World Journal of Engineering Research and Technology
WJERT
www.wjert.org
SJIF Impact Factor: 4.326

WASTE TO WEALTH: CONVERSION OF SAWDUST TO USEFUL ENERGY

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Article Received on 09/10/2017 Article Revised on 30/10/2017 Article Accepted on 20/11/2017

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ABSTRACT

One of the obvious problems of developing countries is generation of insufficient energy to sustain enough economic activities that will catalyze industrial growth. Nigeria is in a serious energy crisis. Frantic efforts are being made both by the government and the private sector in order to run out of the dilemma. Researches on the alternative renewable energy sources which encompass wind, solar, biomass, hydro etc., are ongoing to compliment fossil energy. Biomass energy is harnessed from organic material wastes, such as agricultural waste, lumber scraps, forest debris, wood processing waste etc. In this work, sawdust of (Oje timber) tree sourced from Enugu east timber shade in Enugu state Nigeria was collected, sieved and carbonized at five different temperatures of 400^{o}C, 500^{o}C, 600^{o}C, 700^{o}C and 800^{o}C. The carbonized products were briquetted using cassava starch as binder. The briquettes were dried and calorific values determined in bomb calorimeter. The results showed that the Sawdust briquettes had higher calorific values than briquette from charcoal, palm kernel shell, carbonized palm kernel shell, rice bran and palm kernel shell briquette and un-carbonized sawdust. The carbonized briquette at 500^{o}C produced the highest calorific value of 6835.76cal/g (28.614MJ/kg). The briquettes will be a good source of energy for industrial heating in boilers, furnaces, ovens and also for domestic application.

KEYWORDS: Biomass, sawdust, carbonization, briquette and calorific value.

1. INTRODUCTION

Increasing dependence on a worldwide level of energy resources is that the interest for other energy sources to increase. At the present time, biomass seems to be the most affordable and cost–effective source of renewable energy. Unlike wind energy and solar, investments necessary for the exploitation of biomass are best. Modern biomass fuel technology means; process the biomass matter with a series of advanced transformation technology into the alternative fuel (solid form, liquid form, gas form), those bio–fuels are used in power generation, vehicle fuel, heating stoves, etc. [Mario, 2012]. Wood processing industries in cities and towns produce large quantities of residue in their daily production. Most of the time for the purpose of disposal, the large hips of the debris are set ablaze to burn away for several months.

A popular biomass briquette emerging in developed countries takes a waste produce such as sawdust, compresses it and then extrudes it to make a reconstituted log that can replace firewood. It is a similar process to forming a wood pellet but on a larger scale. There may or not be binders involved in this process. The natural lignin in the wood binds the particles of wood together to form a solid. Burning a wood briquette is far more efficient than burning firewood. Moisture content of a briquette can be as low as 4%, whereas green firewood may be as high as 65% [Imre et al, 2016].

The extrusion production technology of briquettes is the process of extrusion screw wastes (palm kernel shell, straw, sunflower husks, buckwheat, etc.) or finely shredded wood waste (sawdust) under high pressure when heated from 160 to 350°C. The quality of such briquettes, especially heat content, is much higher comparing with other methods like using piston presses. Sawdust briquettes have developed over time with two distinct types: those with holes through the centre, and those that are solid. Both types are classified as briquettes but are formed using different techniques. A solid briquette is manufactured using a piston press that compresses sandwiched layers of sawdust together. Briquettes with a hole are produced with a screw press. The hole is from the screw thread passing through the centre, but it also increases the surface area of the log and aids efficient combustion. Allay koay (2014).

In this work our interest is the sawdust from Oje timber or tree, collected from the sawmill timber shade in Enugu east. This sawdust was finely sieved, carbonized to remove the volatiles at different temperatures then locally briquetting the carbonized sawdust in a conical-mould with the aid of a cassava starch binder. The calorific values of the sawdust briquettes were determined to know the energy content derivable in the carbonized sawdust briquette from Oje timber.

Many researches have been done and are on-going concerning the use of biomass (sawdust, palm kernel shells and the likes), individually or as a mixed blend of fuel to improve the energy supply.

