International Journal of Sustainability Management and Information Technologies
2019; 5(2): 35-38
http://www.sciencepublishinggroup.com/j/ijsmit
doi: 10.11648/j.ijsmit.20190502.12
ISSN: 2575-5102 (Print); ISSN: 2575-5110 (Online)

Investigation into the Combustion Related Properties of Briquettes Produced from *Triplochiton scleroxylon*, *Terminalia superba* and Afezilia *africana*

Adegoke Idowu Abimbola

Department of Forestry and Wildlife Management, Faculty of Agriculture, Federal University Gashua, Gashua, Yobe State, Nigeria

Email address:
adegokeabimbola4u@yahoo.com

To cite this article:
Adegoke Idowu Abimbola. Investigation into the Combustion Related Properties of Briquettes Produced from *Triplochiton scleroxylon*, *Terminalia superba* and *Afezilia africana*. *International Journal of Sustainability Management and Information Technologies*. Vol. 5, No. 2, 2019, pp. 35-38. doi: 10.11648/j.ijsmit.20190502.12

Received: April 19, 2019; **Accepted**: June 3, 2019; **Published**: December 25, 2019

Abstract: This study investigated the combustion related properties of briquette for energy generation. Wood briquettes were successfully produced from air-dried *sawdust of three wood species (Terminalia superba, Triplochiton scleroxylon and Afzelia africana*) that were collected from Forestry Research Institute of Nigeria (FRIN) sawmill. The briquettes were produced at 66% weight of binder to wood. Combustion related properties of the briquettes viz: heating value, water boiling test, percentage volatile matter, percentage ash content and percentage fixed carbon were determined. The results show that briquettes made from *Afezila africana* boiled waterfaster than others as the result ranged from 3:59 min:sec for *Afezila Africana* to 5.02 min:sec for *Triplochiton scleroxylon*. Briquettes produced from *Afezila africana* has the highest calorific value *of 32268.50 kcal/kg followed by Terminalia superba with 26267.16 kcal/kg while Triplochiton scleroxylon* has the least calorific value. The analysis of variance showed that there was significant difference in % fixed carbon, % ash content and the heat of combustion. The use of wood residue for briquette production should be encouraged this would provide employment for the people and reduce deforestation by optimizing efficient use of exploited trees.

Keywords: Briquette, Wood Residues, Calorific Value, CombustionProperties, Binder

1. Introduction

Renewable source of energy is the fastest-growing source of world energy, withconsumption increasing by 3.0 percent per year [1]. This is due to its environmentalfriendliness as against the rising concern about the environmental impacts of fossil fuel useand also strong government incentives for increasing renewable penetration in most countriesaround the world [1].

Forestry and agricultural operations leaves significant quantities of residues and various cuttings on land after harvesting operations, since only a fraction of the trees are removedfrom the forest as timber. However, utilizing the forest residues, mill residues, logging residues and various cuttings for briquette production will go a long way to boost domestic and industrial energy resources and to some extent reduce the pressure on the forest[2].

Wood in form of firewood, twigs and charcoal has been the major source of renewable energy in Nigeria, accounting for about 51% of the total annual energy consumption. The other sources of energy include natural gas 5.2%, hydroelectricity 3.1%, and petroleum products 41.3% [3].As further researches are conducted for a futuristic possible global energy crisis resulting from total exhaustion of fossil energy resources and global warming due to high carbon emission, decliningavailability of fuel wood and menace of desertification and deforestation drew our attention to the need to consider alternative sources of energy for industrial, domestic and cottage level industrial use. Such energy sources should be renewable and also should be accessible to low income class of society [4]

Briquette production can be achieved with or without a binder. Doing without the binder is more convenient but it requires sophisticated and expensive presses and drying equipment which makes such processes inaccessible in a developing country like Nigeria [5]. In Nigeria, large quantities of forestry and agricultural residues produced annually are vastly under-utilized. The common practice is to burn these residues or leave them in the nature to decompose [6, 7].

Conversion of wood residues to briquette is a process of binding together pulverized wood waste materials into a solid block of compressed material under pressure, often with the aid of a binder such as cassava starch. Sawdust constitutes one of the most abundant waste or residue in wood industries. It was estimated that the wood waste generated in the country in 1998 was 1.72 million m^3 out of which sawdust was 15% [8] Moreover, this is mostly burnt off in sawmills while some are used in poultry farms or in land as filling. This arouses the various interests of studies in the maximum profitability usage in which wood residue (sawdust) can be put especially in the production of briquette.

The use of briquette can reduce the demand for fuel wood and therefore decrease the pressure mounted on the forest plantation by the rural and urban dwellers. The utilization of agricultural and wood waste residues (sawdust) could have an appreciable impact in a country, which is suffering badly from fuel wood shortages [9].

