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Impact of Groundnut Shell and Waste Paper Admixture on Briquette Properties

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ABSTRACT

The experimental study was undertaken to assess the combustion characteristic of binder-less briquettes produced from waste paper and groundnut shell. Briquettes were manufactured using a manual briquetting machine using five waste paper and groundnut shells mixing ratios i.e.50:50, 60:40; 70:30; 80:20 and 90:10. Combustion characteristics investigated were ignition time, burning time, density, moisture content, volatile matter, ash content, fixed carbon, calorific values. The values of ash content ranged from 1.27% - 1.07%, the percentage volatile matter ranged from 42.87% - 87.87%, the percentage fixed carbon ranged from 55.86% - 11.06%, the heat value of the briquettes ranged from 33536.77J/Kg – 33228.62J/Kg. The results show that waste paper and groundnut shell up to 20% in composition of the briquettes were found to have good combustion characteristics which qualify them as alternative to firewood for domestic and industrial energy. Further studies should be made on the ultimate analysis of briquettes
Keywords : Admixture, Briquette, Biomass, Groundnut Shell, Waste Paper.

I. INTRODUCTION

The main demand for fuel has been widely reported to be predominantly for domestic, transportation and industry. Many developing countries rely mainly on biomass and open fire for cooking. For the sustainability of the use of biomass briquette provide sustainability, low cost and environmentally friendly fuel.

Briquettes are widely from compressed biomass, although many have depended on coal dust, which have questions in the area of greenhouse gasses emission and air pollution coupled with its non-renewable nature. On the other hand other combustible biomass material are under greater consideration as briquette fuel including charcoal, sawdust, wood chips, peat, groundnut shells and paper.

Briquetting technology involving biomass compression aimed at improving the biomass quality resulting to increase density, reduction in moisture content and improved handling characteristics for transport and storage amongst others.

Various Biomass materials have been employed as a renewable source of fuel for energy. This materials which are of low economic value or classified as waste residues fall under leaves, roots, stems, peels, also derived sometimes from scrap wood and wood mill residuals. Other classifications of Biomass materials include, by-products, residues and wastes from agricultural and forestry activities; biodegradable and non-fossil elements of municipal and industrial wastes.
Briquettes have bridges some fuel demand gaps including;

- Providing less hazardous and more health friendly cooking and industrial fuel.
- Reduces high dependence on forest woods, and protecting forest resources.
- Reduction in the price surge cost by dependence on fossil fuel and fire wood.
- Briquette provides alternative to the conventional fuel with comparative advantage in the area of economy and environmental benefits.

While increase research has focus on Briquettes and briquette technology, it has shown competitive edge in terms of improved heat intensity, environmentally friendly/cleanliness, easy handling and suitability, and less storage problem interns of space requirement for storage.[1][2].

These advantages make the briquettes a more adaptive fuel for rural and urban group proving that embracing of briquette fuel will not only be cost effective but also more hygienic and environmentally friendly and a proven method of disposing the waste and creating wealth by converting waste into energy and also contributing towards a better waste management and environment.

There is high level of in adequate accounting of agricultural and forestry residues production in Nigeria, and these large quantities of agricultural and forestry residues are not properly utilized. The common practice is to burn these residues or leave them to decompose.[3]. Studies have shown that agricultural residues could be processed into upgraded solid fuel products such as briquettes. The major residues are rice husk, corn cob, coconut shell, jute stick, groundnut shell, cotton stalk, cowpea chaffs, sawdust, water hyacinth, etc [4][5][6].

Briquetting can be done with or without a binder. Doing without the binder is more convenient. However, in many of the foregoing studies, the briquettes were produced with the aid of binders such as cassava starch and palm oil sludge which tend to produce smoky briquettes.

As an alternative, waste paper appears to be a viable candidate for binding the agricultural residues for binder-less and perhaps smokeless briquette production.[7]

Previous studies have shown that waste paper could be mixed with other biomass materials to produce relatively cheap and durable binder-less briquettes.[8][9]. Attempts have also been made in the past to create fuel from newspaper by rolling them up into ‘logs’. However, it was found that the product did not burn well. Groundnut shell, on the other hand, has a relatively high calorific value of 4524 Kcal/Kg coupled with relative low ash content[10]. In the present study, efforts were made to produce binder-less briquettes from a mixture of waste paper and groundnut shell particles using a locally fabricated manual briquetting machine.

