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Use of Composite Biomass Briquettes as Cleaner Energy Source

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ABSTRACT:*The demand for energy is becoming a critical challenge for the world as the population continues to grow. This calls for sustainable energy production and supply such as renewable energy technologies. Renewable energy technologies are safe sources of energy that have a much lower environmental impact than conventional energy technologies. In Nigeria biomass is the most dominant source of energy and is used significantly in the domestic sector notably charcoal and wood fuel in an unsafe state which generates CO and* CO_2 *emissions. This paper presents the results of a project focused on the development of sawdust briquettes, Palm Kernel Shell Powder briquettes, and composite biomass briquette. These sawdust and palm kernel shell powder currently lacks useful applications, and its indiscriminate burning generates CO and* CO_2 *emissions. Through a drying and compression process, 100% sawdust briquettes, 100% palm kernel shell powder briquettes and composite biomass briquettes of 85:15, 75:25, 65:35 and 55:45 mixing ratios were produced with the following features: compressed density range from 0.5932 g/cm*^{3} *to 0.8342g/cm*^{3} *as the mixing ratio varies, heating value range from 27.60MJKg*$^{-1}$ *to 33.04MJkg*$^{-1}$*, fixed carbon content for 100% Palm Kernel Shell Powder briquette was 19.10%, and minimum ash content of 1.56% at 53:65 mixing ratio. From the obtained results it was concluded that the heating values for all the various briquettes produced were sufficient to produce heat required for household cooking and small-scale industrial cottage applications.*

KEYWORDS: *Biomass, Briquette, Clean Energy, Sawdust, PKSP*

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I. INTRODUCTION

As the population of the world continues to grow, the demand for energy is becoming critical challenge for the world's energy leaders [1]. Global energy consumption has about doubled in the last three decades of the past century. In 2004, about 77.8% of the primary energy consumption was from fossil fuels (32.8% oil, 21.1% natural gas, 24.1% coal), 5.4% from nuclear fuels, 16.5% from renewable resources, of which the main one was hydro (5.5%) whereas the remaining 11% consisted of non-commercial biomasses such as wood, hay, and other types of fodder, that in rural-economies still constitute the main resource [2]. With improvements in energy efficiency it is expected that global energy demand doubles by 2050. This is the consequence of global population growth, global economic growth, continued urbanization, as well as the resulting increased demand on mobility and other energy dependent services [3].

A briquette is a block of compressed combustible energy carrier suitable for heating. Briquettes are made from waste materials such as old newspaper, sawmill wastes or partially compressed biomass waste. They are largely used as fuel instead of charcoal, firewood or coal. The burning of briquettes depends on the materials used for making them. Briquettes are largely combustible materials made from loose or low-density wastes but compressed together into a solid. The compression leads to a product of higher bulk density, uniform size and shape [4]. Briquetting is defined as the densification (agglomeration) of an aggregate of loose particles into a rigid monolith [5]. A briquette can thus be defined as a product formed from the physio-mechanical conversion of dry, loose and tiny particle size material with or without the addition of an additive into a solid state characterized by a regular shape [6].

In most Nigerian rural communities, forest resources are the predominant fuel source. The trees are felled, allowed to dry and the different parts of the dried plants are used as firewood. Another way that people use to generate heat and light is by converting wood to charcoal. Other plants, apart from trees, are also used as fuel sources. The problem of felling trees for the purpose of using it as fuel source is that it impacts adversely on the environment. One way of limiting the deforestation and protecting the environment is by briquetting of flammable materials. The common forms of briquettes are the coal briquettes and the biomass briquettes. Biomass briquettes originate from mostly agricultural residues which also includes the charcoal briquettes. By converting the agricultural residues to briquettes, a gamut of advantages is derivable. These include:

