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Production and Characterization of Rice Husk Pellet

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Abstract: *Production and characterization of rice husk pellet was investigated as an alternative source of energy. Pellets were produced from the rice husk using a mold and a small hydraulic press (fitted with pressure gauge) the pellets were produced without binder, at three (3) pressures of compaction of 28MPa, 31MPa and 34MPa and three (3) particles sizes of 212µm, 300µm and 425µm. The effects of compaction pressure on the properties of pellets were determined. The properties determined were moisture content, ash content, bulk density, porosity index, and the calorific value. The results showed that, the higher the compaction pressure the lower the porosity index and consequently the higher the bulk density. The fuel pellet's density affects its bulk thermal properties. This effect is seen, when 100g of each pellet sample were combusted. Increased burning time of pellets was observed as the bulk density increases. The result also showed that the maximum calorific value of 17.589MJ/kg was achieved with a compaction pressure of 34MPa and with particle size of 425µm. also the minimum calorific value of 15.129MJ/kg was achieved with a compaction pressure of 34MPa and with particle size of 212µm.*

Keywords: *Ash, Bulk density, Calorific value, Compaction pressure, Moisture, Porosity, Pellet*

I. INTRODUCTION

Rice husk is one of the largest readily available but most underutilized biomass resources. There are many reported uses of rice husk such as a fuel in brick kilns, in furnaces, in rice mills for parboiling process, in the raw material for the production of furfural, sodium silicate, Briquettes, molecular sieves [1]

Despite having so many well established uses of rice husk, little portion of rice husk produced is utilized in a meaningful way, the remaining part is allowed to burn in open piles or dumped as a solid waste or it is used as cattle feed. Many reasons associated with rice husk for not being utilized effectively as stated by [2] include: (1) lack of awareness of its potential, (2) insufficient information about proper use, (3) penetration of technology, (4) lack of environmental concerns etc.

With the global campaign to combat climate change, countries are now looking for alternative sources of energy to minimize green house gas (GHG) emissions. Aside from being carbon neutral, the use of biomass for energy reduces dependency on the consumption of fossil fuel; hence, contributing to energy security and climate change mitigation [3].

Agricultural wastes have been highly promoted to be used in various heating systems, during the past decades. Compared to fossil fuel, however, most of agricultural wastes have higher moisture content and lower density, thus making them technically unsuitable for direct use due to combustion and handling problems. Conversion of biomass wastes to briquettes (pellets) is a solution for such problems. It improves biomass handling characteristics, increases the volumetric calorific values, and reduces transportation, collection, and storage costs [4] and [5].

The densification of biomass into briquettes, logs, bales, chips, pellets, etc has become an important source of energy even in the rural communities. The main advantage of the Biofuel briquettes are its domestic origin, potential for reducing total dependence on oil and gas economy, jobs creation to the rural dwellers and help in the waste management by changing waste to wealth. Biofuels briquettes for utilization as energy source for domestic and industrial heating processes can significantly reduce emissions of air pollutants [6].

This work is aimed at producing rice husk pellet by varying the compaction pressure. Effect of compaction pressure of biomass materials on physical properties and combustion characteristics were also investigated.

II. MATERIALS AND METHODS

2.1. Raw Material Procurement

The rice husk was collected from a rice mill at Yelwa Tudu, it was grinded into a powdered form and sieve through screens to obtain three particle sizes of 212µm 300µm and 425µm.

2.2. Pellet Production

The Rice husk pellet was produced by compaction in a mold with the following dimensions 12mm diameter and 20mm length at three (3) pressures of 28MPa, 31MPa and 34MPa. [4] 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 45Mpa. The rice husk powder was first mixed with a little water directly to moisten it before loading in the mold. Water acts as both a binding agent and a lubricant. Water helps develop Vander Waals' forces by increasing the area of contact between particles [5]. The production of the pellet was done using a manually operated hydraulic press fixed with a pressure gauge for varying the pressure and a simple mould. The setup is shown in fig. 1.

