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Investigation of African Pear (Dacryodes Edulis) Resin as Binder for Briquetting

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Abstract: This study deals with investigation of breadfruit shell (BFS) as potential energy source and efficacy of resin extracted from African pear (Dacryodes Edulis) as binder for briquettes. Different concentrations of the resin were mixed with constant weight of BFS to study the effect of the resin on the performance of BFS briquette. The density, moisture content, ash content, volatile matters and fixed carbon of the BFS briquette were obtained as 0.672g/cm^3, 10.24%, 7.23%, 68.76% and 23.92% respectively. This study showed that the resin has effect on the performance of the briquette. Thus, the ignition time, calorific value and fuel efficiency increased with increase in resin content, while increase in resin content decreased the mass of briquette consumed, burning rate and specific fuel consumption. The optimum performance was recorded at resin content of 0.16g/g biomass, with calorific value and fuel efficiency obtained as 20036.4kJ/kg and 51.12% respectively. Therefore, breadfruit shell is a potential energy sources, and can be useful substitute for refined petroleum products for heating.

Keywords: Briquette, Breadfruit, African pear resin, Combustion characteristics
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I. INTRODUCTION

The cost of energy is no longer a recent challenge, and it is a globally concern. Of course, the major source of energy generation has been from fossil fuel, though, energy can also be extracted from the wind, sun, water and bio-wastes. In Nigeria, kerosene and gas are used for cooking mostly by urban dwellers, but are so expensive. Also, in most developing countries, wood is the major energy source used mainly for cooking in rural communities, and this has depleted to a great extent (Adeniyi *et al*., 2014).

The continuous energy challenges have motivated researcher across the globe to finding alternative sources of energy that are not only environmental friendly, but also, cost effective. One of such alternatives is the making briquettes for heating.

Briquette is the bringing together of carbonaceous materials, in most cases, agro-wastes with or without binder via compaction (Nasrin *et al*., 2008 and Chen *et al*., 2013). Briquetting of biomass has numerous advantages, which include waste management and control of global warming through the limited use of fossil fuel (Deng *et al*., 2009). Also, long time exposure to smoke from wood during cooking has health implications, which can be reduced by using briquettes (Akuma and Charles, 2017).

Previously used biomass include palm kernel shell (Chen *et al*., 2013; Adeniyi *et al*., 2014; Olugbade and Mohammed, 2015; Mbada *et al*., 2013; Kumar *et al*., 2016; and Yugandhar *et al*., 2018), rice husk (Gbabo *et al*., 2018), corn cobs (Zubairu and Gana, 2014), wood waste (Bandara and Kowshayini, 2017 and Shiferaw *et al*., 2017) and groundnut shells (Akuma and Charles, 2017) amongst others. However, in this study, bread fruit shell (BFS) was used as biomass, while African pear (*Dacryodes Edulis*) resin was used as binder. Breadfruit (*Treculia Africana*) is most grown in Africa, and it has high nutritional values (Nwabueze and Okocha, 2008). In the South East of Nigeria, it is a popular and very important food, and it is locally called "Ukwa" (Nwigbo *et al*., 2008). However, the shell which houses the nut is regarded as waste, which would be of great value if properly utilized like other agro-wastes. Thus, the ignition ability demonstrated when thrown as waste in burning fire showed it can be useful energy source.

On the other hand, African pear exudes high viscous brown coloured liquid (resin) when given a cut on the bark. The resin is used locally as biding agent without any special preparation, and it is flammable. Previous studies used starch from cassava, corn or other plant starch as binding agent (Chinyere *et al*., 2014 and Onukak *et al*., 2017).

II. MATERIALS AND METHODS

Breadfruit and African pear resin were collected from Enito II village in Ahoada-West Local Government Area of Rivers of Nigeria. The breadfruits were cut open and the nuts removed. The removed nuts were boiled in a boiler for about 2-3 hours to remove the shell from the edible portion of the fruit. The shell was sun dried daily for two weeks and crushed to powdered size. The crushed particles were sieved through mesh 2mm sizes, and then mixed with the resin extracted from African pear at the following ratios: 20:500, 40:500, 60:500, 80:500 and 100:500. The formulated mixtures was pressed using hydraulic jack to make the briquettes.