- Briquettes provide an easier way of getting energy supply for cooking and ironing of clothes as the briquettes can be transported easily than the agricultural residues
- Briquettes provide cleaner emission than wood and other dried plants usually used for obtaining rural energy supply
- The raw material for making briquettes are sourced from materials that would have been chunked, and as such it converts waste to energy
- Briquettes can be used in stoves and boilers
- Briquetting increases strength, density, heat emitted per volume of the biomass [7]

In this study, the materials of interest are Palm Kernel Shell Powder (PKSP) and Sawdust (SD). The Palm kernel shells Powder and Sawdust were converted into briquettes by adopting very simple process, utilizing readily available and affordable materials. The objectives of this research work are to develop a composite biomass briquettes that can produced useful energy source for low income earners, determine the physical and combustion properties of the produced briquette and thus finding useful application of the vast deposit of biomass waste in the country. The produced biomass briquettes were tested for their combustion and physical characteristics.

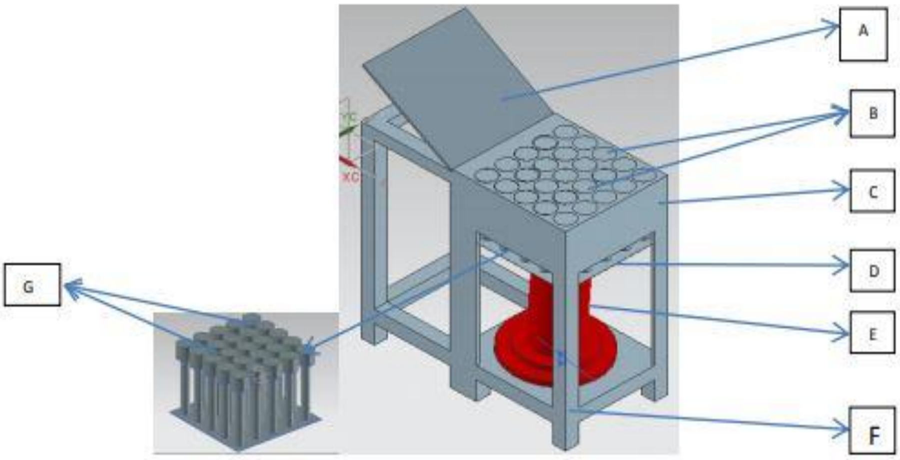
II. MATERIALS AND METHODS

For the purpose of the study, biomass composite of Sawdust and Palm Kernel Shell Powder were used. The sawdust sample was collected from a saw mill in Amu Market, Mushin, Lagos State, South-Western Nigeria, the palm kernel was gotten from Edo State, Southern part of Nigeria. Cassava starch was procured from a local market and used as a binding agent mainly to overcome the major problem of material compaction – post-compaction recovery - which represents enormous waste in energy input [8].

2.1 The Briquetting Machine

A manually operated biomass briquetting machine was used for the production of the composite biomass briquette (Figure 1). A flat metal plate (A), 12mm thick, was hinged to the mould box to cover the open ends of the moulds during compaction and opened during ejection of the briquettes. The briquetting machine consist of 25 moulds (B) each with an internal diameter of 70mm and a depth of 190.5mm welded to a 6mm flat mild steel plate (C) at the top and bottom (D) and positioned vertically over equal number of pistons. The vertical motion of the pistons in the moulds and the ejection of compressed briquettes from the moulds was by manual operation of the 20-Ton hydraulic jack (E). The hydraulic jack rests on angle bars welded to the frame (F) of the machine. The pistons (G) were made such that there was a clearance of about 2mm between the piston head and the mould walls to allow the escape of water during compaction. The opposite ends of the rods were welded on a flat metal plate of 12mm thickness which rests on a 20-ton capacity hydraulic jack. The jack drives the pistons in and out of the moulds during operation. By this arrangement, the force from the hydraulic jack was centrally applied to the metal plate bearing the pistons. The machine was fabricated using mild steel and angle bars. Below is the 3D view of the machine.

