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Performance Evaluation of the Effect of Waste Paper on Groundnut Shell Briquette

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ABSTRACT: Current energy shortage and environmental issues resulting from the use of fossil fuels have led to exploitation of renewable energy resources that includes municipal waste and agricultural residues. These residues are available, indigenous and are environmental friendly but some cannot be used directly in combustion process due high moisture content and low volumetric energy unless by briquetting. The study was undertaken to assess the combustion characteristic of binder-less briquettes produced from waste paper and groundnut shell. Combustion characteristics investigated were ignition time, burning time, calorific values, burning rate, specific fuel consumption, fuel efficiency and water boiling time. The calorific values of the briquettes ranged from 19.51 - 19.92 MJ/kg, while the thermal efficiency ranges between 13.75 – 21.64%, other results shows that the average burning rate between 0.511 and 1.133 kg/hr and the specific fuel consumption ranges between 0.087 and 0.131 J/g. The recorded boiling time values were between 17.5 and 30.0 minutes for cold start and 15.0 and 20.0 minutes for hot start. The results shows that waste paper and groundnut shell up to 25% in composition composite briquettes were found to have good combustion characteristics which qualify them as alternative to firewood for domestic and industrial energy. However, production of briquettes from waste paper and groundnut shell at mixing ratio of 85:15 was found to comparatively better from all experiment conducted.

Keywords: Waste paper, Groundnut shell, Briquette, Binderless, Specific fuel consumption, Water boiling test

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1. Introduction

One of the most challenging problems facing developing countries is finding a means of expanding its energy resources especially to the rural households and also addressing the health hazards and environmental consequences associated with over dependence on firewood for cooking. In regions of many developing countries it is not uncommon for women to spend more than 6 hours each day collecting and preparing the wood despite the fact that there are often vast quantities of waste biomass residues available with the potential to be used as fuel. There are quite a lot of alternative energy which are expected to replace fossil fuel in the future, i.e. hydro, solar, wind, biomass and ocean thermal energy. Among these energy sources, biomass is the only carbon-based sustainable energy and the wide variety of biomass enables it to be utilized by most people around the world. The consequence of this is a gradual depletion of the total forest and desert encroachment of the countries owing to the fact that the deforestation and desertification rate is higher than the afforestation efforts in these countries. Aware of this situation, government had embarked on tree planting campaign at various levels but to make it achieve the desire succeed, there is a need to provide fuel wood alternative to the rural dwellers. Fuel wood refers to wood used as fuel such as firewood, sawdust or charcoal. Regrettably, while pressure is high for fuel wood, most of other biomass in form of agricultural wastes or residues is burnt off indiscriminately. By this action, not only that the biomass resource which can be processed into a useful energy source is wasted, it

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pollutes the environment and reduces soil fertility. Occasionally, if the burning is not controlled, it leads to bushfires thereby causing more havoc. Owsianowski,(2009) wrote that fire affects soil below ground biodiversity, geomorphic process and volatizes large amount of nutrients and carbon accumulated in the soil organic matter. However, processing of these wastes into fuel briquette is a good opportunity for developing nations (Owsianowski, 2009).

Briquettes are not a new concept, in actual fact they are becoming well established in the field various authors have studied the feasibility of briquetting different residues and investigated important parameters involved in briquette manufacture. This has involved the effect of compressive pressure, material moisture content, the time the material is in compression (dwell time), and binder content on briquette durability, mechanical strength, density, handling characteristics and the relaxation behaviour of the briquette when taken out of the mould (Olorunnisola, 2004; Chin and Siddiqui, 2000; Demirbas, 1999). Briquetting of biomass process simply means compressing the material to increase its density and to enhance its handling characteristics. Compressing of biomass employing lignin plasticization mechanism has been widely used in many countries. This requires elevated temperature of about 160^{o}C to 280^{o}C and pressure between 4 Mpa - 60Mpa (Zhanbin, 2003). Chemically, cohesion takes place between the biomass particles during the process as follows: when the biomass is compressed, the surface of the particles form absorption layers which are no longer free to move and remains in close contact by the help of Van der Waals forces and the lignin component of the biomass. Lignin liquefies at that temperature and pressure, hence acts as gluing agent (binder) in the briquette when cooled (Diego, 2003). Likewise, biomass briquette can be prepared at ambient temperature and moderate pressure by compressing the biomass using binder (Patomsok, 2007). In some methods, the biomass is first carbonized before briquetting (Alexis, 2000).