2.1 Proximate analysis

Proximate Analysis was conducted to characterize the BFS briquette.

2.1.1 Briquette density

The BFS briquette density was calculated using the method in (Tembe *et al*., 2014). That is, three briquettes were selected at random. The weight and volume of the selected briquette was then calculated. From the mean weight and volume, the BFS briquette density was calculated using the formula:

$$\rho = \frac{w_1}{V} \quad (1)$$

Where: $\rho =$ Briquette density (g/cm^3), $w_1 =$ Weight of briquette (g) and $V =$ Volume of briquette (cm^3).

2.1.2 Moisture content

Again, the moisture content was determined using the method in Onukak *et al*. (2017). A constant weight of briquette sample was oven dried at 105 ºC until its weight was constant. The moisture content was calculated using the formula:

$$MC = \frac{w_1 - w_2}{w_2} \times 100\% \quad (2)$$

Where: $MC =$ moisture content (%), $w_1 =$ initial weight of briquette (g) and $w_2 =$ weight of briquette at 105 ºC (g).

2.1.3 Ash content

The ash content was determined using the method in Onukak *et al*. (2017). Thus, a constant weight of briquette sample was heated to 450 ºC for 1 hour, and then cooled before weighing. The ash content was calculated using the formula:

$$AC = \frac{w_2}{w_1} \times 100\% \quad (3)$$

Where: $AC =$ ash content (%), $w_1 =$ initial weight of briquette (g) and $w_2 =$ weight of briquette at 450 ºC (g).

2.1.4 Volatile matter

The volatile matter was determined using the method described in Onukak *et al*. (2017). A constant weight of briquette sample was dried at 105 ºC until its weight was constant. The sample was heated further to 550 ºC for about 10 minutes and then cooled before weighing. The volatile matter was calculated using the formula:

$$VM = \frac{w_1 - w_2}{w_1} \times 100\% \quad (4)$$

Where: $VM =$ volatile matters (%), $w_1 =$ weight of briquette at 105 ºC (g) and $w_2 =$ weight of briquette at 550 ºC (g).

2.1.5 Fixed carbon

The fixed carbon of BFS briquette was calculated using the formula (Tembe *et al*., 2014):

$$FC(\%) = 100 - (AC + VM) \quad (5)$$

2.2 Test analysis

The following test analysis was carried on the BFS briquette to determine its performances.

2.2.1 Ignition test

This referred to the time taken for the briquette to ignite. The briquette was ignited with match stick and the ignition time recorded using a stop watch.

2.2.2 Combustion test

500ml of water was poured into a kettle at ambient temperature of 27 ºC. The BFS briquette was placed on a stove and ignited. After ignition, the kettle was few centimeters above the stove with the aid of supports. The time at which the water boils was recorded using stop watch, while the mass of briquette before and after water had boiled were recorded.

2.3 Combustion analysis

To ascertain the thermodynamic value of BFS briquette, the following parameters were studied.

2.3.1 Burning rate

The briquette burning rate was calculated using the formula:

$$m_b = \frac{m_i - m_f}{t} \quad (6)$$

Where: $m_b =$ mass of briquette fuel utilize at boiling point (g), $m_i =$ initial mass of briquette fuel (g), $m_f =$ final mass of briquette at boiling point (g) and $t =$ time at which water boils (min).

2.3.2 Specific Fuel Consumption

The specific fuel consumption is the amount of briquette utilized as fuel in generating heat energy when a given volume or weight of liquid is heated. It is expressed according to the formula:

$$SFC = \frac{m_b}{V_w} \quad (7)$$

Where: $SFC =$ specific fuel consumption (kg/L), $m_b =$ mass of briquette fuel utilize (kg) and $V_w =$ volume of water heated (L).

2.3.3 Calorific Value

The calorific value is the energy released by one kilogram weight of briquette. This was determined using oxygen bomb calorimeter.

2.3.4 Fuel Efficiency

The fuel efficiency is the ratio of the net heat supplied by the briquette to the total heat gain by water during the combustion of briquette. This is calculated using the formula described by Adeniyi *et al*. (2014).

$$\eta = \frac{m_w C_p (T_b - T_o) + m_e \ell}{m_b CV} \quad (8)$$

Where: $\eta =$ fuel efficiency (%), $m_w =$ mass of water (kg), $C_p =$ specific heat capacity of water (4.2 kJ/kg ºC), $T_b =$ temperature of water at boiling point (ºC), $T_o =$ initial temperature of water (ºC), $m_e =$ Mass of water evaporated after boiling (kg), $\ell =$ latent heat of water (2260 kJ/kg), $m_b =$ mass of briquette used as fuel (kg) and $CV =$ Calorific value of briquette (kJ/kg).

