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An experimental study of the combustion characteristics of groundnut shell and waste paper admixture briquettes

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Abstract

The study was undertaken to assess the heat released of briquettes produced from waste paper and groundnut shell admixture in five mixing ratios (90:10; 80:20; 70:30; 60:40; and 50:50). The briquettes were prepared on an existing motorized briquetting machine. The suitability of briquetted fuel as domestic fuel was studied in terms of flame propagation, afterglow, calorific value, and utilized heat, after sun drying the prepared briquettes for nineteen (19) days. The results of propagation rate and afterglow obtained for all the six compositions are satisfactory they range between 0.13 to 0.14 and 365 to 380 respectively. These energy values obtained for the whole samples are sufficient enough to produce heat required for household cooking and small scale industrial cottage applications. Finally it was observed that composition variation affects the properties of the briquettes.

Keywords: Briquette, Groundnut shell, Waste, Calorific values, Utilized heat

1. Introduction

Global warming, caused by CO_2 and other substances, has become a worldwide concern in recent years. To preserve forestry resources, which act as main absorbers of CO_2, controlling the deforestation, desertification, with the raise in the consumption of wood fuels, such as firewood and charcoal. Nearly half the world's population, almost all in developing countries cook using biomass solid fuels [1], predominantly wood [2-4]. With deforestation and desertification becoming a major problem in many parts of the developing world, on this basis, the search for a substitute fuel for firewood is necessary. With advances in biotechnology and bioengineering, some resources, which have been classified as waste, now form the basis for energy production [5]. According to El-Saeidy [6] and Kaliyan and Morey [7], 86 % of energy being consumed all over the world is from fossil fuels. The large quantities of agricultural residues produced in developing nations can play an important role in meeting her energy needs. Among several kinds of agricultural residue, groundnut shells have become one of the most promising choices. Some agricultural wastes such as wood can be directly utilized as fuels. Nevertheless, groundnut shells are not suitable apparently because they are bulky, uneven, and have low energy density. All these properties make them difficult to handle, store, transport, and utilize in their raw form. Hence, there is the need to subject them to compaction processes in order to ease these problems. One of the promising solutions to these problems is the application of briquetting technology [8]. It may be defined as a densification process for improving the handling properties of raw materials and improve volumetric calorific value of the biomass. It can also produce compacted products with uniform shape and sizes that can be more easily handled thereby reduce cost related with transportation, handling, and storage.

The majority of solid fuel researches have been channeled towards reducing the negative effects of solid fuel thermal conversion. One such initiative is the promotion of co-firing options with biomass waste material [9-11]. The use of biomass waste can contribute towards a reduction in the utilization of conventional solid fuels and hence resolve some of the long standing environmental issues. One of the key factors in designing a biomass fuel briquette, apart from moisture content, is the combustion properties. In considering the combustion properties, it is found that briquettes of different materials require different optimum condition of fabrication [12-13]. These findings have led researchers to continue develop the guidelines for manufacturing processes for fuel briquettes made from biomass material. Currently, full scale utilization of biomass briquettes is in biomass stoves for domestic applications and in industrial grade boilers for power plants [14-15]. As a result of the growing importance and need for briquettes, particularly from biomass materials, many renowned scholars such as Waelti and Dodie [16], Mohsenin and Zaske

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[17], Singh and Singh [18], O'Dogherty and Wheeler [19], Faborode and O'Callaghan [20-21], Faborode [22], and Olorunnisola [23], have worked on various aspects of briquetting, the nature of the materials, the behaviour and characteristics of such materials during and after briquetting. The behaviour and characteristics of biomass residue briquetting can be classified into physical, mechanical and combustive depending on the measured parameters.

The overall aim of this work is to investigate and evaluate the combustion characteristics of briquettes produced from groundnut shell and waste paper admixture in varying composition by weight. The used of waste papers in this research is to utilized the abundant papers into something useful, thus helps in reducing the number of municipal wastes generated every year. Papers are selected as a material to be used compared to the other types of recycled wastes such as glass and plastic because it is known to be a good material for a combustion ignition. As for plastics, it may be compatible to papers to be used as ignition material in combustion, but it will spread a toxic gas while it is burning.

2. Materials and methods

The manufacture of briquettes in rural locations is of interest in this study. In this study waste paper and groundnut shell was chosen as the material for the briquettes, because it is readily available in the Northern part of Nigeria where the problem of desert encroachment is biting harder. Furthermore, because of its fibrous nature it is likely to behave in a similar way in the densification process to other fibrous organic residue matter. It is this type of material that is more likely to be available for briquetting in rural locations.