Figure 1: Manual hydraulic press fixed with a pressure gauge

Figure 2: The mould use for the production

Figure 3: Pellets produced

2.3 Determination of Bulk Density

Bulk density measurement was determined according to the method of [7] which states that for all densified products (cubes, pellets, or crumbles); use a cylindrical container with a height-diameter ratio within the range of 1.25–1.50. The diameter of the container must be at least ten times larger than the largest dimension of a single product. The bulk density was determined by calculating the ratio of the mass to the volume occupied. A cylindrical metal container with 100 mm diameter and 130 mm height was weighed. The bulk density measurement was repeated five times and the average value and range were reported. The bulk density was calculated from the relationship:

$$Bulk\ density\ (\boldsymbol{B}_d) = \frac{W_1 - W_0}{V_2} \qquad (1)$$

Where:
W_0 = Mass of the container
W_1 = Mass of the sample and the container
V_2 = Volume occupied by the pellet

2.5 Determination of Ash Content

Ash content was determined using the method of [8]. 3 pieces of each pellet samples were placed in a pre-weighted crucible and were weighed out. The samples were incinerated in a furnace at 760^0C until complete ashing was achieved. The crucibles were left over night to cool. The cooled samples were then weighed. The ash content was calculated by using equation (2):

$$Ash\ content\ (\%) = \frac{(W_5 - W_3) \times 100\%}{W_4 - W_3} \qquad (2)$$

Where:
W_3 = Weight of the crucible,
W_4 = Weight of the crucible + sample before incineration and
W_5 = Weight of the crucible + sample after incineration

2.6 Determination of Moisture Content

The moisture content of each pellet sample was determined by the oven drying method. This was carried out at temperature of 103 ± 2^0C in accordance with the method of [9]. The samples were dried in the oven for 1 hour. The moisture content was calculated by using equation (3):

$$Moisture\ content\ (\%) = \frac{[(W_7 - W_6) - (W_8 - W_6)] \times 100\%}{W_7 - W_6} \qquad (3)$$

Where:
W_6 = wt of empty container
W_7 = wt of container + sample before drying
W_8 = wt of container + sample after drying

2.7 Determination of Porosity Index

The porosity of each pellet sample was determined based on the amount of water two pieces of each pellet sample was able to absorb. Each pellet sample was immersed in water at room temperature for 30s. The porosity index was calculated as the ratio of the mass of water absorbed to the mass of the sample immersed in the water [10]. The test was replicated five times and the average value recorded.

$$Porosity\ index\ (P_i) = \frac{(W_{10} - W_9) \times 100}{W_9} \qquad (4)$$

Where:
W_9 = mass of sample
W_{10} = mass of sample immersed in water
$(W_{10} – W_9)$ = mass of water absorbed

2.8 Determination of Calorific Value

The net calorific values of the 12 samples were determined by using the relationship below of [11]

$$NCV = 18.7(1.0 - AC - MC) - (2.5MC) \quad (5)$$

Where

NCV = net (lower) calorific value
AC = ash content
MC = moisture content

2.9 Determination of Burning Rate

Burning rate is the ratio of the mass of the fuel burnt (in grams) to the total time taken (in minutes) [12].

$$Burning\ rate\ (B_R) = \frac{mass\ of\ fuel\ consumed\ (g)}{total\ time\ taken\ (\text{min})} \quad (6)$$

100g of each pellet samples were weighed using an electronic weighing machine. Each sample at the time of burning was put in a domestic stove. The combustion was initiated by the addition of a little kerosene and igniting with matches. The temperature of the burning samples was taken by means of thermocouple at every two minute intervals using a stop watch until it was completely burnt. The temperature was taking from a particular point on the stove for all the samples.

III RESULTS AND DISCUSSION

3.0 Results

The results of the experiments carried out on the properties of the rice husk pellet are presented on table 1 to

Table 1: The description of pellet samples

Samples	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
Particles size (µm)	425	425	425	300	300	300	212	212	212
Compaction pressure (MPa)	28	31	34	28	31	34	28	31	34

Table 2: The result of bulk density of pellet samples

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
Mass of container, W_0 (kg)	.0736	.0736	.0736	.0736	.0736	.0736	.0736	.0736	.0736
Mass of sample + container, W_1 (kg)	.5979	.6300	.6407	.8050	.8143	.8236	.8443	.8650	.8665
Range (kg)	.0029	.0033	.0028	.0026	.0022	.0021	.0044	.0026	.0022
Volume occupied, V_2 (m^3)	.001	.001	.001	.001	.001	.001	.001	.001	.001
Bulk density, B_d (kg/m^3)	524.3	556.4	567.1	731.4	740.7	750.0	770.7	791.4	792.9

