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EVALUATION OF RICE HUSK BRIQUETTES AS ALTERNATIVE HOUSEHOLD FUEL FOR RURAL NIGERIA

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ABSTRACT
This paper reports the production of briquettes from rice husk as a sustainable and affordable alternative to fuel wood which has caused wide deforestation thus contributing significantly to rising temperatures due to increased greenhouse effects. The briquetting process advocated in this paper uses a method of low compaction with the addition of appropriate binder in varying proportions. Proximate analysis and physical evaluation tests were undertaken to determine the quality of the briquettes. Starch gel and acacia gum were used as binders in six different proportions to determine the most suitable for use as briquette binder. Sample A made with 60% wt/wt starch gel was found to be the most suitable briquette because of its high heating value of 31, 093.77 kJ/kg. Sample C with 40% (wt/wt) of starch had the second highest with a heating value of 30, 429.58 kJ/kg while sample E with 50% (wt/wt) of acacia gum had recorded the least heating value of 29, 096.75 kJ/kg. In comparison with existing household fuels, the rice husk briquettes were second best (with 12 minutes) to kerosene (with 11 minutes) in the water boiling test. These results are strong indications that rice husk briquettes can be used as ready alternative to fuel wood in meeting household energy needs, thus safeguarding our forest resources. This will go a long way in boosting the carbon sequestration potentials of our forests to reduce the green house effects and reduce rising global temperatures. By safeguarding our forest resources, the natural habitat of wild life will be maintained and strengthened. In addition, briquetting rice husks will go a long way in sustainably managing solid wastes from rice mills which presently constitute aesthetic nuisance, fire hazard and a source of danger to playing children in rice producing and milling areas.

Key words: *Deforestation, rice husk briquettes, solid waste, biomass, briquetting.*

INTRODUCTION

A briquette can be defined as a product formed from the physico-mechanical conversion of dry, loose and tiny particle size material with or without the addition of an additive into a solid state characterized by a regular shape (Osaremwinda and Ihenyen, 2012). Briquettes are generally used as household fuels or in industries for cooking, heating productive processes, firing ceramics, clay wares and powering boilers to generate steam. Increase in the use of biomass as an alternative source of energy for heating applications basically depends on the availability of residue (biomass) and appropriate technologies for briquetting (Felfli *et. al,* 2011). The overall bio-briquetting process from production to end-use offers solution to the disposal of waste, results in a cheaper form of energy, creates employment and business opportunities and is eco-friendly (Grover and Mishra, 1996). In a developing country like Nigeria, some industries have chosen as a method of disposal, the direct burning of loose agro waste residues like rice husk, palm kernel shells, and groundnut shells in a conventional manner and this is associated with very low thermal efficiency, loss of fuel and widespread air pollution. When they are made into briquettes, these problems are mitigated, transportation and storage cost are reduced and energy production by improving their net calorific values per unit is enhanced (Grover and Mishra, 1996).

Hilderman (2010) associated deforestation with the growing demand for forest products. He further added that deforestation not only affects the climate by increasing the atmospheric level of carbon dioxide but also affects the environment by inhibiting water recycling, triggering severe flooding, aquifer depletion, soil degradation and the extinction of plant and animal species.

With the growing issues of inappropriate waste disposal practices, the careless disposal and dumping of solid wastes, the discharge of effluent into the aquatic media and the emission of hazardous substances into the atmosphere, the health and wellbeing of man has become more adversely affected. This paper focuses on the recycling of rice husk in the production of briquettes used as an alternative household solid fuel for a sustainable environmental management of rice husk solid waste.

Rice husk is the hard protective cover of rice grains. It is separated from the rice grains through the milling process. Rice is the third highest produced cereal crop world wide. It has a total annual production of 738.1 million tonnes of which 20% is the rice husk (FAOSTAT, 2012). In Nigeria alone, 2.9 million metric tonnes of paddy rice was produced in 2013 (Nwafor, 2015), which implies that the quantity of rice husk produced in Nigeria in 2013 amounts to 580,000 metric tonnes and with the increasing cropping intensities of two and three in irrigation projects, this number is expected to rise significantly which multiplies the burden of rice husk solid waste on the environment.

Rice husk has long before now been a nuisance in the environment. Rice millers have always had a hard time disposing of it. Some leave heaps of rice husk unattended to in corners of their mills which is so light that the winds and rains move it from place to place polluting the surrounding environment. Abakaliki rice mill for example, have a production capacity of 11,000 tonnes of rice monthly (Nwafor, 2015). Their method of rice husk disposal is by manual labour where women carry them to a dump site behind the rice mill where they are heaped to eventually form a husk mountain. Because of its low nutritional value, most rice husk produced in Nigeria is currently disposed of by uncontrolled burning as an agricultural waste (Abalaka, 2012). Such disposal method constitute hazard to playing children because of its prolonged and slow burning nature even under rainfall conditions.