A lot of studies have been carried where briquettes are produced with the aid of binders such as cassava starch and palm oil sludge which tend to produce smoke during usage. Waste paper appears to be a feasible option for binding the agricultural residues for binderless and perhaps smokeless briquette. Approximately 25 to 40% of the municipal solid waste each year world wide consists of paper and paper products (Grigorion, 2003). Waste papers was used in this work so as exploit the abundant papers seen as waste to wealth, thereby helps in reducing the quantity of municipal wastes generated every year. Papers are also known to be good materials for a combustion ignition without spreading toxic gas while it burns. Furthermore, it can act as a binder during the blending of papers and groundnut shell and during compacting process. The main aim of this study is to evaluate the performance of binder less groundnut shell and waste paper biomass briquette.

2. Materials and Methods

2.1 Preparation of the raw materials

Groundnut shells were collected from the processing sites at Dawanu, Kano - Nigeria, while the waste paper was collected from wasted paper from Hydraulic Equipment Development Institute, Kano - Nigeria waste bins. The shells were sun dried for 3 days to reduce the moisture content before it was hammer- milled and sieved. Particles that passed through the 850μm sieves and were retained on the 600μm sieves were used. The waste papers were shredded into small bits and soaked in cold water at room temperature for a period of three days. Thereafter, the paper was converted into pulp by pounding with a pestle and a mortal as used in (Oyelaran et al, 2014). Thereafter, waste paper and groundnut shell were thoroughly mixed at ratios of 95:05, 90:10, 85:15, 80:20 and 75:25 labelled throughout the paper as A, B, C, D and E, respectively. In each case, fixed quantities of the samples were hand-fed into the briquetting machine and compacted. The dwell time of 5 minutes as in (Oyelaran et al, 2014) was used. The machine is a motorized briquetting machine which applied 30MPa of pressure producing twelve (12) briquettes per batch.

2.2 Determination of Ignition Time

Ignition time is the minimum time at which the substance ignites and burns without further addition of heat from outside. The briquette was placed on gauze and a bunsen burner was used to ignite its base from under the gauze. A stopwatch was used to note the time the base of the briquette ignites.

2.3 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.

2.4 Determination of calorific value

Calorific value is one of the most important characteristics of a fuel. This is the measurement of the heat or energy released by a fuel during the complete combustion and expressed as kcal/kg or MJ/kg (Islam et al, 2014). Leco AC-350 Oxygen Bomb Calorimeter interfaced with a microcomputer was used to assess the heat values of the produced briquettes (Oyelaran, 2014).

2.5 The water boiling test (WBT)

What is interesting about the energy content of a briquette is how much of the energy in the briquette that can be actually be utilized. If the same test is carried out on each briquette and firewood, a good evaluation can be made. The test is known as the Water Boiling Test and it will be used for assessing the briquettes with each other. The modified version of the WBT, which was developed for the Shell Household Energy Programme based on the procedures proposed by VITA and Baldwin was used in this work (Oyelaran et al, 2015). It consists of three phases.

(a) The first phase began with the stove at room temperature and using a pre-weighed bundle of wood to boil a measured quantity of water in a standard pot. Next the boiled water is replaced with a fresh pot of cold water to perform the second phase of the test.
(b) In the second phase which is the high power test with hot start, water is boiled beginning with a hot stove in order to identify differences in performance between a stove when it is cold and when it is hot.
(c) The third phase which is the simmering test, the second phase test is continued using a pre-weighed bundle of wood, simmering the water at just below boiling for a measured period of time (45 minutes).

The same procedure is repeated on the samples of briquettes made with the various groundnut shell and binder varied proportions. Fuel samples of similar size of average dimension 193mm x 37mm x 45mm were used for the test in order to minimize variation due to fuel differences. This size is in accordance to Olle and Olof (2006) who states that: the type and size of fuel can affect the outcome of the stove performance tests. In order to minimize the variation that is potentially introduced by variations in fuel characteristics VITA (1985) recommends taking the following precautions:

(i) Use only wood that has been thoroughly air-dried. Drying is accelerated by ensuring wood is stored in a way that allows air to circulate through it.