Figure 1*: *Biomass Briquetting Machine



2.2 Production of Biomass Briquettes

Sawdust (SD) and Palm Kernel Shell Powder (PKSP) samples were mixed in different mixing ratios of 85:15, 75:25, 65:35 and 55:45 of PKSP to Sawdust respectively and 100% of both Sawdust and Palm Kernel Shell Powder, the mixture was mixed with an already prepared cassava starch in a constant mixed ratio of 25% by weight were produced. The starch and the composite biomass samples were well mixed without forming a mixture with high moisture content because the formation of a mixture with higher moisture content due to excess addition of water reduces both the durability and density of the briquette [9]. The biomass-binder mixture was hand fed into the moulds and compacted to form the briquettes after which they were sun dried to constant weight. The produced composite biomass briquettes are shown in the figures below

***Figure 2:* Briquette Ejection Stage**

***Figure 3:* Samples of the Produced Composite Biomass Briquettes**

2. 3 Performance Evaluation

Briquette samples from the produced composite biomass briquettes were selected for the performance evaluation. On ejection of the briquettes from the moulds, the mass and the dimensions of the briquettes were taken to determine the density in g/cm^3 using an electronic weighing balance and a calliper. The compressed density, relaxed density, relaxation ratio and dimensional stability of the produced briquettes were determined in accordance with the methods described by [10].

2.4 Physical Properties Determination

The bulk density of the loose biomass sample was determined by weighing an empty cylindrical container of known volume and mass, and then carefully filled with the biomass sample. After filling every one-quarter portion of the container with the sample, it was tapped on a table for some number of times to allow the material to settle down. After completely filling the container, excess material at the top was removed by moving a straight edge over the 32 the container. The mass of the containing sample was determined. The compressed density (density immediately after compression) of the briquette was determined immediately after ejection from the moulds as the ratio of measured weight to the calculated volume. The relaxed density (density determined when dried) and relaxation ratio (ratio of compressed density to relaxed density) of the briquette were determined in the dry condition of the briquette after 8 days of sun drying to a constant weight at an ambient temperature. The relaxed density was calculated as the ratio of the briquette weight (g) to the new volume (cm^3). This gives an indication of the relative stability of the briquette after compression. The compaction ratio was obtained from the ratio of the maximum density and the initial density of the biomass [3]. Briquette stability was measured in terms of its dimensional changes when exposed to the atmosphere. The dimensional stability of the briquette was determined by measuring the height at an interval of 0, 30, 60, 1440, 2880, 4320, 5760, 7200, 8640 and 10,080 minutes [11]. Durability represents the measure of shear and impact forces a briquette could withstand during handling, storage and transportation processes [12]. The durability of the briquette was determined in accordance with the chartered index described by [13] after sun drying to a constant weight. The briquette was dropped repeatedly from a height of 1.5m onto a metal base. The fraction of the briquette that remained unshattered was used as an index of briquette durability [14, 15]. The durability rating of the briquette was expressed as a percentage of the initial mass of the material remaining on the metal plate and this gave an indication of the ability of the briquette to withstand mechanical handling. Water resistance of the briquette was tested by immersing the briquette in a container filled with cold tap water and measuring the time required for the onset of dissolving in water. The higher the water resistance time, the more stable the briquette is in terms of weathering resistance [16].

2.5 Combustion Properties Determination

Proximate analysis was carried out to determine the percentage volatile matter, fixed carbon and ash content of the produced composite biomass briquettes. The proximate analysis was determined based on ASTM Standard [17]. For the percentage volatile matter, 1g of the produced composite biomass briquette was placed in a crucible of known weight and oven dried to a constant weight after which it was heated in a furnace (Isotemp Muffle Furnace Model 186A – Fisher Scientific) at a temperature of 600^oC for 10 minutes. The percentage volatile matter was then expressed as the percentage of loss in weight to the oven dried weight of the original sample. The percentage of ash content followed the same procedure as the volatile matter except that the sample was heated in the furnace for 3 hours. The ash content obtained after cooling in a desiccator was then expressed as a percentage of the original sample [18]. The percentage of fixed carbon was calculated using the equation below:

$$\%\,Fixed\ Carbon\ Content = 100 - (\%\,Volatile\ Matter + \%\,Ash\ Content) \qquad 1$$

The heating value for the sawdust briquette produced was calculated using the Gouthal formula:

$$H_v = 2.326(147.6C + 144V) \qquad 2$$

Where,
H_v is the heating value ($MJkg^{-1}$)
C is the percentage fixed carbon
V is the percentage volatile matter [19].