This paper is aimed at evaluating the prospects of recycling rice husk into briquettes to meet household energy needs. Its overall objective is to manage rice husk as solid waste through its recycle in briquette production as household energy source, thereby converting waste to energy.

MATERIALS AND METHODS

a). Production of Rice Husk Briquettes

The rice husk briquettes evaluated in this paper are made by low compaction using a fabricated briquette press held in a main frame holding the briquette press together. Other components of the press include a chamber of twelve (12) mould dies with twelve (12) pistons and a hydraulic jack with a pressure gauge. The briquette press is operated by using the hydraulic jack as a source of pressure. As the jack head rises, it applies pressure to the plate carrying the pistons which subsequently transfers the applied pressure to the content of the moulds. This causes the densification of the mould content. With the addition of the binding agent to the rice husk, the entire mixture is favourably agglomerated to enable the formation of the briquettes. Subsequently, the respective densities (the Compressed and Relaxed Densities) of the produced briquettes using different binding agents were computed using the relationships in equations (1) and (2) respectively

$$\text{Compressed density} \quad \frac{\text{mass of sample immediately after compression}}{\text{calculated volume}} \qquad (1)$$

$$\text{Relaxed density} \quad \frac{\text{mass of dried sample}}{\text{calculated volume}} \qquad (2)$$

b). Characterization of Briquettes

Proximate Analysis of the Briquettes

The procedure of ASTM Standard D5373-02 (2003) was adopted to determine the % ash content, % moisture content and % volatile matter of the briquette samples in accordance with the works of Oladeji (2010) while the carbon content and heating value were calculated theoretically using the Gouthal formula.

Experimental Design

The experiment was set up as a Completely Randomized Design (CRD) with four replications. The statistical analysis was conducted using Statistical Analysis Software (SAS) Version 2002. The analysis of variance (ANOVA) for CRD was carried out at 1% probability level ($p<0.01$) and where significant levels were identified, the difference between the mean values was tested for significance using the least significant difference (LSD) test at 1% level of probability.

RESULTS AND DISCUSSION

Sample Composition

Six categories of briquettes were fabricated and are reported in this paper. These categories were made with different binding agents and had different proportions of the rice husk and the binding agents. These six categories are as described and some of which are pictured in Fig 1.

Sample A: Briquettes with 60% (wt/wt) starch gel
Sample B: Briquettes with 50% (wt/wt) starch gel
Sample C: Briquettes with 40% (wt/wt) starch gel
Sample D: Briquettes with 60% (wt/wt) acacia gum
Sample E: Briquettes with 50% (wt/wt) acacia gum
Sample F: Briquettes with 40% (wt/wt) acacia gum

Fig. 1: Samples of Fabricated Briquettes with Different Proportions of Binders

Briquett Densities

The briquettes produced were assessed for the compressed density and the relaxed density. These generated the results presented in Table 1.

Table 1: Evaluated Densities of Produced Briquettes

Sample	Compressed density (g/cm^3)	Relaxed density (g/cm^3)
A	0.961^{a}	0.566^{b}
B	0.957^{b}	0.589^{a}
C	0.804^{c}	0.519^{d}
D	0.722^{d}	0.546^{c}
E	0.668^{e}	0.462^{e}
F	0.601^{f}	0.429^{f}
LSD	0.002	0.0026

Means followed by the same letter along a column are not significantly different using LSD at $P<0.01$

The means of the compressed densities as shown in table 1 ranged in decreasing order from 0.961 g/cm^3 for sample A (60% wt/wt starch gel) to 0.601 g/cm^3 for sample F (40% wt/wt acacia gum). Sample A (60% wt/wt starch gel) had the highest compressed density, followed by sample B (50% wt/wt starch gel) and sample F (40% wt/wt acacia gum) had the least value. This is a measure of the compaction of the rice husk by the briquette press at a force of 6.29 KN. In comparison with other briquettes from other materials in similar researches, these densities are found to be considerably of higher values except sample F (wit40% wt/wt acacia gum) that was lower in some instance. Among such researches are those undertaken by Obi *et. al.,* (2013) which obtained density values which ranged from 0.6125 g/cm^3 to 0.7269 g/cm^3 for sawdust briquettes while Oladeji, (2010) recorded 0.524 g/cm^3 for rice husk and 0.650 g/cm^3 for corn cob briquettes. These higher density values obtained in this research indicate the capacities of these produced briquettes to generate higher amount of heat during combustion thereby making them more suitable for use as household fuels than had been earlier reported

However, sample B had the highest relaxed density (density of dried briquettes) of 0.589 g/cm^3, which was statistically higher than the other samples, followed by sample A with 0.566 g/cm^3 and sample F recorded the least relaxed density with a value of 0.429 g/cm^3. The relaxed densities of the samples were also found to be in decreasing order from sample A to F ranging from 0.566 g/cm^3 to 0.429 g/cm^3. The relaxed densities were lower than the compressed densities due to the loss in moisture making the briquettes less dense than they were when wet. The densification of these briquettes influenced the combustion rate (with higher densities favouring lower combustion rates, while lower densities have enhanced combustion rates) due to reduced porosity which hampered the rate of infilteration of oxidant and outflow of the combustion products during combustion.

