Investigating The Effect of Shapes (Cylindrical Vs Hexagonal) On The Burning Rate of Briquettes

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ABSTRACT

The use of briquettes as a substitute for fuelwood is now becoming increasingly popular. This is because of the several benefits associated with using briquettes such as environmental protection, renewability, smokeless combustion, high density and so on. This research investigated the effect of shape or configuration on the burning rate of briquettes. The result of the study shows that the average burning rate of the cylindrical briquettes is 1.14g/min, while that of the hexagonal briquettes is 1.40g/min. ANOVA test performed on the result indicated that that there is a statistically significant difference between the burning rates of the briquettes, with the result showing that the hexagonal briquettes generally exhibited better burning rate than the cylindrical one. The findings of the research can help in selecting between cylindrical and hexagonal briquettes for different applications.

Keywords: Briquettes, Fuelwood, Ignition time, Burning rate, Combustion.

INTRODUCTION

Over-reliance on fuel wood is a major cause of woodland and forest degradation (Forestry Administration, 2002). Such degradation often leads to unintended environmental consequences that include among others climate change, biodiversity loss and physical land degeneration (DeFries et al., 2004).

Therefore, there is need to look for an inexpensive, renewable and environmentally friendly source of energy that will serve as fuel wood replacement in order to contain the aforementioned challenges.

Agro-industrial biomass comprised of lignocellulosic waste is an inexpensive, renewable, abundant source of fuel material, which provides a unique natural resource for large-scale and cost-effective bio-energy collection (Anwar et al., 2014).

One possible means of making more efficient use of the biomass residues is by briquetting. This involves collecting biomass materials that are not normally considered a useful fuel, due to their low density, and compressing them into a solid fuel of a convenient size and shape that can be burned in the same way as wood or charcoal. Briquetting increases the bulk density of the biomass material, increasing its energy density, which in turn reduces transport costs and makes it much easier for the end user to handle. Indeed, agricultural residues in their raw state are often bulky and difficult to handle and in combustion they often burn fast and are smoky (Wamukonya & Jenkins, 1995).

Densification of the material results in marked improvement in combustion characteristics compared with loose bio waste (Husain et al., 2002).

Despite the aforementioned benefits of briquettes, there is potential to improve briquettes' design for greater performance.

One important factor in briquette design that affects combustion is its shape. While cylindrical and hexagonal briquettes are the most common, the effect of these shapes on combustion characteristics has not been extensively studied. This research aims to fill this gap by examining how the shapes of cylindrical and hexagonal briquettes influence their burning profiles.

The findings of the research can go a long way in identifying the optimum shape for briquettes that can improve their combustion characteristics. This can be useful for both manufacturers and consumers of briquettes.

THEORY

Importance of Briquettes and their Advantages over Loose Biomass

Briquetting or densification is the process which involves compaction of the biomass residue into a uniform solid fuel called briquettes. Production of briquettes from agro-waste can help fuel-wood users (particularly rural dwellers) access alternative source of energy at lower cost (Aliyu et al., 2020). One of the advantages of briquetting is that the bulk density of the material is increased, making transportation easier and cheaper; the energy content per unit volume of material is increased; a homogenous product is obtained from an often heterogeneous mix of materials; a uniform quantity of energy per unit of combustion feedstock is maintained and a highly cohesive product is obtained from materials that might otherwise be difficult or expensive to process (Olorunnisola et al., 2004).

Factors Influencing Combustion Efficiency

One of the factors affecting the performance of briquettes is the use of binders during briquetting.

The amount of binder selected should give the final product its required strength, so that it is able to withstand handling, transportation and storage (Engelleitner, 2001). Another factor that influences the performance of briquettes is the density. According to (Loo & Koppejan, 2008), the higher the density of the fuel, the greater the energy density. For a stoked fire, this therefore influences the ratio of energy input per unit volume into a cookstove's combustion chamber.

In 2018, Nigeria's primary energy consumption was about 155 Mtoe (Nigeria Energy Outlook). Most of the energy comes from traditional biomass and waste, which accounted for 73.5% of total primary consumption in 2018. The rest is from fossil fuels (26.4%) and hydropower (Nigeria Energy Outlook, 2019). Another perspective on Nigeria primary energy consumption is by Anosike et al., (2016) which is presented in Fig. 1.