III. RESULTS AND DISCUSSIONS

Results of the proximate analysis of BFS briquette is presented in Table 1. The density, ash content, moisture content, volatile matters and fixed carbon are obtained as 0.917g/cm^3, 2.3%, 4.6%, 65.3% and 19.83% respectively. The density of BFS briquette was obtained as 0.672g/cm^3, which is less 1.27g/cm^3 for PKS briquette (Adeniyi *et al*., 2014), but was similar to groundnut shell briquette (Akuma and Charles, 2017). Also, the ash content, moisture content, volatile matters and fixed carbon (Table 1) are within reported values for briquettes obtained from groundnut shell and rice husk (Tembe *et al*., 2014 and Gbabo *et al*., 2018). The fixed carbon was less than 44.27 - 61.67% reported by Shiferaw *et al*. (2017) for wood waste briquette.

Table 1: Proximate analysis of BFS briquette

Parameter	Value
Density (g/cm^3)	0.672
Moisture content (%)	10.24
Ash content (%)	7.32
Volatile matter (%)	68.76
Fixed carbon (%)	23.92

Effect of binder (resin extracted from African pear) on breadfruit shell briquette performance was investigated. Table 2 showed the results of the analysis, while profiles of combustion analysis as influenced by the resin content in the briquette was illustrated in the Figures.

Table 2: Effect of resin binder on BFS briquette

Resin (wt)	IT (min)	BR (g/min)	SFC (kg/L)	CV (kJ/kg)	FE (%)
0.04	9.12	3.73	0.178	18795	36.23
0.08	8.34	4.11	0.166	19122.1	42.17
0.12	6.41	3.38	0.107	19587.2	45.49
0.16	5.37	2.06	0.092	20036.4	51.12
0.2	4.46	2.66	0.093	19952.3	47.65

IT: ignition time, BR: burning rate, SFC: specific fuel consumption, CV: calorific value, FE: fuel consumption