Kuti (2007) established that, the use of charred palm kernel shell (PKS) as a biomass additive in composite sawdust briquette increases the energy content of the fuel and thus can be converted to high grade solid fuel that will be suitable for both domestic and industrial applications. The results showed that the addition of PKS in various proportions increases the average calorific value when compared with the briquette produced from 100% pure sawdust material. It was also observed that the finer grade (i.e., 1.18mm) of PKS in the briquette of composite blend [70:30] had the highest calorific value of 23.57MJ/kg.

Olugbade (2015) made briquette blend of rice bran and palm kernel shell (PKS) of different grades and determined their calorific values. The results showed that irrespective of the grain sizes, the calorific value increased with increased weight of the PKS in the briquette up to a little above 30% by weight. The highest calorific value was 14.25MJ/kg.

In Chin (2013) the palm kernel shell briquettes were found to have calorific value of 19.38KJ/g, higher than the palm fibre and lignite which calorific values were 18.08 and 16.28KJ/g respectively.

Also, Ndubuisi (2016) obtained higher heating value from carbonized palm kernel shell (26541.204KJ/kg) compared with those from firewood, peat and lignin but less than bituminous and anthracite coals.

2.0 MATERIALS AND METHOD

2.1 Materials

The biomass used in this work is Sawdust from Oje tree with cassava starch as binder. The materials are readily available and locally sourced. The sawdust of (Oje timber) was collected from Enugu east timber shade in Enugu state, Nigeria. The cassava starch was sourced locally in Ogbete market in Enugu, and the equipment used in the experiment are located at the Ceramic Production department (CPD) of Projects Development institute (PRODA) Enugu

2.2 Carbonization

The sawdust were sieved, weighed and placed in the crucible and then inserted in the furnace for carbonization. The first sample of 430g of sawdust was heated to about 400^{o}C and kept at steady state to drive off all the volatiles in four and half hours (4hrs 30mins). After cooling, it was stored until needed. Similar procedure was carried out on equal 430g sample of sawdust at different temperatures of 500^{o}C, 600^{o}C, 700^{o}C and 800^{o}C respectively.

2.3 Briquetting

Carbonized sawdust and cassava root starch binder were fed in proper proportions in a ratio of 85:15 into a peddle mixer, where, they are thoroughly blended. The blended material is dropped into a conical briquetting-mold, properly rammed and allowed to air dry for seven days, reducing their moisture content to about 5%. This manual method was employed to meet the need of rural dwellers or low income earners who may not afford the expensive briquetting machines.

Table 1: Experimental data.

sample	Temperature (^{o} C)	Duration (hours)	Initial weight (g)	Carbonized weight (g)	Loss in ignition (g)	Calorific value (cal/g)	Calorific value (MJ/kg)
1	400	4.30	430	79.00	351.00	6549.13	27.414
2	500	5.50	430	66.30	363.70	6835.76	28.614
3	600	4.05	430	63.20	366.80	6630.34	27.754
4	700	3.83	430	63.10	366.90	6412.19	26.841
5	800	3.27	430	52.10	377.90	5997.41	25.105

Source: Oriaku et al 2017

3.0 RESULTS AND DISCUSSIONS

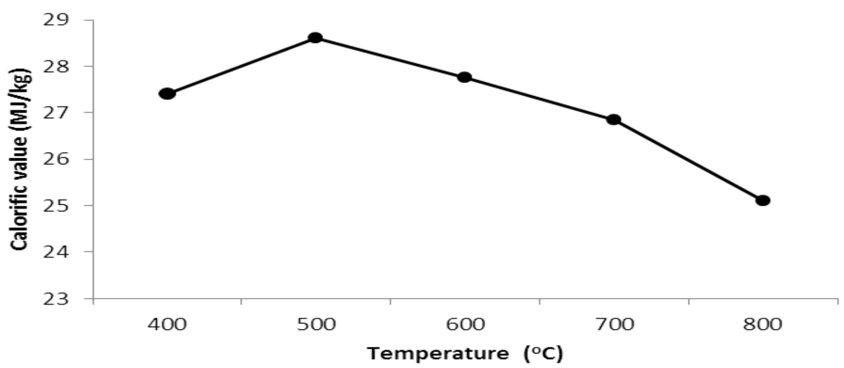

Fig 1: Calorific values of sawdust briquettes at different temperatures

Fig 1 shows that the calorific value of sawdust briquette increased as carbonizing temperature increased from 400°C to 500°C and then reduce from 500°C to 800°C. This implies that the optimum carbonization temperature of the sawdust briquette for highest calorific value is at 500°C (28.614MJ/kg), while the minimum calorific value is at 800°C (25.105MJ/kg). The decrease in calorific values as shown in the plot indicates degrading of the combustion elements in the briquettes resulting to chars.