(ii) Different sizes of wood have different burning characteristics. While stove users may not have the ability to optimize fuel size, use only similar sizes of wood to minimize this source of variation throughout the world.

Due to the lack of adequate turn - down ability of the three stones stove to maintain a desired temperature without the fire going out, the minimum amount of fuel sample necessary to keep the fire from dying completely was used.

The fuel sample outputs to be analyzed include:

(a) Thermal efficiency(η): This is the ratio of the work done by heating and evaporating water to the energy of the fuel consumed. This is given by (Prasad et al, 1983).

$$\eta = \frac{C_{pw}\times(P_i-P_e)\times(T_f-T_i)+H_L\times(P_i-P_f)}{f_m\times H_f} \quad (1)$$

(b) Burning Rate (R_b): This is a measure of the rate of wood consumption while bringing the water to a boil. It is calculated by dividing the equivalent dry wood consumed by the time of the test (Prasad et al, 1983).

$$R_b = \frac{f_m}{t_f-t_i} \quad (2)$$

(c) Specific fuel consumption (F_{sc}) : This is a measure of the amount of wood required to produce one gram of boiling water or maintain one gram of boiling water within 3^{o}C of the boiling point (Prasad et al, 1983).

$$F_{sc} = \frac{f_d}{P_f-P_e} \quad (3)$$

$$f_m = f_i - f_f \quad (4)$$

$$f_d = f_i - f_f - \Delta C \quad (5)$$

$$W_v = P_i - P_f \quad (6)$$

$$W_r = P_f - P_e \quad (7)$$

$$\Delta\theta = t_f - t_i \quad (8)$$

$$\Delta T = T_f - T_i \quad (9)$$

2.6 Smoke characteristics

The thickness and colour of smoke produced during burning was determined using physical method (i.e. by observation).

3. Results and Discussion

3.1 Ignition time

In this process, ignition time was taken as the average time taken to achieve steady glowing flame. Table 1 shows the ignition time for the composite briquettes produced. From the results it can be seen that ignition time decreases with increased 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 decreased in ignition time observed as groundnut shell increases. A combustible material should be easily ignitable, particularly for household. The ignition time of 41.34 – 48.84 seconds obtained in this experiment is lower than 286 seconds obtained for coal (Onuegbu et al, 2011) and 66.61 - 107.92 seconds for Water Hyacinth Briquettes with binder ratio of 10 – 50% (Davies and Abolude, 2013). However the values are within the corresponding values of 19 -186 seconds for bio-coal briquettes produced by blending elephant grass and spear grass at different concentration of 10 -50% with coal (Davies and Abolude, 2013).

Table 1.
The ignition time for the produced composite briquettes

Sample	Ignition time (sec)	Burning rate (min)
A	48.84	26.07
B	45.97	24.64
C	45.33	23.43
D	43.67	20.91
E	41.34	18.65

3.2 Burning Time

Burning time indicates that the burning duration of briquettes decreased with amount of groundnut shell as seen in Table 1. 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. The burning time in this work ranges between 18.65 – 26.07 minutes this is lower than 29 - 46.4 minutes obtained in rice husk-bagasse-charcoal dust composite briquettes with binder ratio of 10 – 25% (Chirchir, et al, 2013)

3.3 Calorific value

The calorific value of the composite briquettes ranges between 19.51 and 19.92 MJ/kg. From Figure 1, we found that the calorific value decreases as the percentage of groundnut shell increases. The composition with 5% groundnut shell has the highest calorific value while that with 25% groundnut shell has the least calorific value of 19.92 MJ/kg. The variation is expected since paper has higher calorific value than groundnut shell.

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) (Oyelaran et al, 2014). They can therefore produce enough heat required for household cooking and small-scale industrial cottage applications. The results of the calorific value of the briquettes compare well with the results of the heating value of rice husk briquette 12,600 kJ/kg (Musa, 2007); cowpea 14,372.93 kJ/kg; and soy-beans-12,953 kJ/kg (Enweremadu, et al., 2004)