Table 3: The result of ash content of pellet samples

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
Weight of crucible, W_3 (g)	61.9	51.2	63.8	62.4	96.6	110.2	66.3	90.3	114.9
Weight of crucible + before incineration W_4 (g)	67.8	56.9	69.2	69.8	102.6	115.9	72.3	96.7	120.2
Weight of crucible + after incineration W_5 (g)	62.4	51.5	64.0	63.0	97.4	110.8	67.2	91.2	115.6
Ash content (%)	8.5	6.0	3.7	10.5	13.3	10.5	15.0	14.0	13.2

Table 4: The results of moisture content of pellet and charcoal samples

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
wt of empty container W_6 (g)	24.1	24.0	23.9	24.0	23.7	24.7	24.1	23.8	24.0
wt of container + sample before drying W_7 (g)	34.3	34.1	33.8	35.7	34.2	34.2	34.5	34.5	33.6
wt of container + sample after drying W_8 (g)	33.8	33.8	33.6	35.4	33.9	33.9	34.2	34.1	33.1
Moisture content %	4.9	3.0	2.0	2.6	2.9	3.2	2.9	3.7	5.2

Table 5: The results of porosity index of pellet samples

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
Mass of sample W_9 (g)	4.7	4.7	4.8	5.1	4.3	4.2	4.8	5.1	4.9
Mass of sample immersed in water W_{10} (g)	9.3	9.2	9.3	7.3	5.8	5.6	5.5	5.8	5.5
Mass of water absorbed ($W_{10} – W_9$) (g)	4.6	4.5	4.5	2.2	1.5	1.4	0.7	0.7	0.6
Porosity Index %	97.9	95.6	93.8	43.1	34.9	33.3	14.6	13.7	12.2

Table 6: result of net calorific value of pellet samples

Sample	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
NCV unit	16.072 MJ/kg	16.942 MJ/kg	17.584 MJ/kg	16.185 MJ/kg	15.598 MJ/kg	16.058 MJ/kg	15.281 MJ/kg	15.292 MJ/kg	15.129 MJ/kg

Table 7: The result of proximate analyses for pellet samples

Sample	Moisture content %	Ash content %	Bulkdensity kg/m^3	Porosity index %	Calorific value MJ/kg	Burning rate (g/min)
P_1	4.9	8.5	524.3	97.9	16.072	2.38
P_2	3.0	6.0	556.4	95.6	16.942	2.27
P_3	2.0	3.7	567.1	93.8	17.584	2.27
P_4	2.6	10.5	731.4	43.1	16.185	1.79
P_5	2.9	13.3	740.7	34.9	15.598	1.47
P_6	3.2	10.5	750.0	33.3	16.058	2.17
P_7	2.9	15.0	770.7	14.6	15.281	2.17
P_8	3.7	14.0	791.4	13.7	15.292	2.00
P_9	5.2	13.2	792.9	12.2	15.129	1.85

Table 8: Results of time and temperature for burning 100g of fuel

Time (min)	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
0	26	26	26	26	26	26	26	26	26
2	44	47	52	54	32	38	38	31	30
4	95	91	161	84	46	68	60	57	39
6	128	108	180	89	54	94	83	90	66
8	160	115	189	78	59	132	106	97	95
10	147	123	217	80	67	145	108	101	103

12	129	124	167	79	77	136	122	112	112
14	112	107	130	73	94	118	148	119	131
16	97	97	100	73	104	104	154	122	136
18	88	89	81	76	97	92	148	113	122
20	77	82	76	83	72	90	126	104	102
22	73	77	69	100	54	79	113	90	85
24	68	71	59	101	46	74	103	73	72
26	62	66	57	89	42	70	92	67	63
28	56	58	49	78	44	60	82	60	59
30	50	56	49	71	46	54	69	54	54
32	46	51	47	60	50	49	63	48	54
34	43	47	39	51	50	46	44	46	55
36	38	42	39	48	48	39	42	44	50
38	35	37	35	45	48	38	38	39	47
40	33	35	33	46	51	36	36	38	44
42	31	33	32	42	51	34	34	36	38
44		32	31	51	50	32	32	35	37
46				37	50	31	30	34	35
48				37	43			32	34
50				36	42			31	34
52				35	43				33
54				33	42				32
56				32	38				
58					36				
60					37				
62					37				
64					36				
66					33				
68					32				
70									