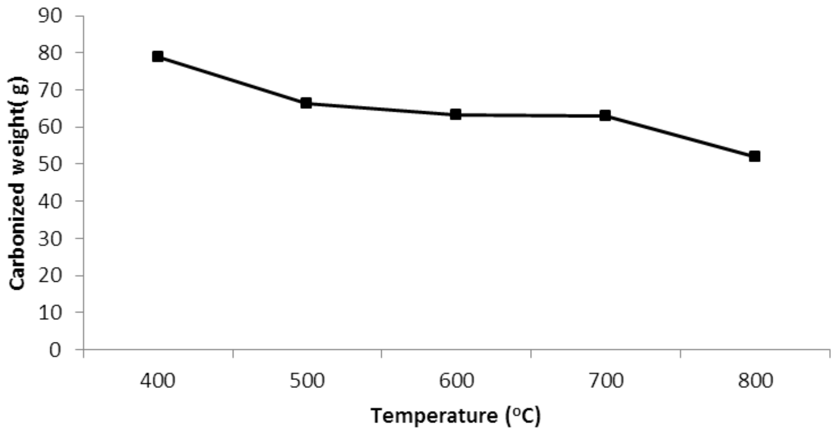

Fig 2: Carbonized weight of sawdust at different temperatures.

Fig 2 shows that the carbonized weight decreases with increase temperature. The sawdust briquettes lose more volatiles at higher temperatures, subsequently decrease in weight. From the experimental result, equal sample of 430g sawdust at minimum reduced 52.10g carbonized sawdust occurred at 800°C.

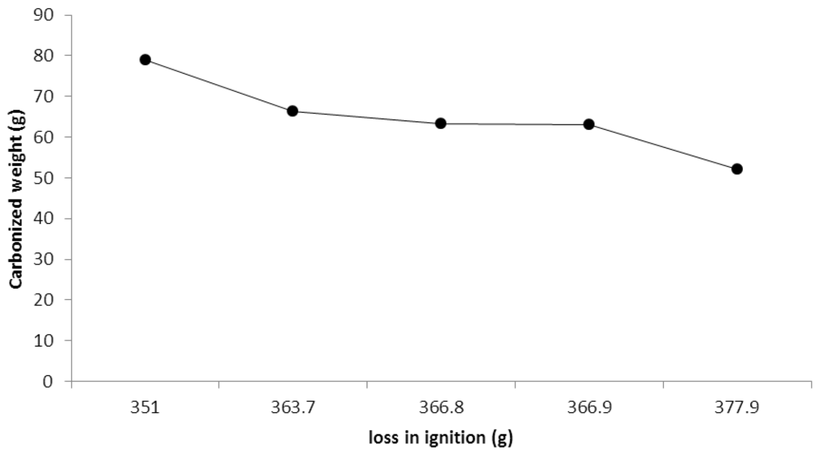

Fig 3: Carbonized weight of sawdust at different losses in ignition.

From Fig 3, the higher the loss in ignition the lesser the carbonized weight of sawdust. Thus with increasing temperature, the ignition loss increases while the carbonized weight decreases. This implies that the carbonized and loss in ignition are function of temperature.

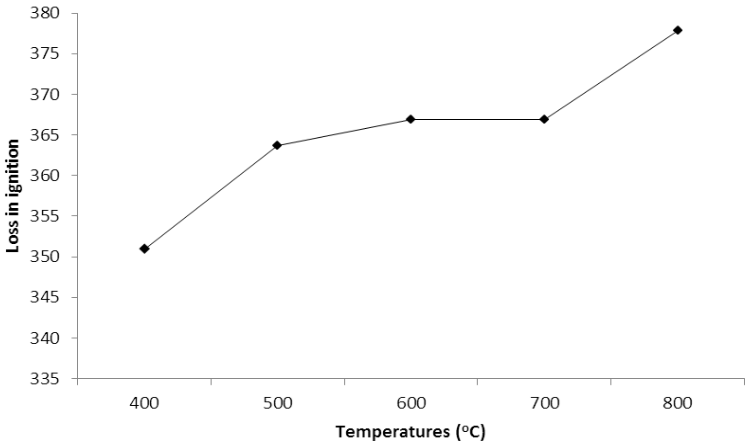

Fig 4: Loss in ignition of the sawdust at various temperatures.