It is now obvious that most of the world energy demand does not meet by a wide spread uses of fossil fuel e.g. coal, petrol, kerosene and natural gas. Alternative to the fossil fuel has been a major concern to the bio-energy scientist which is mostly dependable by people.[10] estimated depreciation in the quality and production of fossil fuel within the next twenty to thirty years in Nigeria, these recent observations on energy supply by the frequent astronomical fluctuation in the price of crude oil, which has reached an unprecedented records of over US$70 per barrel, have a native impact on the environmental conditions. This led to increase in deforestation, over-exploitation and shortage of merchantable wood species.

Briquette production is becoming a major concern to the scientists over the globe; the raw materials for the production of briquette are changing every day. This is revealed by the recent invention of using wastes from other products apart from wood waste. Briquette are now being produce from wood wastes like sawdust which are generated either at post-harvest point or after consumption, which are indiscriminately disposed thereby causing extensive pollution and menace to the environment. Briquettes material for fuel wood is creating awareness as alternative firewood in many developing countries like Nigeria, Uganda, Kenya, Niger etc. the development of briquette is due to the indiscriminate encroachment of our forest plantations. Limited information's are provided on the suitability of some wood species for the production of briquette which still pose danger to the forest plantations.

Consequently, these have led to re-emergence and testing of combustion properties of some wood wastes i.e. *Terminalia superba, Triplochiton schleroxylum* and *Afzelia africana* woodwastes like many other combustible materials are often not useable in the way they freely exist, due to their low density and sizes. There is need to compress some wood species sawdust to briquette for a social fuel product of any convenient shape that can burn like wood. Its development results in a cleaner environment and reduction in environmental pollution through the recycle of wood wastes to produce briquette, which solves the country environmental problem and improper disposition of waste [11]. Briquette as one of the bio-energy resources from wood and agricultural residues is suitable not only for domestic but also for industrial purposes. Wood briquette is usually regarded as high-grade due to its heating value. In the United State, the product is used as a special fuel for kitchen of lounge cars, buffet car ranges of western streamlined trains, automobile trailers and many intercostals vessels [12].

The introduction of briquette has revealed state of inefficiency in burning characteristics, combustion efficiency over the original material, which would improve the volumetric calorific value of a fuel. Briquette from sawdust has been for commercial production in some countries like Nigeria, Thailand, India, Sri-Lanka, Malaysia and Nepal. Availability of briquette would reduce the serious desert encroachment problem [13], which is peculiar to the northern part of the country (Nigeria) and some other developing countries like Tanzania, Niger, Liberia, Kenya, Burundi etc.

2. Methodology

Sawdust of*Triplochiton sclroxylon*(Obeche), *Terminalia superba* (Afara) and *Afezilia Africana* (Apa) were collected from the sawmill of Forestry Research Institute of Nigeria (FRIN), IbadanThe sawdust was air-dried and sieved with 2mm µm wire mesh to reduce the particle size into fine particles. Briquettes were produced in a locally fabricated molding machine using cassava starch bought from Dugbe market in Ibadan as binder. Appropriate quantity of sawdust was weighed at constant mixing proportion of 100g of starch to 150g of sawdust (weight to weight basis). The starch was prepared by stirring thoroughly the mixture of starch powder with 250ml of hot water at 102°C ± 2 to form prepared stock. The prepared starch was blended with the sawdust and introduced into the fabricated briquette molding machine and press under hydraulic jack. Four replicate were produced from each wood species. The total numbers of briquettes produced was 12 samples. The briquettes after production were air-dried for 30 days. After air-drying, the briquettes were subjected to test for calorific value of product in kcal/g; the percentage ash content of the briquette was determined by the weight of Ash divided by the original weight of sample in percentage; the percentage volatile matter was determined with 2g of pulverized sample of selected wood species which was weighed into crucible before transferred into muffle furnace at 550°C. This was left for 10minutes; the content was later cooled in dessicator and weighed to determine the percentage volatile matter with the formula below (ASTM, 1991):

$$\text{Volatile Matter (\%)} = \frac{B-C}{B} \times 100 \quad (1)$$

Where B = Weight of oven dried samples

C = Weight of sample after 10minutes in the furnace at 550°C

The percentage fixed carbon was determined as shown below:

$$\% \text{ fixed carbon} = 100 - (\%V + \%A) \quad (2)$$

Where %V = Percentage Volatile Matter

% A = Percentage Ash Content

The formula below was used to determine the calorific values of the samples in each wood species.

$$\text{Calorific Value } \left(\frac{\text{kcal}}{\text{kg}}\right) = \frac{\text{Galvanometer deflection x Calibration constant}}{\text{Weight of sample}} \quad (3)$$

The percentage ash content, volatile matter, fixed carbon and calorific value were conducted according to (ASTM, 1991) [14].The data were analyzed using SPSS-statistics tool in complete randomized design (CRD) at 5% level of significance.