Table 9: Result for burning rate of pellet samples

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
Mass of fuel (g)	100	100	100	100	100	100	100	100	100
Total time taken (min)	42	44	44	56	68	46	46	50	54
Burning rate (g/min)	2.38	2.27	2.27	1.79	1.47	2.17	2.17	2.00	1.85

IV DISCUSSIONS

4.1 Bulk Density

It was observed from the results of tables 1 and 2 that the bulk density of the rice husk pellet was influence by the compaction pressure. As the compaction pressure increases from P_1 to P_3, P_4 to P_6 and P_7 to P_9, the bulk density also increase. The fuel pellet's density affects its bulk thermal properties. The lower the density, the less heat is required for a specific volume of fuel to reach the ignition temperature. This was in line with the observation of [13]. This was seen on the burning rate of the different samples, for instant pellet $P_{1,}$ P_2 and P_3 recorded slightly higher temperatures within few minute of combustion, while P_6, P_7, P_8, and P_9 recorded slightly lower temperature within the same time range. And again, while pellet $P_{1,}$ P_2 and P_3 maintained high temperatures for a relatively short period, P_6, $P_{7,}$ P_8, and P_9 maintained high temperature for a relatively longer period as shown on Table 8. The deviation of pellet sample P_4 and P_5, may be attributed to prevailing atmospheric wind condition at the time of the combustion.

4.2 Porosity index

The porosity, which is the measure of the resistance to water penetration, is an important physical property in the determination of the quality of the pellet fuel: The lower the porosity, the higher the resistance to water penetration. In his finding, [14] observed that the higher the percentage resistance to water penetration of briquette, their best shatter and durability indices showed that they have good shock and impact resistance and are good for handling and transportation.

The investigations reveal from tables 1 and 5 that pellet porosities are influenced by compaction pressure. The less the compaction pressure the high porosity and the lesser the porosity the higher the bulk density. The lowest density was 524.3 kg/m^3 at a pressure of 28MPa, while the highest was 792.9 kg/m^3 at a pressure of 34MPa. The lower porosities will hinder mass transfer, such as drying, devolatilization and char burning processes, due to fewer free spaces for mass diffusion (e.g. water vapor, volatile matter, and carbon dioxide outflows and simultaneously oxygen infiltration). Consequently its combustion rates were lowered, given rise to longer period of combustion as observed by [15]. This condition was observed for pellet samples P_1 to P_3 and P_7 to P_9 as shown on Tables 8 and 9. For samples P_4 to P_6, the deviation show that there are other factors that may affect the combustion rate. Further investigation may be carried out to ascertain this.

4.3 Calorific value

Significant differences in heating values were found among pellet samples produced. From the result shown in Table 6 and table 1, the maximum calorific value of 17.589MJ/kg was achieved with a compaction pressure of 34MPa and with particle size of 425µm. also the minimum calorific value of 15.129MJ/kg was achieved with a compaction pressure of 34MPa and with particle size of 212µm. From the result of table 4, as the moisture content increases the heating value reduces. This was observed for instance P_1, P_2 and P_3, with moisture content 4.9%, 3%, and 2% and heating value 16.072MJ/kg, 16.942MJ/kg and 17.584MJ/kg respectively. Higher moisture content implies a lower calorific value as each unit mass of fuel contains less oven dry biomass – which is the part of the fuel that actually undergoes combustion to release heat (The Carbon Trust, 2008). The ash content also affects the heating value. From table 3, it was observed that P_5 and P_7 have the same moisture content of 2.9, ash content of 13.3% and 15% and calorific value of 15.598MJ/kg and 15.281MJ/kg respectively. This was in line with the observation of [13], the higher the fuel's ash content, the lower the calorific value. [16] and [17] also observed that the presence of high mineral matter components in wood is not desirable, because they are not degraded during carbonization and they remain in charcoal as ash, which also contributes to the reduction of charcoal heating value.

V CONCLUSION

Energy demand, most especially in the developing nations can be augmented by the use of waste biomass, a renewable energy source which is available in abundance. Ineffective utilization of the biomass residues constitutes environmental hazard and pollution and also emits strong irritating smell due to microbial decomposition activities at dump sites. This calls for production and characterization of rice husk for energy production. This study has shown that compaction pressure has influence on the physical and thermal properties of the fuel. Although the moisture and ash contents affects the calorific value of the fuel, the net calorific value for the pellet samples P_1 to P_9 are high to produce enough heat required for domestic household cooking and small-scale industrial cottage applications.

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