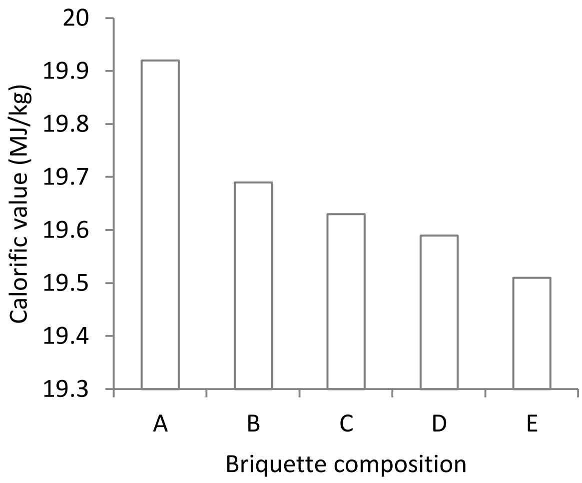

Figure 1. Calorific value of Briquettes

3.4 Average thermal efficiency for fuel samples

Figure 2 shows the average thermal efficiencies of the various fuel samples. The values were estimated using equation 1 with data obtained from the WBT for high power (cold start), high power (hot start) and low power (simmering). Comparison of the average thermal efficiencies of each of the briquettes as in Figure 2 shows that briquette C with 15% groundnut shell has the highest value of 21.64%, briquette A with 5% groundnut shell is 13.75%, briquette B with 10% groundnut shell is 16.51%, briquette D with 20% groundnut shell is 18.46% and briquette E with 25% groundnut shell is 17.78%.

However, comparing the efficiency of the various samples, it is observed that the cooking efficiency of the briquettes increase with increase in groundnut shell concentration upto 25% and somewhere beyond this range, the efficiency will start to drop. This value is higher than the values obtained in the thermal fuel efficiency of cashew shell briquettes of 15.5% (Sengar et al. 2012), but composition C compared well with red mangrove wood and firewood 23.55 and 21.31% respectively (Davies et al, 2013). Prasad and Verhaart (1983) also reported thermal fuel efficiencies for sawdust and rice husk ranged between 19.97 and 21.64%, and 26.20 and 27.27% respectively.

3.5 Average burning rate of fuel samples.

The average burning rates as shown in Figure 3 of the various fuel samples were estimated using equation 2 with data obtained from the WBT. The average burning rates values for all five fuel samples at high power (cold start), high power (hot start) and low power (simmering). The burning of the briquettes was steady and it produced red hot charcoal. Comparison of the performance between the average burning rates of the briquettes shows that briquette sample A with 5% groundnut shell is 0.511 kg/hr with the lowest burning rate, briquette B with 10% groundnut shell is 0.738 kg/hr, briquette C with 15% groundnut shell is 0.788 kg/hr, briquette D with 20% groundnut shell is 1.003 kg/hr while briquette E with 25% groundnut shell is 1.133 kg/hr. From the results obtained it can be seen that burning rate increases with increase in groundnut shell. The variation of the burning rate values of samples could be attributed to porosity exhibited between inter and intra–particles which enable easy infiltration of oxygen and out flow of combustion briquettes.