Fig 4 shows the losses in ignition of the sawdust during carbonization at different temperatures. From the result, it could be seen that the loss in ignition (volatiles) increases with increasing temperatures.

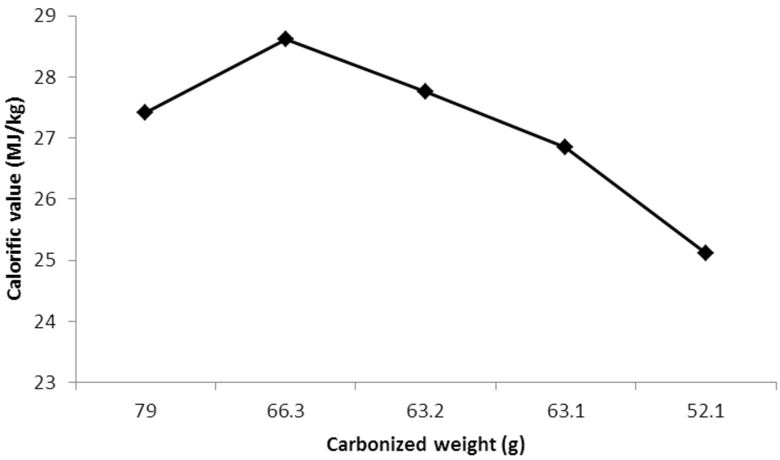

Fig 5: calorific values of sawdust briquette at various carbonized weights.

Fig 5 shows the calorific values with respect to the carbonized weights. The result indicates that the sawdust with carbonized weight of 66.3g at 500^{o}C had the highest calorific value of 28.614MJ/kg with reduced moisture content to around 5%.

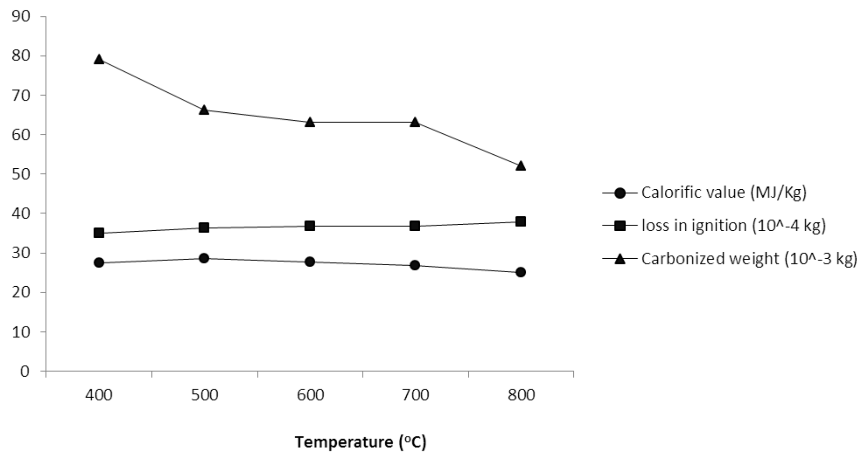

Fig 6: Sawdust Calorific value (MJ/kg), Loss in Ignition (10^{-4}kg) and Carbonized weight (10^{-3}kg) at different temperatures (^oC).

Fig 6 shows the combine plot of the sawdust's calorific values (MJ/kg), loss in ignition (10^{-4}kg) and carbonized weight (10^{-3}kg) at different temperatures (^oC). From the plot, it can be deducted that the carbonized weight of sawdust reduces with increasing temperatures due to increasing loss in ignition (volatiles), while the calorific values increases up to 500^oC then start decreasing at higher than 500^oC. It could be imply that the carbonized sawdust had reached optimum temperature at 500^oC, thus, subsequent increase in temperature results to decrease in energy content because the sawdust is becoming charred.