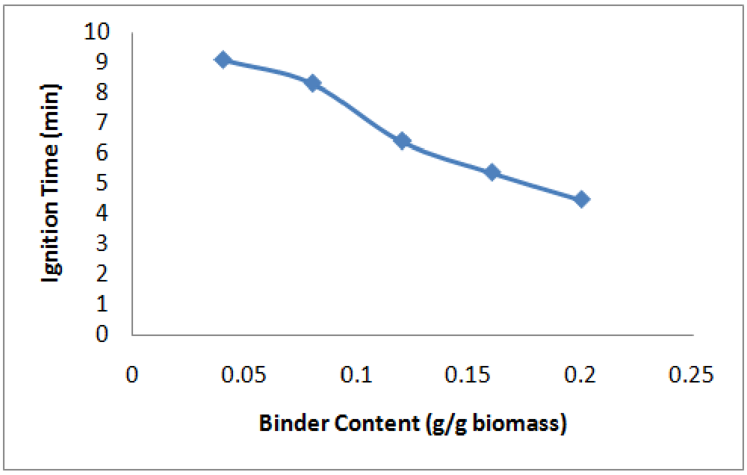

Figure 1: Effect of binder content on ignition time

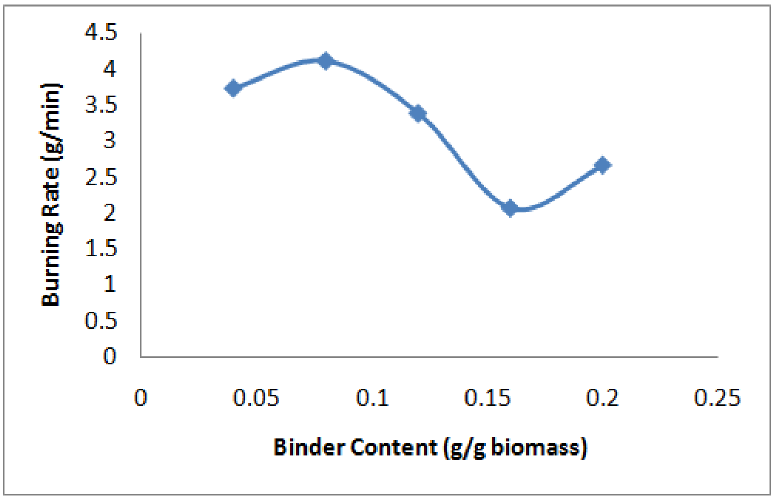

Figure 2: Effect of binder content on burning rate

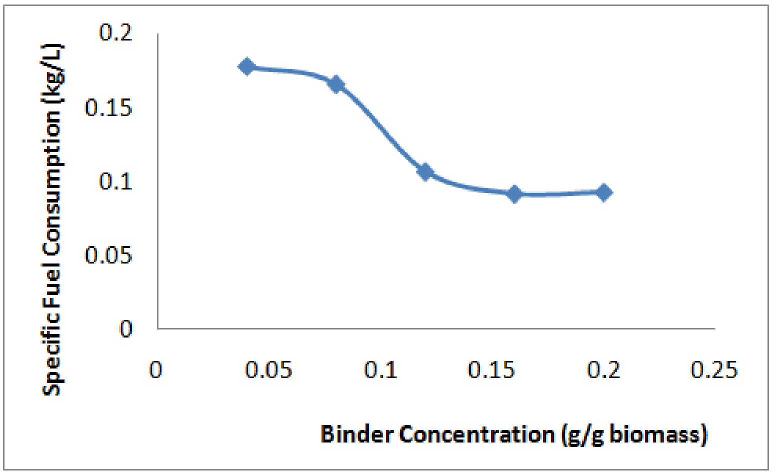

Figure 3: Effect of binder content on SFC

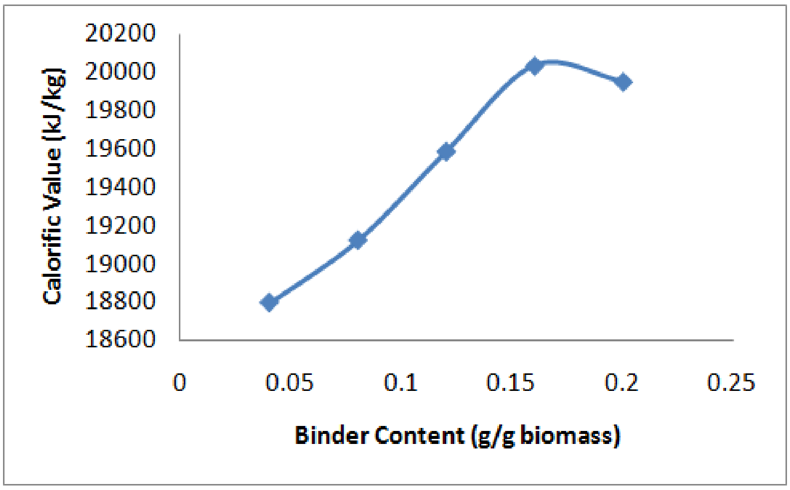

Figure 4: Effect of binder content on calorific value

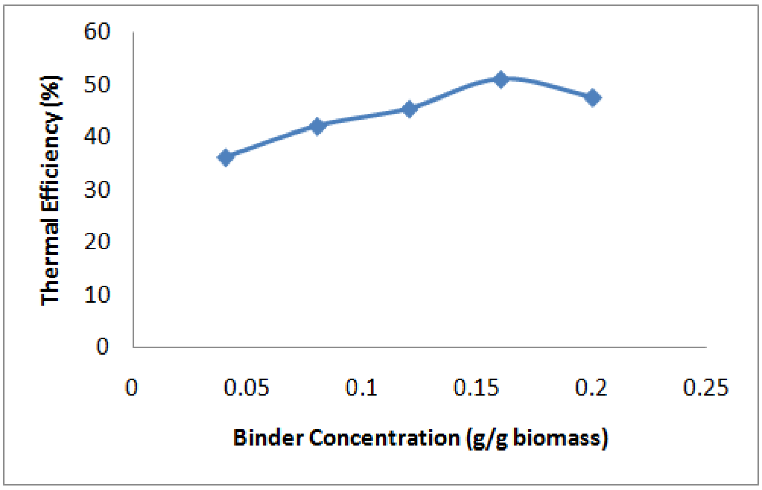

Figure 5: Effect of binder content on fuel efficiency

Resin extracted from African pear as binder for briquetting has effect on the performance of briquette as indicted by profiles in the Figures above. Thus, in Figure 1, increase in resin concentration decreased the ignition time of BFS briquettes. The ignition time was less than briquette bind with corn or cassava starch (Chinyere *et al.*, 2014 and Onukak *et al.*, 2017), but it was similar to groundnut shell briquette bind with rice starch (Akuma and Charles, 2017). Interestingly, the briquette required no spiking of kerosene to ignite it. This is due to high flammability of the resin.

In Figure 2, increase in resin content initially increased the burning rate of BFS briquette from 3.73 to 4.11g/min, and then decreased to 2.06g/min at optimum content of 0.16g/g of resin. Further increase of resin content in the briquette by 0.20g/g of resin subsequently increased the burning rate to 2.66g/min. This is because the flammability characteristics of the resin at 0.20g per biomass weight, the porosity of bonded material opens to increase the rate of oxygen diffusion into the briquette pores. Similar investigation has reported similar trend in burning rate for sawdust briquette bind by corn starch (Chinyere *et al*., 2014), while between 2.4g/min and 3.3g/min burning rate was obtained for either palm branch or mixture of palm branch and coconut coir briquettes using Maida flour as binder (Kumar *et al*., 2016 and Yugandhar, *et al*., 2018).

Figure 3 showed that the specific fuel consumption of BFS briquettes decreased with increase in resin content, but further increased with increased resin content. Thus, from 0.04 to 0.016g/g of resin, the specific fuel consumptions decreased from 0.178 to 0.0926kg/L, but increased to 0.093kg/L with 0.20g/g biomass resin content. This implied that between 0.092kg of briquette was consumed while 1 litre of water to its boiling point. This is comparable to 0.021kg/L reported for palm kernel shell briquette bind with 12.90% cassava flour (Adeniyi *et al*., 2014).