II. METHODS AND MATERIAL

Materials and their sources

- ✓ Paper: waste papers were obtained from the waste bin in Choba campus, University of Port Harcourt, Port Harcourt, Nigeria.
- ✓ Groundnut shell: This was obtained from the campus environment Choba (i.e. cooked groundnut shell).
- ✓ Water: this was gotten from chemical engineering laboratory, University of Port Harcourt, Port Harcourt, Nigeria.

Preparation of Materials

Groundnut shell: The groundnut shell was sundried for five days to reduce the moisture content, after which they were crushed and ground to fine powder using a milling machine. The groundnut shell powder obtained after grinding was sieved to obtain powder of particle size 1mm in diameter.

Waste paper: Waste paper in form of disused typing sheets, photocopying and printing paper (excluding cardboard papers) was obtained from an office waste paper bin in the University of PortHarcourt - Nigeria. The papers were manually shredded into small bits, mixed together, and soaked in cold water at room temperature (22 ±30C) for a period of two days. Thereafter, the water was drained off with the aid of a mesh and the paper was converted into pulp by manual pounding with a pestle and a mortal.

Figure 1 : Biomass material, Groundnut shell Groundnut shells and crushed groundnut shells

Figure 2 : Soaked Shredded Waste Paper

Briquette Formulation

The briquettes were formulated using different percentages of waste paper and groundnut shell. The ratio of waste paper to groundnut shell made were 50:50, 60:40, 70:30, 80:20, 90:10 which are labelled A, B, C, D and E respectively.

Table 1: Experiment Briquette Composition

Raw material	**Biomass composition**				
	A	B	C	D	E
	50:50	60:40	70:30	80:20	90:10
Waste paper (g)	100	120	140	160	180
Groundnut shell (g)	100	80	60	40	20
Water (ml)	600	600	600	600	600

Procedure

A specific quantity of soaked waste paper and fine groundnut shell powder were weighed out using a triple beam balance into a plastic basin. They were mixed thoroughly until a uniform mixture was obtained. The briquetting moulds of the hydraulic press briquette moulder were filled with the mixture, making sure that the moulder plates were inserted first. The lid of the moulder was closed and the mixture was briquetted by applying pressure on the hydraulic jack. This action moves the movable part of the mould up to the immovable part (the lid), causing the mixture in the mould to be compressed, and it agglomerate into a briquette.

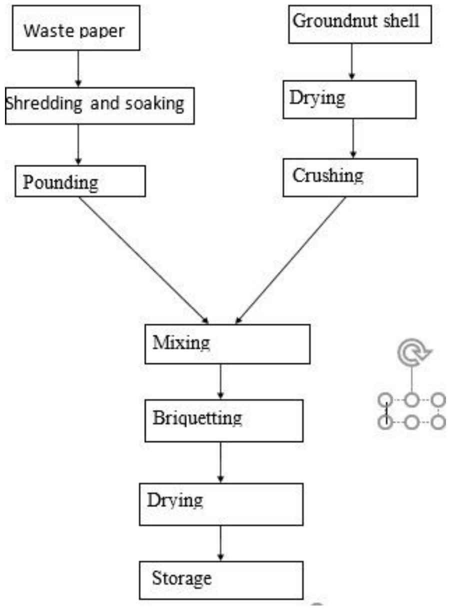

Figure 3: Briquette technology flow process

Basic flow process for briquette production using waste paper and groundnut shell

Figure 4: Briquettes composition with different mixing ratios

Analysis of Briquette Properties

- Determination of density

Density is a physical property of briquettes. It is defined as structural packing of the molecules of the substance in a given volume. Since the briquettes are cylindrical of equal diameters (12cm) and equal height (2cm) which were measured using venier calipers. The volume was evaluated using $\pi r^2 h$. The density was computed as the ratio of mass to the volume of the briquette.

$$\text{Density } (g/cm^3) = \frac{mass\ (g)}{volume\ (cm^3)}$$

- Determination of Ignition Time

Ignition time is the time taken for a flame to raise the briquette to its ignition point. The briquette samples were ignited at the edge of their base with a lighter adjusted to give a steady light. The time taken for each briquette sample to catch fire was recorded as the ignition time of the sample. The test was repeated twice for each sample and the average time taken.

- Determination of burning time

Burning time is obtained by observing the mass changes recorded on mechanical balance and also by using stop watch. It is time taken for the briquette combustion to be complete.

