a heat release of about 30 kJ. A Gallenkemp Autobomb calorimeter was used with a pressure of 20 bar to determine the calorific value. The method used in the above investigation is based on as described in ASTM D240.

C. *Density*

The density was found out by weighting a known volume of material using an electronic balance.

D. *Ash Content*

The ash content was determined according to TAPPI standard T 211 om-85 [21]. Wood samples were weighed before they were placed in a furnace at 575 °C for 4 h.

E. *Elemental analysis*

The CNS analysis was done in the Elemental Analysis Laboratory of National University of Singapore using an Elementar Vario Micro Cube apparatus. The samples were weighed in a tin capsule and combusted in a furnace at 1150 ^{o}C. A conductivity detector is used to measure the evolved gas and determine the composition.

F. *Combustion Test*

We have fabricated a small stove out of scrap metal. There are two layers in which the inner layer acts as a compartment for the briquettes to burn and an air hole has been cut underneath to ensure a constant volume of air flow.

Figure 6 Stove for Burning Test

Before the test was carried out the briquettes were all measured to a constant value of 60 g. It is then dipped into kerosene and let to burn for 3 minutes to achieve a steady burning state. Wire mesh is then placed on top of the stove where a conical flask containing 100 ml of water is laid to boil. Throughout the test, smoke characteristics and smell emitted have been observed.

A thermocouple thermometer has been put into the water to ensure a boiling point of 100 degree Celsius is achieved before the time is noted. The total time for the briquettes to fully burn out is also taken.

It may be mentioned that, we were unable to perform this experiment on sample I as there was difficulty in keeping the fire burning even with the use of kerosene.

These properties will be used later on to compare with the different types of briquettes made from it.

B. Properties of Briquette

The properties of briquette are shown in Table 3. From the table it is seen that the calorific value increases with increase amount of sawdust and it reaches a maximum of 25.75 MJ/kg at 52.5% of sawdust and it decreases with increase of sawdust to 75%. The increase of calorific value with increased percentage of saw dust seems to be logical as the calorific value of sawdust is more than that of rice husk. The above maximum calorific value is slightly more than the constituent biomass for making the briquettes. The above amount of sawdust for which the caloric value is maximum, might be a critical amount. The ash contain of A and B is less than the consistent biomass (rice husk), whereas the ash contain of C to E, which are made of the combination is in between the two of its constituents. The ash contain of briquettes F to G is comparable with the ash contain of sawdust, since these are mainly made from it.

Table 3. Properties of Briquette

Biomass Briquette	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Density (kg/m^3)	167.33	283.84	245.13	329.32	229.70	351.70	262.60	293.41	650.00
C (%)	40.97	37.27	41.37	43.27	45,08	45,92	46,37	45,89	47,90
H(%)	5,05	4,92	5,23	5,33	5,28	5,63	4,97	5,05	5,50
N(%)	0,36	0,64	0,46	0,30	0,20	0,14	0,15	0,22	0,11
S(%)	0,09	0,09	0,04	0,06	0,07	0,16	0,09	0,11	0,03
Ash (%)	10.26	9.54	7.45	5.51	3.57	1.61	0.93	0.46	7.33
Calorific Value (MJ/kg)	21.07	22.89	19.97	22.07	25.75	20.60	19.81	22.07	21.79

III. Results and Discusscions

A. Properties of Biomass

The calorific value and ash contain of different type of sawdust and rice husk is given in table 2. As seen from the table the all kind of saw dust is better compared with the rice husk in terms of calorific value and ash contain.

Table 2. Heating Values of Saw Dust and Rice Husk

Pure Biomass	**Loose Grinded Rice Husk**	**Loose Coarse Rice Husk**	**Loose Fine Saw Dust (Peat)**	**Loose Coarse saw dust (Hilly)**	**Loose Fine Saw dust (hilly)**
Calorific Value (MJ/kg)	18.080	21.848	21.888	27.467	23.175
Percentage Ash Content %	12.80	13.52	0.93	1.33	0.78

The ash contents of all the briquettes except the two made from total rice husk and binder (A and B) is nearly equal or less than the ash content of the commercially available (I) briquette. The Sulphur, Hydrogen and the Nitrogen contain for the briquettes A to H are comparable with the commercially available briquette (I).

C. Environmental Impact

Table 4 summarizes the properties of all nine investigated briquettes and a rating in terms of energy output and environmental impact based on the elemental analysis. The amount of C, N and S has a negative impact, whereas H has a positive impact on the environment. It may be mentioned that presence of C in a biomass does not account for additional CO_2 generation. But the amount of C mentioned in the table is used for comparison between different briquettes.

For each property, the samples were assigned a value between 1 and 9, with 1 being the best and 9 being the worst. The final rating value was determined as the sum of all values divided by the number of measured six properties [22]. From the rating it is seen that the commercial briquette is still the best followed by briquette F, which is also 2nd compare to the calorific value. Since the material for making briquettes are not expensive, briquette F might be a good alternative to the commercially available version. Further work needs to be done with different combination of bio-mass.

Table 4. Rating of Briquettes

	Briquettes (1 = best, 9 = worst)								
Properties	A	B	C	D	E	F	G	H	I
Density	9	5	7	3	8	2	6	4	1
Calorific Value	5	2	8	4	1	6	7	4	3
Ash Content	9	8	7	5	4	3	2	1	6
Carbon	8	9	7	6	5	3	2	4	1
Nitrogen	7	9	8	6	4	2	3	5	1
Sulphur	3	5	2	3	4	7	5	6	1
Rating	6.8	6.3	6.5	4.5	4.3	3.8	4.2	4.0	2.2

D. Combustion Test

The results of the combustion test are summarized in table 5. From the table it is seen that the briquette E is the best with respect to longer time of burning and quickest to reach the boiling point of water.

Table 5. Results of Combustion Test

Biomass Briquette	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Total Time taken for Water to Boil @ 100°C (s)	347	479	444	432	355	358	402	360
Total Time taken for finish Burning (s)	519	479	687	853	1035	924	794	870

Majority of the flame and smoke characteristics are similar for all. Yellow flame with heavy smoke can be seen for all the briquettes. This could be due to the newspaper binder which produces black smoke. The kerosene also produced a pungent smell during burning. The use of a different binder could produce a better result in terms of flame, smoke and smell quality.

IV. Conclusions

Different types of briquettes were manufactured using rice husk and sawdust as filler and newspaper as binder. Their properties are investigated and compared with a commercially available briquette. All the briquettes have low sulphur content. They also do not emit additional carbon-di-oxide as it is made from biomass. It was found that briquette E has the highest caloric value than all the investigated briquettes. However comparing other properties the commercially available briquette (I) is the best. But the main disadvantage of briquette I is that, it is not readily combustible. From the test results it is also concluded that further investigation is needed to improve on the other properties (beside calorific value) of the manufactured briquettes.

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