Proximate Analysis

An assessment of the proximate analysis to determine the composition and characteristics of the produced briquettes was undertaken in the research. Results of this assessment are presented in Table 2

Ash Content

The mean ash content across all six briquette samples were found to have high significant difference. Sample E was statistically higher than the other samples with a value of 13.40%, followed by sample F (13.25%) and sample A (7.45%) had the least value. No statistically similar values for ash content were observed. Evidently, the samples with acacia gum as binder i.e., samples D, E and F had higher values i.e., 10.95%, 13.4% and 13.25% respectively, than samples with starch gel as binder i.e., samples A, B and C with values of 7.45%, 10.15% and 9.35% respectively. The higher values of ash from the briquettes could have been due to a high concentration of the ash forming elements like silicon, phosphorus and potassium found in the rice husk and possibly its combustive interaction with the acacia gum. Like the briquettes made using starch gel, fuels with lower ash content are preferred due to their ease in transporting, utilizing, storage or in the case of their disposal.

Table 2: Proximate Analysis of the Produced Rice Husk Briquettes

Sample	Ash content (%)	Moisture content (%)	Volatile matter (%)	Fixed carbon (%)	Heating value, Hv (kJ/kg)
A	7.45^f	5.20^a	81.24^b	6.11^e	31, 093.77^a
B	10.15^d	3.19^c	78.65^c	8.01^a	30, 188.50^c
C	9.35^e	4.01^b	82.66^a	3.98^f	30, 429.58^b
D	10.95^c	3.04^d	78.01^d	8.00^b	29, 919.21^d
E	13.40^a	2.85^e	75.78^f	7.97^c	29, 096.75^f
F	13.25^b	2.64^f	76.16^e	7.95^d	29, 145.07^e
LSD	0	0	0	3E-8	0

Means followed by the same letter along a column are not significantly different using LSD at $P<0.01$

The rice husk ash is not regarded as a waste product, but rather, as a residue which could be re-used in other processes such as improving quality of cement in construction, as a source of silica, ceramics and in refractory industries for making refractory bricks.

Volatile matter

The mean values across the six samples were observed to show high significant difference. Sample C had the highest volatile matter content of 82.66%, followed by sample A (81.24%) while sample E had the least value of 75.78%. These values were expected due to the natural combustion potential of rice husk. These high percentages of volatile matter are important for the briquettes because they enhance the ignition potentials of the briquettes as fuel. In conformity with Jenkins *et al* (1998), findings, fuels with high volatile matter ignite easily as exhibited by results of this research because sample C and A ignited faster at 2 minutes, even though not having equal volatile matter content but very close amount. Samples B and D were next with 2

minutes and 15 seconds to get fully ignited, and sample F took 2 minutes and 28 seconds, while sample E took 2 minutes and 40 seconds (Fig. 2).