The paper was soaked for at least 3 days and thereafter, the water was drained off and the paper was converted into pulp by manual pounding with a pestle and a mortal as suggested by Olorunnisola [24]. Groundnut shells were collected were hammer-milled and sieved. Particles that passed through the 850μm sieves and were retained on the 600μm sieves were used. The groundnut shell was sundried for about three days before stocking.

The digested waste paper and groundnut shell were thoroughly mixed by hand until a uniformly blended mixture was obtained. Mixtures were prepared at the following groundnut shell: waste paper weight ratios, i.e. 0:100, 10:90, 20:80, 30:70, 40:60, 50:50 and 100:0 with a fixed amount of binder 10%. The briquettes were then formed using existing briquetting machine. The machine is a motorized briquetting machine, according to the design of the moulds, twelve (12) briquettes were produced per batch. The prepared briquettes are sun drying for nineteen (19) days before being subjected to various tests for assessing the heat quality of fuel.

2.1 Flame propagation rates

The flame propagation rates of the briquette samples were determined as highlighted by Musa [6]. To do this, one piece of the oven-dried briquette was graduated in centimeters and ignited over a Bunsen burner in the laboratory environment until the fire extinguished itself. The flame propagation rate was estimated by dividing the distance burnt by the time taken in seconds.

$$Flame\ propagation = \frac{L}{t} \quad (1)$$

Where,
L = Distance of briquette burnt
T = Time taken to burn in seconds

2.2 Afterglow time

The afterglow time was estimated and determined. This became necessary in order to estimate how long the individual briquette will burn before restocking when they are used in cooking and heating. The procedure of Musa [25] was also used. One piece of oven-dried briquette was ignited over a Bunsen burner and after a consistent flame was established, the flame was blown out. The time in seconds within which a glow was perceptible was recorded.

2.3 Calorific value test

Leco AC-350 Oxygen Bomb Calorimeter interfaced with a microcomputer was used to assess the heat values of the produced briquettes. Two grams of the briquettes was measured and the screw mould bracket was used to re-mould the briquette to the appropriate calorimeter bucket size. Ten (10) ml distilled water was poured into the bomb and the industrial oxygen cylinder was connected to the bomb and the valves were opened and bomb was filled slowly at pressure range of 2.5 – 3.0 Mpa for a minute. The bomb was placed inside a canister bracket containing the distilled water and the bomb lid was covered. The switch was turned on and the microcomputer was set for the determinations which automatically calibrate and measure the energy values and display the values on the screen for recording after feeding the necessary data on the briquettes. The data and result of the experiment are displayed on computer screen [26]. The result of the test is shown on Figure 2.

2.4 Utilized heat

The methods and formular adopted by Martins et al. [27], to obtained the heat value was used in this work. The utilized heat can be calculated from testing of briquettes using stove. The briquettes were used to boil 250 grams of water. The data measured were initial and the final mass of briquettes that consumed temperature of water from initial to final. To get the heat value, the formulas were as follow;

Sensible Heat, Qs = $m_w C_w \Delta T$ (2)

where:
C_w = specific heat of water, (1cal/g°C)
m = mass of water, (g)
ΔT = change in temperature (k)

Heat Value, q = $\frac{Qs}{m_b}$ (kJ/g) (3)

where,
Qs = Sensible heat (kJ)
m_b = weight of the briquettes consumed (g)

3. Results and discussions

The results of the determination of flame propagation rate, afterglow time and heat value of briquettes examined are shown in Tables 1, 2 and 3 respectively while the results of calorific value of the briquettes examined in this study is presented in Figure 1. The longer afterglow and slow propagation rate obtained in this study mean that briquettes from the seven compositions will ignite more easily and burn with intensity for a length of time. From Table 1, it can be interpreted that propagation time decreases with increase in groundnut shell. In general, briquetted waste paper is likely to be more difficult to ignite because of the low porosity and higher density. As a result, as the density of briquette increased its ignitability decreased. There are no optimum limits for acceptable ignitability of briquettes due their much ease of ignition hence waste material are not ideal for direct firing for domestic purposes.

Calorific value of briquettes from Figure 1 shows the comparison of heating values generated by different samples when tested in a bomb calorimeter. Highest calorific value of 220,665 kJ/kg, resulted from bomb calorimetry of 100:0 waste paper and groundnut shell admixture (Sample A), and the least been 100% groundnut shell (Sample G). Variation in blending ratio was discovered to considerably influence the calorific values of the briquettes, the calorific value decreases as the ratio of groundnut shell increases.