Water boiling test

Water boiling test is one of the very important tests necessary in assessing combustion efficiency of briquette. A fixed mass of water (500ml) was boiled with charcoal briquette of 100g. Comparing the time taken to boil the water assessed the performance of the briquettes. The burning characteristics of briquettes are important in assessing both its performance and likely acceptance in domestic fireplaces.

3. Results and Discussion

The mean values of all the parameters assessed are presented in Table1 Briquette produced from *Afezila africana* has the highest calorific value of 32268.50 kcal/kg followed by *Terminalia superba* with26267.16 kcal/kg while *Triplochiton scleroxylon* has the least calorific value.The most important fuel property is its calorific or heat value [15].Finally the result shows that briquette produced from *Afezila afica*na is the most suitable alternative source of fuel energy for domestic and industrial application as indicated in Table 2. On the other hand, water boiling test result shown that*Afezila Africana* briquette boiled water at faster rate than others as the result ranged from 3:59 min:sec for*Afezila Africana,* to 5.02 min:sec for *Triplochiton scleroxylon* as revealed in Table 3.

Volatile matters are gases released during combustion. These gases include CO_2, CH_4, and SO_2 etc. The mean result of the percentage volatile matter from Table 1 revealed *Afezila africana* with the highest mean value of 76.25% followed by *Triplochiton scleroxylon*with 76.00% and the least mean value was recorded for *Terminalia superba* and the result of the analysis of variance is presented in Table 5. However, the percentage ash content ranged from 1.93% to 2.98% for *Terminalia superba* with least mean percentage ash content which is a good combustion characteristic and *Triplochiton scleroxylon* respectively. Table 4 showed the ANOVA conducted on the percentage ash content at 0.05 level of significance and the result revealed that there is significant difference between briquettes produced from different wood species.

The Anova Table for percentage fixed carbon (%) for briquette produced is presented in Table 5. The result from the analysis shows that there is significant difference between briquettes produced from different wood species. Meanwhile the Descriptive statistical table shows the different mean in the briquette produced. The result of Duncan follow up test revealed that *Triplochiton scleroxylon* has the highest percentage mean value followed by *Afezila africana* while *Terminalia superba* has the least percentage mean value. All the parameters assessed are significantly different.

Table 1. *The mean values of all the parameters assessed.*

Wood species	% Ash Content	% Volatile Matter	% Fixed Carbon
Terminalia	1.93	62.25	15.78
Afezila	2.70	76.25	19.60
Triplochiton	2.98	76.00	21.55

Each value is an average of 4replicates.

Table 2. *The result of the calorific values for briquette produced.*

Wood Species	Heating Value (Kcal/Kg)
Terminalia superb	26267.16
Afezila Africana	32268.50
Triplochiton scleroxylon	7398.49

Each value is an average of 4replicates.

Table 3. *Anova Table for Calorific Value (Kcal/Kg) for Briquette Produced.*

Source of Variation	Sum of Squares	Df	Mean Square	F	Sig.
Treatment	1.902	2	.951	5.602	0.26
Error	1.527	9	.170		
Total	3.429	11			

Table 4. *The result of the water boiling test conducted.*

Wood species	Time (Min/Sec)
Terminalia superba	4:38
Afezila Africana	3:59
Triplochiton scleroxylon	5:02

Each value is an average of 4replicates.

Table 5. *The result of analysis of variance (ANOVA) for Percentage Volatile Matter(%) for Briquette Produced.*

Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Treatment	513.500	2	256.750	41.635	.000
Error	55.500	9	6.167		
Total	569.000	11			

4. Conclusion

The briquettes produced from (*Terminalia superba, Afezilia africana* and *Triplochiton scleroxylon*) have good handling property which implied that it could be transported over a long distance without disintegrating; this means that the right proportion of starch was used to the right proportion of sawdust. Based on the result of analysis conducted, briquette produced from *Afezilia africana* has the highest calorific value compared to *Terminalia superba*and *Triplochiton scleroxylon*.

5. Recommendations

Sequel to the observations from the result, briquette should be produced using *Afezilia Africana* because of its high heating value. There is need for aggressive publicity and awareness by government, non-governmental organizations and individuals to encourage the use and production of briquette samples. This bio-energy technology would also provide employment; reduce deforestation as a result over-reliance on timber for fuel wood and also reduce quantity of wood waste going into landfill.

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