- Determination of the ash content of the raw materials

The mass of incombustible material remaining after burning a given briquette sample as a percentage of the original mass of the briquette. 1g of the briquette samples were weighed. These were transferred into the muffle furnace set at 550^{O}C and left for about 4 hours. About this time, it had turned to white ash. The crucible and the content were cooled to about 100^{o}C in air, then to room temperature in a desiccator and weighed. The percentage ash content was computed as:

$$\text{Percentage Ash Content} = \frac{Weight\ of\ ash}{Original\ weight\ of\ sample} \times 100$$

That is, $\%\ \text{Ash content} = \frac{W_A - W_C}{W_O - W_C} \times 100$

Where

W_A = weight of ash + can

W_C =weight of empty can

W_O =original weight of sample + can

- Determination of the moisture content of the briquette.

The moisture content of biomass is the quantity of water in the material, expressed as a percentage of the material's weight. The moisture content can be calculated using the equation below

$$\%\ \text{moisture content} = \frac{initial\ weight\ of\ sample - final\ weight\ of\ sample}{initial\ weight\ of\ sample} \times 100$$

$$\%\ \text{Moisture content} = \frac{W_0 - W}{W_0} \times 100$$

Where W_0 = Initial mass of briquettte before drying

W = Final mass of briquette after drying

- Determination of the volatile matter in the samples

Volatile matter is defined as those products, exclusive of moisture, given off by a material as gas or vapour. Volatile matter refers to the part of the biomass that is released when the biomass is heated (up to 400 to 500°C). During this heating process the biomass decomposes into volatile gases and solid char. Volatile matter given off by a material as gas or vapor, was determined by definite prescribed methods. In order to determine the percentage volatile matter, 2g of briquettes were placed in the oven. The briquettes were now kept in the furnace at a temperature of 550 ^{o}C for 10 minutes(just before the materials turns black i.e. before it ashes) and weighed after cooling. The percentage volatile matter was then expressed as the percentage of loss in weight to the oven dried weight of the original sample.

Volatile matter = weight of residual dry sample – weight of dry sample after heating

$$\text{Percentage volatile matter} = \frac{W_i - W_f}{W_i} \times 100$$

Where W_i is the weight of oven dried sample

W_f is the weight of sample after 10 minutes in the furnace at 550 ^{o}C

- Determination of fixed carbon

Carbon fixation is the conversion of inorganic carbon (carbon dioxide) to organic compounds by living organisms. Essentially, the fixed carbon of a fuel is the percentage of carbon available for char combustion. This is not equal to the total amount of carbon in the fuel (the ultimate carbon) because there is also a significant amount released as hydrocarbons in the volatiles. Fixed carbon represents the quantity of carbon that can be burnt by a primary current of air drawn through the hot bed of a fuel [11]. Fixed carbon gives an indication of the proportion of char that remains after the devolatisation phase. Fixed carbon is the solid combustible residue that remains after a coal particle was heated and the volatile matter was expelled.

The formula for fixed carbon is obtained following the procedure [11]and is given as:

Fixed Carbon =100 – (% volatile matter + % ash content)

- Determination of Calorific (heating) value

Heat value or calorific value determines the energy content of a fuel. It is the property of biomass fuel that depends on its chemical composition. The most important fuel property is its calorific or heat value. The gross or high heating value is the amount of heat produced by the complete combustion of a unit quantity of fuel. This was calculated using the formula:
Heating value = 2.326 (147.6C +144V)
Where
C is the percentage fixed carbon
V is the percentage volatile matter.[11]

III. RESULTS AND DISCUSSION

From the results in the table below, it can be seen that the density of the samples decreases with increase in waste paper and this will help for easy transportation of the sample.

Table 2: Variation of density the various briquettes

SAMPLE	PERCENTAGE COMPOSITION	DENSITY (g/cm^3)
A	50% P : 50% G	0.656
B	60% P : 40% G	0.586
C	70% P : 30% G	0.599
D	80% P : 20% G	0.547
E	90% P : 10% G	0.535