Table 1 Flame propagation

Sample burnt (cm)	Distance taken (s)	Time rate (cm/s)	Propagation
A	10.12	72.29	0.14
B	9.90	70.71	0.14
C	9.90	70.71	0.14
D	9.11	70.10	0.13
E	9.09	69.92	0.13
F	9.08	69.85	0.13
G	8.05	67.12	0.12

Table 2 Showing the afterglow time of the briquette samples

Sample	Time taken (sec)
A	374.78
B	374.50
C	380.40
D	380.40
E	370.40
F	365.55
G	356.30

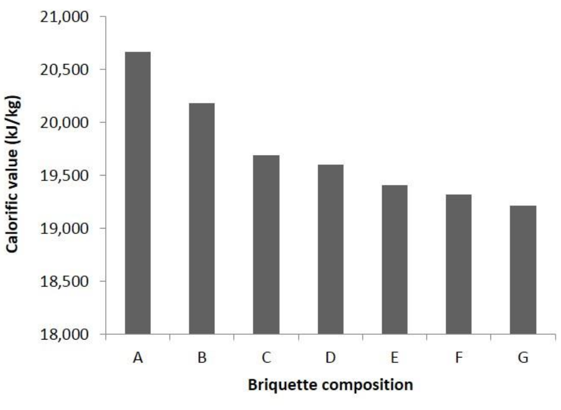

Figure 1 Calorific value of briquettes

The heating value of the briquettes in this study compares with 19,534 kJ/kg for briquettes from a mixture of palm kernel cake (PKC) and sawdust and 18,936 kJ/kg for sawdust of some hardwood species [28]. This value is also in concord with the findings of Oladeji [29], who tested the heating value of five briquettes produced from corncob, groundnut shell, melon shell, cassava and yam peels and were found to be 20,890, 18,634.34, 21,887, 12,765, and 17,348 kJ/kg, respectively. These energy values obtained for the whole samples are sufficient enough to produce heat required for household cooking and small scale industrial cottage applications. Furthermore, these energy values compare well with most popular biomass residues. For examples, rice husk briquette- 12,600 kJ/kg [6]; cowpea-14,372.93 kJ/kg; and soy-beans-12,953 kJ/kg [30]. Combustion characteristics based on the figure below, it is found that most of the briquettes fulfill the minimum requirement of calorific value for making commercial briquette (>17500 J/g), as stated by DIN 51731[31].

From Table 3, it can be seen that utilized heat increases with the amount of groundnut shell. It therefore implies that sample G (100% groundnut shell) was able to boil water faster than sample A with the highest calorific value. It can therefore be concluded that calorific value alone is not a single factor controlling efficiency of fuels but burning rate is equally important.

Table 3 Result of Utilized Heat

Sample	weight of Briquettes consumed (g)	Sensible heat (kJ/g)
A	192	92.45
B	189	93.92
C	187	94.92
D	190	93.42
E	187	94.92
F	187	94.92
G	174	102.01

4. Conclusion

From the experiment carried out, the flame propagation rate, after glow, calorific value and utilized heat of briquettes ranges between o.12 to 0.14 cm/s, 356.30 to 374.78 sec, 19,215 to 20,665 kJ/ kg and 92.45 to 102.01 kJ/g respectively. It was generally found that the characteristics of groundnut shell biomass briquettes produced from compaction with waste paper were satisfactory and compatible with the other researches that involved the agro waste briquettes. It was also found that composition material affects the heating value of briquettes.

5. References

[1] Bruce N, Perez-Padilla R, Albalak R. Indoor air pollution in developing countries: a major environmental and public health challenge. Bulletin of the World Health Organisation 2000;78(9):1078-1092.

[2] Amous S. The role of wood energy in Africa. Rome: FAO, working Paper Regional Studies.; 1999.

[3] Lefevre T, Todoc JL, Timilsina GR. In the role of wood energy in Asia. Rome: FAO, Forestry Department; 1997.

[4] Energy Commission. In Strategic National Energy Plan 2006-2020. Ghana: The energy Commission ; 2005.

[5] McKendry P. Energy production from biomass (part 1): Overview of Biomass. Bioresource Technology 2002;83(1):37-46.

[6] El-Saeidy EA. Technological fundamentals of briquetting cotton stalks as a bio-fuel [dissertation]. Humboldt: Humboldt University; 2004.

[7] Kaliyan N, Morey RV. Factors affecting strength and durability of densified biomass products. Biomass and Bioenergy 2009;33(3):337-359.