Primary Energy Consumption in Nigeria

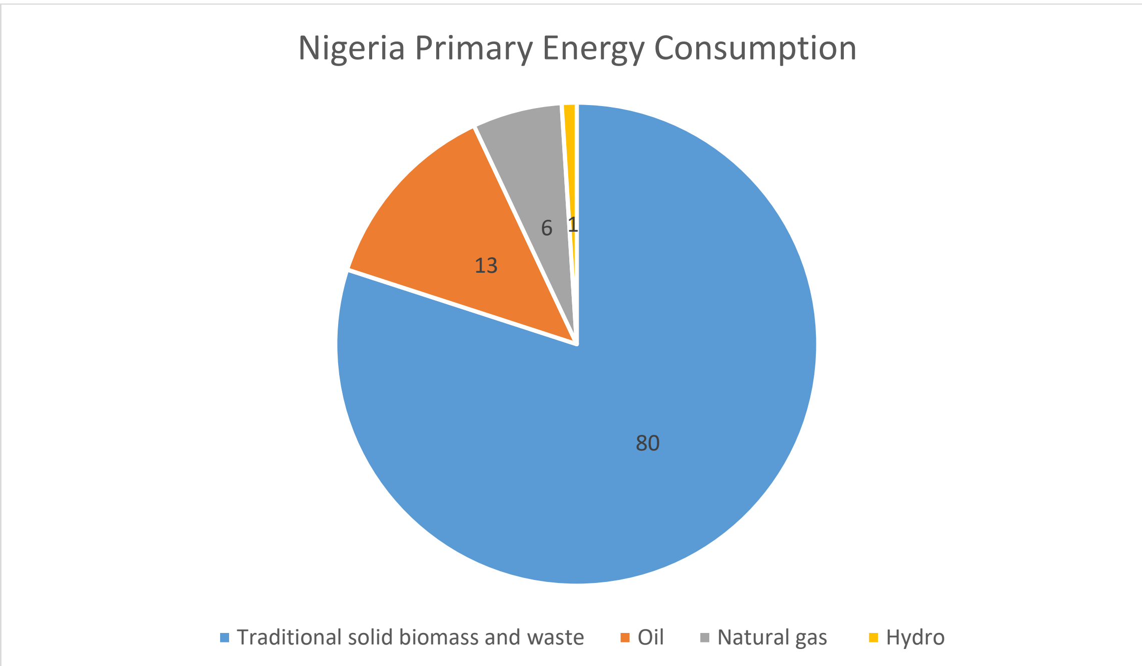

Figure 1: Nigeria Primary Energy Consumption,
Source: Anosike et al., (2016).

EXPERIMENTAL DESIGN

The flowchart below shows the steps involved in the production and the performance evaluation of the briquettes in this research.

MATERIALS AND METHODS

MATERIALS

Materials used in this research includes charcoal dust, cassava flour, cylindrical and hexagonal briquetting moulds, hammer, thermometer, measuring cylinder, tarpaulin, briquette stove, stop watch, pot, bowl, stirrer etc.

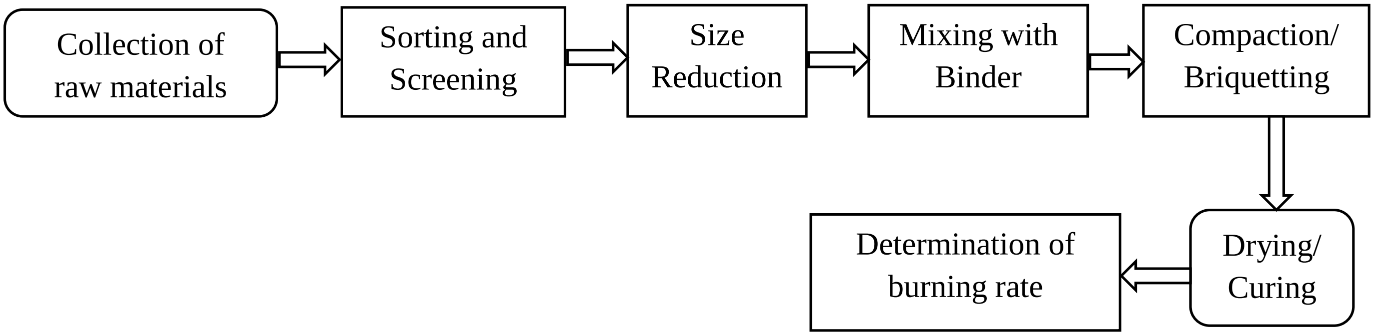

Figure 2: Briquettes Production Layout

METHODS

Collection of Raw Material

The feedstock used for the production of the briquettes in this research is charcoal dust. The dust was collected from nearby charcoal vendors in a bag and delivered to the production site.

Sorting and Screening

The charcoal dust was spread on a tarpaulin and it was screened from foreign materials such as stones, plastics, sand and so on in order to obtain a pure charcoal dust.

Figure 3: Sorting and Screening of Charcoal Dust

Size Reduction

The charcoal dust was grinded using pestle and motar to reduce the particle size in order to obtain a charcoal powder.

Binder Preparation and Mixing

Binder solution was prepared by using cassava powder and hot water. A good quantity of the binder solution was mixed with the charcoal powder and homogeneous mixture of binder and charcoal was obtained.

Figure 4: Binder Preparation and Mixing

Compaction/Briquetting

The charcoal-binder mixture is manually fed into both the cylindrical and the hexagonal molds.

Using an appropriate pressure, the mixture was compressed to form the briquettes. The briquettes were then manually ejected from the mold.

Drying/Curing

The briquettes were sun-dried in an area devoid of rain and moisture in order to reduce their moisture content for efficient burning.