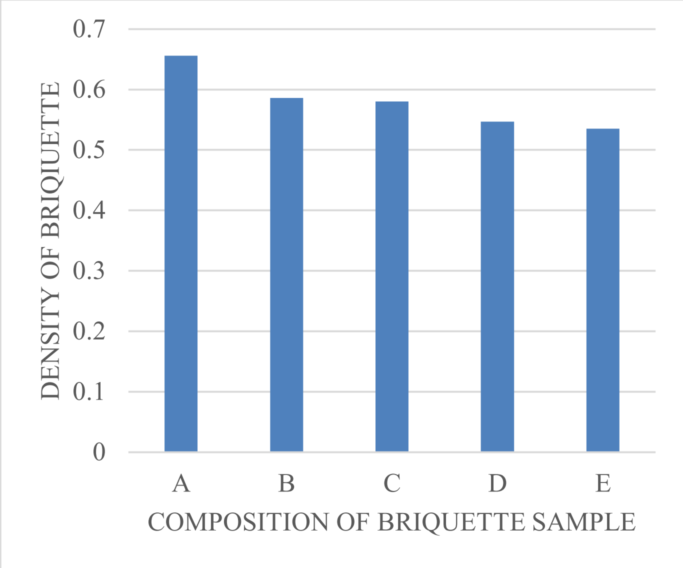

Figure 5: Density of briquette sample

- **Ignition time of the briquette sample**

In this process, ignition time was taken as the average time taken to achieve steady glowing flame. The table below shows the ignition time for the composite briquettes produced. From the results it can be seen that ignition time decreases with an increase in the content of groundnut shell. It shows that the more the groundnut shell content in the briquette the more the pores which create opening for the decrease in ignition time observed as groundnut shell increases.

Table 3. Variation of the ignition time of the briquettes

SAMPLE	PERCENTAGE COMPOSITION	IGNITION TIME (sec)
A	50% P : 50% G	56.34
B	60% P : 40% G	53.86
C	70% P : 30% G	52.49
D	80% P : 20% G	49.30
E	90% P : 10% G	45.01

Burning time of the briquette sample

Burning time indicates that the burning duration of briquettes decreased with amount of groundnut shell as seen in the table below. The rapid combustion observed as the groundnut shell increases could be due to increase in pores observed as groundnut shell content increases in briquettes. The increase in pores as groundnut shell content in briquettes increases enables the volatiles to leave more readily and be consumed rapidly. The decrease in the burning time with groundnut shell could also be attributed to poorer bonding which might have resulted in relatively high porosity hence promote the infiltration of oxidant and outflow of combustion products during combustion.

Table 4. Variation of the burning time of the briquettes

SAMPLE	PERCENTAGE COMPOSITION	BURNING TIME (min)
A	50% P : 50% G	30.24
B	60% P : 40% G	29.46
C	70% P : 30% G	27.39
D	80% P : 20% G	24.22
E	90% P : 10% G	23.01

Ash content of the briquette sample

The level of ash content in the briquettes directly affects their burning efficiency. The lower the ash content, the more the burning efficiency of the briquette. The effect of biomass on the ash content of the briquette samples are indicated in the table below. The value of the ash content decreases with an increase in waste paper. It therefore shows that groundnut shell has more ash content than paper.

Table 5: Variation of the ash content of the briquettes

SAMPLE	PERCENTAGE COMPOSITION	ASH CONTENT(%)
A	50% P : 50% G	1.27
B	60% P : 40% G	1.21
C	70% P : 30% G	1.11
D	80% P : 20% G	1.09
E	90% P : 10% G	1.07

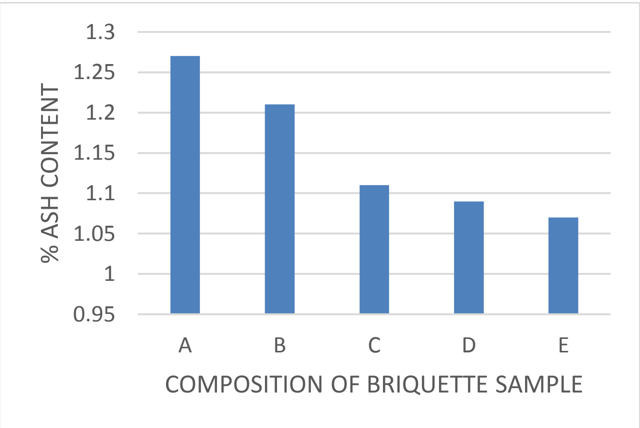

Figure 6: Percentage of ash content of briquette sample

Moisture content of the briquette sample

From literature, the moisture content of biomass should be as low as 10-15% so that there will be complete combustion of the briquettes [12]. Low moisture content of biomass also helps in their storage (prevents rotting and decomposition). The table below shows that the value of moisture content increases with an increase in waste paper and a decrease in groundnut shell.