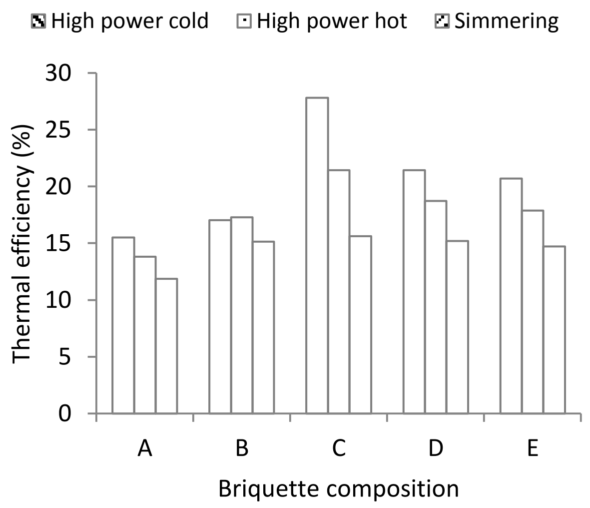

Figure 2. Results of thermal efficiency of fuel samples

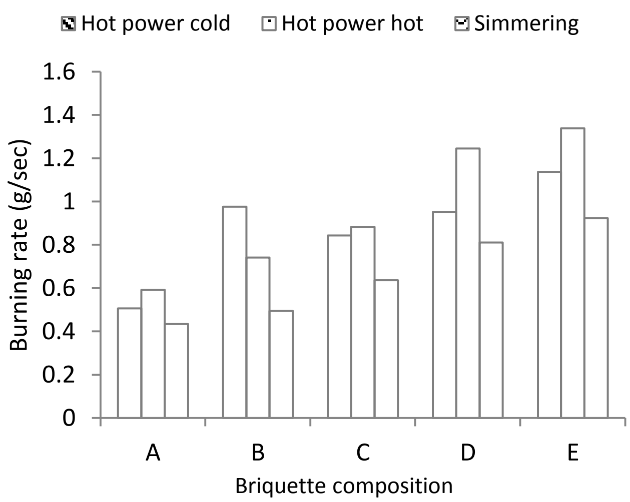

Figure 3. Results of burning rate of fuel samples.

The Burning rate in this research 0.511 – 1.133 kg/hr elucidated with that reported by Islam et al (2014) of briquette from Coir Dust and Rice Husk Blend which varies between 0.789 - 0.945 kg/hour. However the briquette compositions of 5% groundnut shell have a relatively lower burning rate while25% groundnut shell composition has the highest.

3.6 Average specific consumption for fuel samples

The average specific fuel consumption as shown in Figure 4 of the various fuel samples were estimated using equation 3 with data obtained from the WBT. The average specific fuel consumption values for all five fuel samples at high power (cold start), high power (hot start) and low power (simmering). Comparison of the performance between the average specific fuel consumption of the briquettes showed that briquette C with 15% groundnut shell is 0.087 J/g with the lowest specific fuel consumption, briquette A with 5% groundnut shell is 0.261 J/g, briquette B with 10% groundnut shell is 0.129 J/g, briquette D with 20% groundnut shell is 0.110 J/g and briquette E with 25% groundnut shell is 0.131 J/g.

The specific fuel consumption which measures the quantity of the fuel required to boil 1litre of water shows that sample C with 15% groundnut shell composition will be more economical than the other samples followed by samples D and E with 20 and 25% groundnut shell respectively.

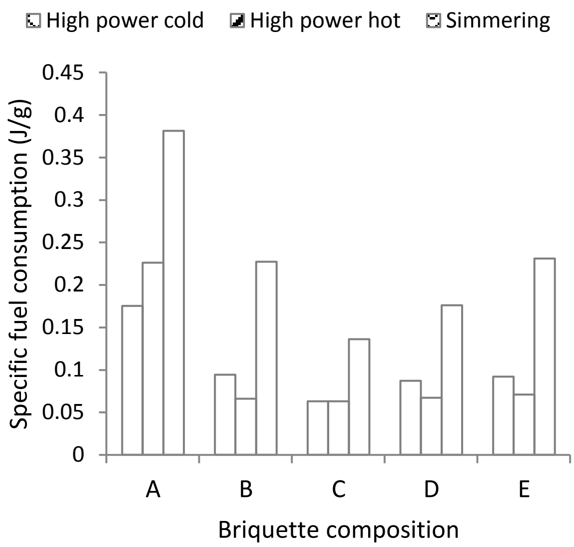

Figure 4. Results of specific fuel consumption of fuel samples

3.6 Boiling time

The values obtained during the water boiling test for the various fuel samples were used to plot a graph of temperature against time as shown in Figure 5 and 6. Repeating the test with a hot stove Figure 6 helps to identify differences in performance of the briquettes when the stove is hot or cold. From the plotted graphs it was observed that the sample C briquettes with 15%

groundnut shell has the fastest rate of boiling water in both cases, followed by sample D with 20% groundnut shell. The results of water boiling test showed that the time required for each set of briquettes to boil an equal volume of water decreases with increase in the groundnut shell concentration up to 15% as shown in Figure 5. Provision of adequate heat for the time necessary is an important quality of any solid fuel. The results of water boiling test showed that the time required for each set of briquettes to boil an equal volume of water decreases with increase in the groundnut shell concentration up to 15% for both cold and hot start as shown in Figures 5 and 6. However, the fact that the briquette samples A containing 15% biomass boiled water faster than the one containing 20% is a clear indication that somewhere beyond this concentration, the water boiling time will eventually begin to fall. The briquette sample A, took the longest time to boil water (30 minutes at cold start) while the sample A took the shortest time (17.5 minutes) The burning rate (how fast the fuel burns) and the caloric value (how much heat released) are two combined factors that controlled the water boiling time. This explained why sample C was able to boil water faster than Sample E even when the latter burns faster than the former. Sample D which has lower calorific value than sample A also took shorter time to boil equal volume of water.