Increase in resin content from 0.04 to 0.016g/g also increased the calorific value of BFS briquette as shown in Figure 4. Thus, from 0.04 to 0.016g/g of resin content, the calorific value of BFS briquette increased from 18795 to 20036.40kJ/kg, and then reduced to 19952.30kJ/kg with 0.20g/g resin content. The calorific value BFS briquette was similar to palm branch briquette (Yugandhar, *et al*., 2018), while very high calorific values had been reported for corn cob and sawdust briquettes (Zubairu and Gana, 2014 and Chinyere *et al*., 2014). However, increase in binder content has also been reported to have decrease effect for briquette calorific value (Hamid *et al*., 2016; Shiferaw *et al*., 2017 and Gbabo *et al*., 2018).

Like calorific value, fuel efficiency of BFS briquette increased with increase in resin content. As shown in Figure 5, increase in resin content from 0.04 to 0.016g/g of resin, increased the fuel efficiency of BFS briquette from 36.23 to 51.12% before reducing 47.67% when 0.20g/g resin content was mixed with the BFS briquette. The fuel efficiency are within the range (45.8 to 50.40%) reported for sawdust briquettes bind with 30 to 50ml corn starch (Chinyere *et al*., 2014), while about 72% was reported for palm branch briquette (Kumar *et al*., 2016).

IV. CONCLUSION

The density, moisture content, ash content, volatile matters and fixed carbon of the BFS briquette showed it is suitable for briquetting. Also, ignition time, calorific value and fuel efficiency increased as resin content in the briquette was increased, with optimum performance recorded at resin content of 0.16g/g biomass. However, increase in binder content decreased the mass of briquette consumed, burning rate specific fuel consumption, which are indication of improved performance.

The study revealed that breadfruit shell (BFS) is a potential energy sources for heating, which can be useful to rural dwellers where there are abundant of this raw materials. Therefore, with the high challenges faced in accessing and procuring refined petroleum products for domestic heating, it advised that the locals utilize the available resources at their disposal to maximum energy potential of BFS briquettes for cooking of foods and other domestic heating requirements.

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