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3.1. COMPARISON OF CALORIFIC VALUES OF BIO-FUELS AND BRIQUETTES

The calorific values of the carbonized sawdust (Oje timber) briquette were found to be high enough as useful energy ranging from 25.105MJ/kg to 28.614MJ/kg. The values are higher compared to those reported in literatures on other bio-fuels as shown in table 2. The figure 7 shows the chart comparison of the bio-fuels and briquettes.

Table 2: **Comparison of calorific values of some bio-fuel.**

Fuel	Calorific value (MJ/kg)
Rice bran/PKS [Olugbade 2015]	14.250
Lignite [Chin et al, 2013]	16.280
Palm fibre [Chin et al, 2013]	18.080
Palm kernel shell [Ugwu et al, 2011]	18.611
Palm kernel cake [Ugwu et al, 2013; Nasrin et al, 2008]	18.838
Sawdust briquette [Ugwu et al, 2013; Nasrin et al, 2008]	18.936
Palm kernel shell briquette [Chin et al, 2013]	19.380
Palm kernel shell carbonized briquette[Ugwu et al, 2011]	23.603
Charred PKS/Sawdust briquette [Kuti, 2007]	23.570
Palm kernel shell carbonized [Ndubuisi et al 2016]	26.541
Sawdust carbonized [Oriaku et al, 2017]	28.614

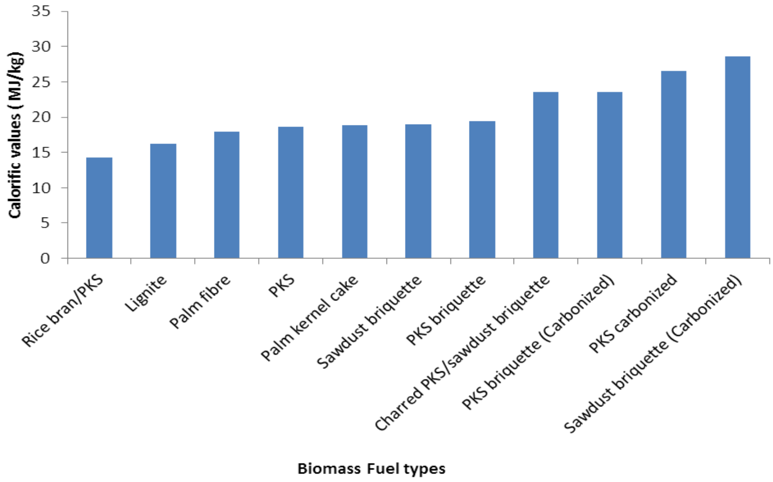

Fig 7: Comparison of biomass fuels and increasing calorific values.

3.2 ADVANTAGES OF CARBONIZED SAWDUST BRIQUETTES

- ✓ Carbonized briquettes from Sawdust are clean–burning
- ✓ Carbon–neutral
- ✓ Locally produced–a renewable resource grown in sustainable forests. That's as green as a fuel can get.
- ✓ Environmentally- possibly be the definite alternative of fossil fuel and do best to atmosphere.

APPENDIX 1

Fig 4: Raw Sawdust.

Fig 6: Sieved Sawdust.

Fig 7: Crucible.

Fig 8: Gaseous volatiles.

Fig 9: Liquid volatiles.

Fig 10: Carbonized Sawdust.

Fig 11: Sawduct briquettes (Carbonized).

Fig 12: Furnace experimental set-up (Carbonization).

Fig. 13: Furnace interior.

4.0 CONCLUSION

The sawdust briquette with cassava starch binder (85:15 ratios) had high calorific values irrespective of the weight (430g sample each). The highest calorific value is 28.614MJ/kg at 500^{o}C. It is suggested that the decrease in value of the sawdust at temperatures above 500^{o}C could be as result of degradation of the combustibles, thus, leaving us with the conclusion that the optimum temperature for high and useful calorific value from the sawdust briquette is at 500^{o}C.

Therefore, the experimental analyses carried out has revealed that the sawdust waste usually generated in uncontrolled quantities in the country when mixed with cassava starch binder can be converted into wealth, as high grade fuel (useful energy) suitable for both industrial and domestic applications. The fig 11 at the appendix shows the locally produced carbonized sawdust briquettes.

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