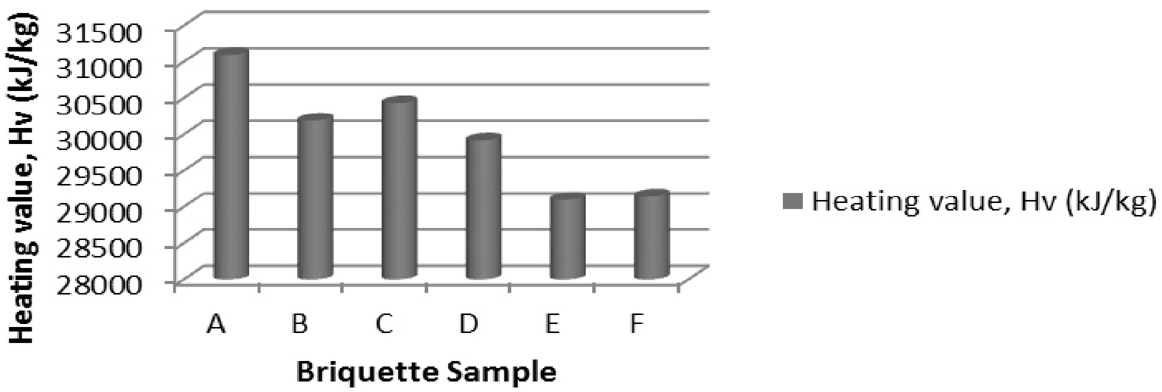

Fig. 2: Variation of the Heating Value Among Briquette Samples

Fixed Carbon Content

The results expressed in Table 2 reflect the percentage mean fixed carbon content of each of the briquette sample. These values, did not maintain a specific trend among the samples of briquettes produced. However, even though the values were numerically close, they were found to be highly significantly different due to the very low least significant difference value of 0.008 (LSD 3E-8). Sample B was found to have the highest fixed carbon with a value of 8.01%, closely followed by samples D, E, F and A with values of 8.00%, 7.97%, 7.95% and 6.11% respectively. Sample C was found to have the least value of 3.98%. These values could be referred to as quite low and are probably due to the high volatile matter content of the briquettes. This low carbon content is the reason for the short combustion time of the briquettes.

Moisture Content

Table 2 also shows the proportion of moisture content among the samples of briquettes produced. These proportions of moisture ranged from 2.64% for sample F to 5.20% for sample A. The samples (A, B and C) with starch binder contained more moisture than those with acacia binder (D, E and F). Statistically, the mean moisture content values across the six samples were highly significantly different. Sample A recorded the highest moisture content with a value of 5.20%. This is suspected to be due to the fact that it had the highest binder to rice husk ratio, i.e., 60% (wt/wt) starch gel. Sample C had the next highest moisture content of 4.01% while sample F had the least which is a value of 2.64%. Sample F consisted of 40% (wt/wt) acacia gum which was not as wet as the starch gel of the same proportion before drying. This research noted that on the average, samples D, E and F generally had the least drying times averaging 6 hours unlike samples A, B and C whose drying times ranged from 10 - 12 hours. These low moisture levels in the briquettes are important in both the storage and the utilization of the briquettes as it would not add unnecessary weight during handling and transportation of the briquettes.

Heating Value

The heating value of all the six briquette samples ranged from 31, 093.77 kJ/kg for Sample A to 29, 145.07 kJ/kg for sample F in decreasing order except for sample C which had a higher value than that of B with 30, 188.50 kJ/kg. As with the arithmetic differences, all the samples were found to be highly significantly different and no similarities were observed. Heating value is the most important combustion property for determining the suitability of any material as a fuel. A direct relationship was observed between heating value and moisture content; the higher the moisture content of a briquette sample, the higher its heating value. Sample A was found to produce the highest amount of energy (31,093.077 kJ/kg) which was influenced by its high moisture content (5.20%). The denser the briquette samples, the higher the heating value as evident from sample A with the highest compressed density of 0.961 g/cm^3 and the highest heating value of 31,093.077 kJ/kg.

Water Boiling Test

To compare the produced briquettes with presently used household fuels, the research included a simple but appropriate water boiling test to determine which of the fuels boil the same quantity of fastest. The results of the boiling tests are shown in Table 3. From these results, the produced briquettes was faster in boiling water at twelve (12) minutes while kerosene boiled the same quantity of water at eleven (11) minutes while fuel wood used twenty (20) minutes to boil the same quantity of water. These results indicate that while kerosene could be a superior household fuel to rice husk briquette (the difference most probably not statistically significant), rice husk briquette is in turn superior to fire wood as a household fuel.

Table 3:Results of the Water Boiling Test

Time	Type of Fuel Material		
	Briquettes	Fuel Wood	Kerosene
0	32	32	32
2	58	39	39
4	74	46	48
6	81	51	60
8	88	59	73
10	94	67	89
11	97	71	100
12	100	75	
14		82	
16		90	
18		95	
20		100	

CONCLUSION

This paper has established from the research conducted the feasibility of using rice husk soild waste to produce briquettes which can burn and serve as fuel for meeting household fuel needs. It has also shown that the produced briquettes can favourably replace fire wood as household energy source for domestic cooking and other uses. This is because it can boil water faster (12 minutes) than fuel wood (20 minutes) as shown in Table 3. As a result households should be encouraged to use rice husk briquettes for their household fuel needs instead of fire wood thereby conserving forests and their resources against exploitation. Such will safeguard these forests to enhance their carbon sequestration, reduce the green house effects and its attendant global warming. The quality of the rice husk briquettes produced was determined by the density and the proximate analysis values obtained. Sample A had a compressed density of 0.961 g/cm^3, durability rating of 100%, ash content of 7.45%, volatile matter of 81.24%, fixed carbon content of 11.31% and heating value of 31, 093.77 kJ/kg. Sample A having the highest heating value, the next highest volatile matter and the highest durability rating, is the most preferred composition of the rice husk briquette recommended by this paper. This choice is strongly influenced by the high heating value because that is the most important factor in determining suitability of a solid fuel.

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