[8] Wilaipon P. Physical characteristics of maize cob briquette under moderate die pressure. American Journal of Applied Science 2007;4(12):995-998.

[9] Saidur R, Abdelaziz EA, Demirbas A, Hossain MS, Mekhilef S. A review on biomass as a fuel for boilers. renewable and sustainable energy reviews 2008;15(5):2262-2289.

[10] Koh MP, Hoi WK. Sustainable biomass production for energy in Malaysia. biomass and bioenergy 2003;25(5):517-529.

[11] Sasaki N, Knorr W, Foster DR, Etoh H, Ninomiya H, Chy S, Kim S, Sun S. Woody biomass and bioenergy potentials in southeast Asia between 1990 and 2020. Applied energy 2009;86:140-150.

[12] Kaliyan N. Densification of biomass [dissertation]. Twin Cities: University of Minnesota; 2008.

[13] Nasrin AB, Ma AN, Choo YM, Mohamad S, Rohaya MH, Azali A, Zainal Z. Oil palm biomass as potential substitution raw materials for commercial biomass briquettes production. Science publication 2008;5(3):179-183.

[14] Husain Z, Zainac Z, Abdullah Z. Briquetting of palm fibre and shell from the processing of palm nuts to palm oil. Biomass and Bioenergy 2002;22(6):505-509.

[15] Ibrahima ABA, Arisb M.S, Chin YS. Development of fuel briquettes from dewatered poultry sludge. International conference on future electrical power and energy systems: Lecture notes in information technology 2012;9:469-476.

[16] Waelti H, Dodie JB. Cubability of rice straw as affected by various binder. Transactions of ASAE 1973;16(2):380-383.

[17] Mohsenin, M. N and Zaske, J. Stress relaxation and energy requirements in compaction of unconsolidated materials. Journal of Agricultural Engineering Research 1976;21(2):193–205.

[18] Singh A, Singh Y. Briquetting of paddy straw. Agricultural Mechanization in Asia, Africa and Latin America 1982;13(4):42-44.

[19] O’Dogherty MJ, Wheeler JA. Compression of straw to high densities in closed cylindrical dies. Journal of Agricultural Engineering Research 1984;29(29):61-72.

[20] Faborode MO, O’Callaghan JR. Optimizing the compression/briquetting of fibrous agricultural materials. Journal of Agricultural Engineering Research 1987;38(4):245-262.

[21] Faborode MO, O’Callaghan JR. A rheological model for the compaction of fibrous agricultural materials. Journal Agricultural Engineering Research 1989;42(3):165-178.

[22] Faborode MO. Briquetting waste hyacinth for domestic and rural agro- industrial fuel application. The Proceedings of the International Workshop/Seminar on Water Hyacinth; 1988 Aug 7-12; Lagos, Nigeria. Federal Ministry of Science and Technology; 1988.

[23] Olorunnisola AO. Briquetting of rattan furniture waste. Journal of Bamboo and Rattan 2004;3(2):139-149.

[24] Olorunnisola AO. Production of fuel briquettes from waste paper and coconut husk admixture. Agricultural Engineering International: the CIGR E-journal Manuscript EE 06 006 2007; Volume IX.

[25] Musa NA. Comparative fuel characterization of rice husk and groundnut shell briquettes. NJRED 2007;6 (2):23-26.

[26] Oyelaran OA. Development of a motorized biomass fuel briquetting machine [dissertation]. Abeokuta: University of Agriculture; 2014.

[27] Martin JF, Pineda RMA, Manaay JA, Handa SA, Ocreto AB. Design and development of charcoal briquetting machine. USM R & D 2008;16(2):85-90.

[28] RETSASIA [Internet]. Results earlier reported for sawdust briquette and torrefied wood [cited 2012 Oct 1]. Available from: www.retsasia.ait.ac.th/publication /WRERC2005/RONAST-WRERC05(2005).

[29] Oladeji JT. Comparative study of briquetting of few selected agro-residues commonly found in Nigeria. The Pacific Journal of Science and Technology 2012;13(2):80-86.

[30] Enweremadu CC, Ojediran JO, Oladeji JT, Afolabi IO. Evaluation of energy potential of husks from soy-beans and cowpea. Science Focus 2004;8:18-23.

[31] Yuhazri1 MY, Sihombing H, Nirmal U, Lau S, Prak Tom P. Solid fuel from empty fruit bunch fiber and waste papers Part 1: Heat released from combustion test. Global Engineers & Technologists Review 2012;2 (1):7-13.