Figure 5: Drying of the Briquettes

Determination of Burning Rates of the Briquettes

The burning rates of the briquettes were computed by determining the time taken for a pre-set quantity of briquettes to burn (Abodenyi & Yakmut, 2020). The burning rate were then calculated using the following equation:

$$Burning\ rate\ \left(\frac{g}{min}\right) = \frac{Total\ Weight\ of\ the\ briquettes\ (g)}{Time\ Taken\ (min)} ------(1)$$

RESULTS AND DISCUSSIONS

RESULTS

Burning Rates of the Briquettes

Table 1: Burning Rates of the Briquettes in g/min

S/N	Cylindrical Briquettes	Hexagonal Briquettes
1	1.15	1.42
2	1.11	1.44
3	1.09	1.37
4	1.18	1.39
5	1.18	1.37

Table 2: Result of ANOVA Test for Burning Rate.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.16384	1	0.16384	124.1212	3.77E-06	5.317655
Within Groups	0.01056	8	0.00132			
Total	0.1744	9				

DISCUSSION OF RESULT

ANOVA test with a conventional p- value of 0.05 was carried out to determine if there is a statistically significant difference between the burning rates of the cylindrical and the hexagonal briquettes. The results presented on Table 1 indicated that the average burning rates for the cylindrical and hexagonal briquettes are 1.14 g/min and 1.40 g/min respectively.

The ANOVA test of the burning rates in Table 2 shows an F-statistic value of 124.1212 and a p-value of 0.00000377. The p-value is less than the conventional p-value of 0.05 which signifies that there is a significant difference between the burning rates of the cylindrical and the hexagonal briquettes. Specifically, the hexagonal briquettes have higher burning rates than the cylindrical briquettes. This implies that the shape or configuration of the hexagonal briquettes can increase the surface area available for combustion and subsequently facilitate efficient burning of the briquettes.

CONCLUSION

In summary, this research investigated the influence of shape (cylindrical and hexagonal) on the burning rates of briquettes. ANOVA test indicated that there is a significant difference between the burning rates. Generally, the hexagonal briquettes showed better combustion properties when compared with the cylindrical ones. The findings of this research can help both the manufacturers and users of briquettes to select appropriate shape of briquettes for different applications.

RECOMMENDATIONS

Considering the findings of the research, the following recommendations are suggested:

i. Combustion characteristics of other shapes of briquettes such as oval, rectangular, square and so on, should be investigated.
ii. Briquetting machine should be used when conducting similar experiment in order to ensure uniform compression during the briquetting.
iii. Influence of other factors such as binder type, binder ratio, particles size and so on that are not explored in this research should be investigated.

REFERENCES

Abodenyi, V.A. & Yakmut, S. (2020). Comparative Study of the Burning Rate of Briquettes Made from Agricultural Waste. *African Scholar Journal of Agriculture and Agricultural Tech. 18*(1). ISSN: 2877-1990.

Aliyu, M., Mohammed, I.S., Usman, M., Dauda, S.M. & Igbetua, I.J. (2020). Production of composite briquettes (orange peels and corn cobs) and determination of its fuel properties. *AgricEngInt: CIGR Journal 22*(2). 133-144.

Anosike, N., El-Suleiman, A. and Pilidis, P. (2016). Associated Gas Utilization Using Gas Turbine Engine, Performance Implication - Nigerian Case Study. *Energy and Power Engineering. 8*, 137-145.

Anwar, Z., Gulfraz, M. & Irshad, M. (2014). Agro industrial lignocellulosic biomass a key to unlock the future bio-energy: A brief review. *J. Radiat. Res. Applied Sci.*, 7. 163-173. DOI: 10.1016/j.jrras.2014.02.003

DeFries, R.S., Foley, J.A. & Asner, G.P. (2004). Land-use choices: Balancing human needs and ecosystem function. *Front Ecol Environ 2*(5) 249-257.

Engelleitner, W.H. (2001). Binders: how they work and how to select one. *Powder and Bulk Engineering. 15*. 31–38.

Forestry Administration. (2002). Public Work Project of Forest Management. *Forestry Administration*, Seoul.

Husain, Z., Zainac, Z. & Abdullah, Z. (2002). Briquetting of palm fibre and shell from the processing of palm nuts to palm oil. *Biomass and Bioenergy*. *22*, 505–509.

Loo S.V. & Koppejan J. (2008). The Handbook of Biomass Combustion and Co-firing. *Earthscan*, 2008.

Nigeria Energy Outlook (2019). U.S. Energy Information Administration. Retrieved 8 April 2014.

Olorunnisola, A.O. (2004). Briquetting of rattan furniture waste. *Journal of Bamboo and Rattan. 3*(2). 139–149.

Wamukonya, L. & Jenkins, B. (1995). Durability and relaxation of sawdust and wheat-straw briquettes as possible fuels for Kenya. *Biomass and Bioenergy*. *8*(3) 175–179.