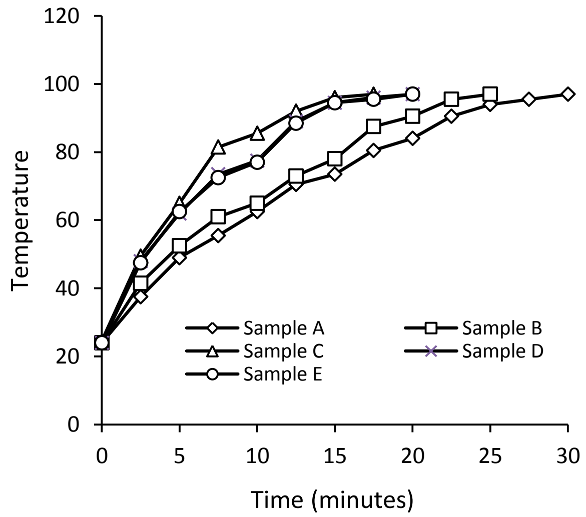

Figure 5. Results of water boiling test (Cold start) for fuel samples.

3.7 Nature of the Flame

Nature of the flame colour of a burning fuel gives an indication of the quality of heat and the cleanliness of the flame. A blue flame indicates a clean and high quality heat. On the other hand yellow flame indicates a low quality heat with soot deposits. During the water boiling test, the colour of the flame for sample A with 5% groundnut shell briquette was pale yellow throughout with less smoke, while for 15 - 25% groundnut shell, the colour of the flame was pale blue which signifies complete combustion and high heating efficiency and for sample B with 10% groundnut shell, the colour of the flame was pale yellow initially but as it stabilized, the colour became pale blue

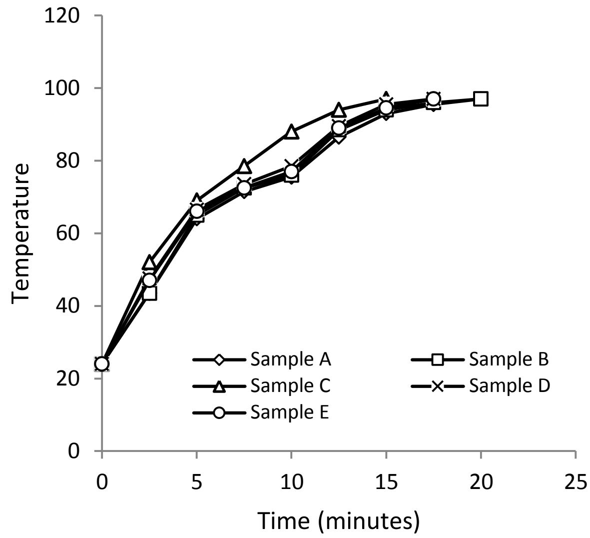

Figure 6. Results of water boiling test (Hot start) for fuel samples.

CONCLUSION

This study confirm the possibility of utilizing binderless briquettes from waste paper and groundnut shell mixtures as fuel energy for domestic and industrial application. However the groundnut shell should not exceed 25% for good binderless briquette, above this composition the briquette will disintegrate. The briquettes under study possess high calorific values as well as high value combustible fuel, which qualify them as alternative to firewood and charcoal for domestic and industrial energy. The fuel efficiency of the briquettes produced from this densification variables are good, however the 15% groundnut shell composition possess better characteristic study.

NUMENCLATURE

P_e = Dry mass of pot (g)
P_i = Initial mass of pot and cold water (g)
P_f = Final mass of pot and hot water (g)
W_r = Water remaining after water boiling test (g)
W_v= Water vaporized
f_m = Mass of fuel (kg)
T_i = Initial temperature of water (℃)
T_f= Final temperature of water (℃)

f_i = Initial mass of fuel (g)
f_f = Final mass of fuel (g)
f_m = Mass of fuel that bring the water to boil (g)
f_d = Equivalent dry wood consumed (g)
C_w= Specific heat capacity for water (J/g℃)
ΔT = Temperature difference in water boiling test (℃)

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