Table 7: Variation of moisture content of the briquettes

SAMPLE	PERCENTAGE COMPOSITION	MOISTURE CONTENT(%)
A	50% P : 50% G	6.76
B	60% P : 40% G	6.89
C	70% P : 30% G	7.21
D	80% P : 20% G	7.56
E	90% P : 10% G	7.89

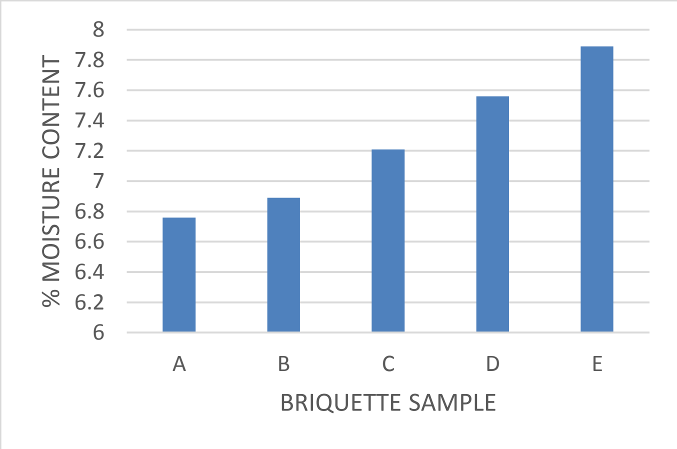

Figure 7: Percentage of ash content of briquette sample

Volatile matter of the briquette sample

The level of volatile matter in the briquettes directly affects their burning efficiency. The higher the volatile matter, the more the burning efficiency of the briquette. The table below shows that the value of volatile matter increases with an increase in waste paper. It shows that waste paper contains more volatile matter than groundnut shell.

Table 6: Variation of the volatile matter of the briquettes

SAMPLE	PERCENTAGE COMPOSITION	VOLATILE MATTER(%)
A	50% P : 50% G	42.87
B	60% P : 40% G	63.63
C	70% P : 30% G	82.87
D	80% P : 20% G	85.75
E	90% P : 10% G	87.87

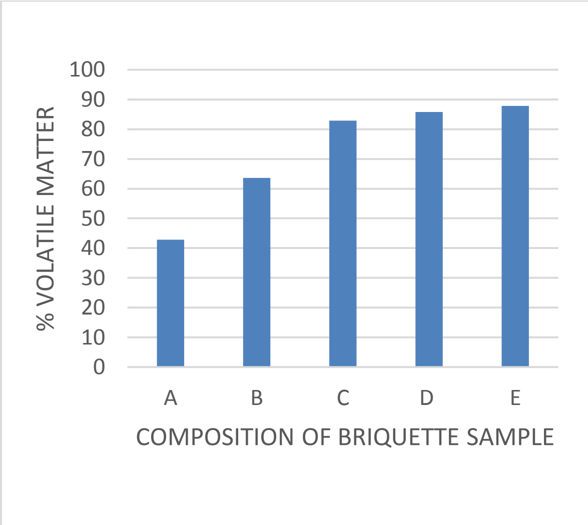

Figure 8: Percentage volatile matter of briquette sample

Fixed carbon of the briquette sample

The level of fixed carbon in combustible materials is indicative of its burning efficiency. In contrast to volatile matter, the lower the fixed carbon, the higher the efficiency of burning. The table below shows that the value of fixed carbon increases with an increase in groundnut shell. It therefore shows that briquette sample with more groundnut shell has a higher carbon content.

Table 8: Variation of fixed carbon of the briquettes

SAMPLE	PERCENTAGE COMPOSITION	FIXED CARBON(%)
A	50% P : 50% G	55.86
B	60% P : 40% G	35.16
C	70% P : 30% G	16.02
D	80% P : 20% G	13.16
E	90% P : 10% G	11.06

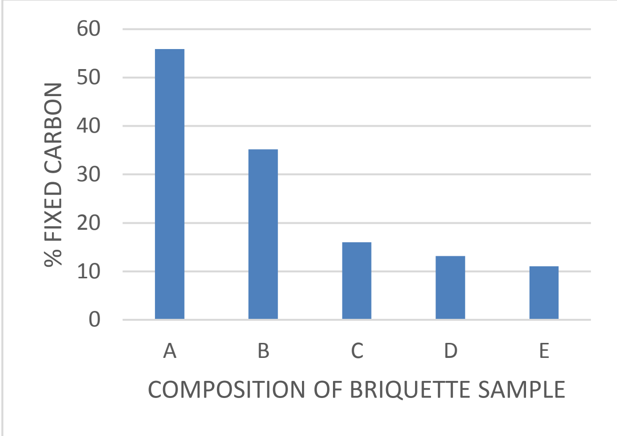

Figure 10 : Percentage of fixed carbon of briquette sample

Heat (calorific) value of the briquette sample

Heat value or calorific value determines the energy content in a fuel. The calorific value of the composite briquettes ranges between 33,536 and 33,228J/kg. in the table below, we found that the calorific value increases as the percentage of groundnut shell increases. The composition with 50% groundnut shell has the highest calorific value while that with 10% groundnut shell has the least calorific value of 33,159J/kg. The variation is expected since groundnut shell has higher calorific value than paper. The energy value obtained for the various compositions is found to meet the minimum requirement of calorific value for making commercial briquette (>17,500 J/g) [12]. They can therefore produce enough heat required for household cooking and small-scale industrial cottage applications.

Table 9 : Variation of heat (calorific) value of the briquettes

SAMPLE	PERCENTAGE COMPOSITION	HEAT (CALORIFIC) VALUE (J/kg)
A	50% P : 50% G	33536.77
B	60% P : 40% G	33383.53
C	70% P : 30% G	33256.76
D	80% P : 20% G	33239.51
E	90% P : 10% G	33228.62

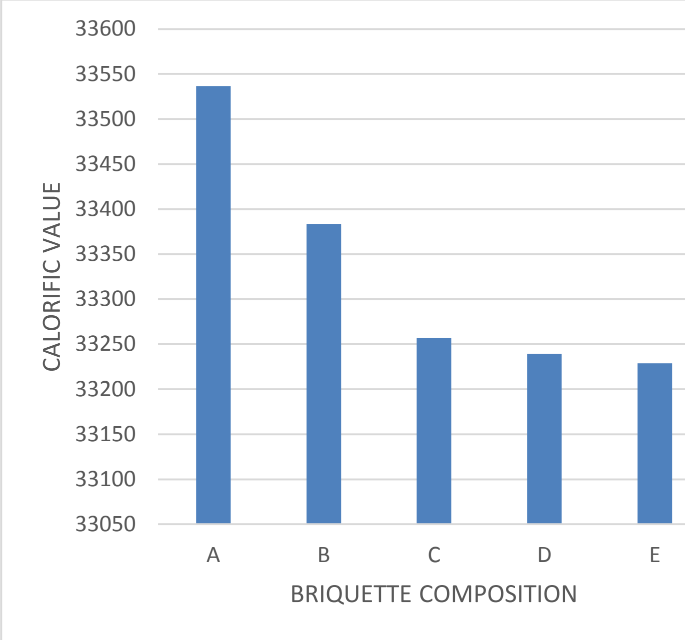

Figure 9 : Percentage of heat (calorific) value of briquette sample

IV. CONCLUSION

This experimental study confirms the possibility of utilizing binder-less briquettes from waste paper and groundnut shell mixtures as fuel energy for domestic and industrial application. From the experiment carried out, it was observed that the characteristics of biomass briquettes produced from compaction of groundnut shell and waste paper were satisfactory and compatible. Nevertheless, the results obtained have met the objectives of the research. The objective to develop a solid fuel from the mixing of groundnut shell and waste paper at different ratios has been achieved successfully by producing sample briquettes in five different ratios. It can be concluded that waste paper and about 10% - 20% groundnut shell admixture (Sample E and D) briquettes gives the best properties. The briquettes were compatible with each other and it is suitable as a new solid fuel source that can be utilized in many applications. The blending of groundnut shell with waste paper can improve its physical and mechanical properties. In view of this, the utilization of groundnut shell and waste paper in the production of briquettes can greatly provide alternative energy sources for domestic cooking and also serve as a measure in curbing the environmental hazard posed by poor methods of agricultural waste disposal in addition to reducing the popular use of charcoal which has an adverse effect on our environment (deforestation). Therefore, the briquetting technology has a great potential for converting waste biomass into a superior fuel for household as well as industrial applications in an affordable, efficient and environment friendly manner. Recycling of biomass can be significantly helpful in alternate fuels.

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