2.6 Combustion Analysis

The combustion tests were carried out using boiling water test, which is the normal materials in every household. An open-air stove was used for the boiling water test. A known quantity of water (1L) was measured into a cooking pot whose weight had been noted. Some lumps of the briquettes were placed on the cooking stove after they were weighed. The briquettes were sprinkled with about 2mL of kerosene for ignition. After 5 minutes, the briquettes had ignited and the kerosene had burnt out, the pot of water was placed on the stove. This was after the initial temperature of 303K of the water had been noted. The temperature of the water was noted at intervals of five minutes until the water boiled at 363K. The weight of the evaporated water was calculated from the difference between the final weight of water after cooling and the initial weight of water in the pot. The weight of the fuel burnt was calculated from the difference in the initial weight of briquettes put on the stove and the final weight after the water had boiled [20]. This procedure was repeated for each mixed ratio of the produced biomass briquettes.

III. RESULTS AND DISCUSSION

The physical properties of the biomass briquette are shown in Table 1. The influence of composite biomass was significant on the physical properties of the briquettes. The compressed density of the composite biomass briquette ranged from 0.5932 to 0.8342g/cm^3 as the mixing ratio varies. The maximum compressed density of 0.8342g/cm^3 was achieved with the 100% briquette sample of PKSP this was as a result of the finer particle size of the PKSP briquette which resulted in better compaction density when compared to the least compressed density of 0.5932g/cm^3 which was as a result of the coarse particle size of the Sawdust briquette. The compressed density of the composite biomass briquette varies base on the percentage of Sawdust in the Palm Kernel Shell Powder.

A direct relationship was observed between the compressed density and the relaxation ratio: the higher the compressed density, the higher the relaxation ratio. This shows that the sawdust briquettes, Palm Kernel Shell Powder briquettes and the composite biomass briquettes became more unstable with increasing compressed density. The durability rating of the briquettes ranged from 37.75% to 92.99%. The durability rating was observed to vary directly with the compressed density. A durability rating of 92.99% was recorded for 100% Palm Kernel Shell Powder briquette while 37.75% was recorded for the briquette with 15:85 of Sawdust to PKSP composite biomass briquette having the least compressed density. This shows that the durability of the briquettes is dependent on the compressed density. The resistance of the briquette to weathering effect measured in terms of the length of time it takes just for the onset of dispersion in water was observed to vary directly with the compressed density and the durability rating of the briquette.

Table 1: Physical Properties of Biomass Briquettes

Mixed Ratio (SD:PKSP)	Compressed Density (g/cm^3)	Relaxed Density (g/cm^3)	Relaxation Ratio	Compaction Ratio	Durability Rating (%)	Water Resistance Test (hrs.)
0:100	0.8342	0.3195	2.6110	3.2959	92.99	8.02
15:85	0.6125	0.2663	2.3002	2.4199	37.75	4.33
25:75	0.7269	0.2518	2.8873	2.8721	91.43	7.86
35:65	0.7028	0.2878	2.4422	2.7768	87.52	6.02
45:55	0.6822	0.2756	2.4749	2.6952	76.71	5.27
100:0	0.5932	0.2134	2.7798	2.3437	79.35	5.89

The physical behavior of the produced briquettes is shown in Table 2. It was observed that all the samples produced shows good physical characteristics after drying. The 100% Palm Kernel Shell Powder briquettes and 35:85 composite biomass briquettes have initial poor handling properties within 24hrs of production but these properties were greatly improved as it is cure further.

Table 2: Physical behaviour (characteristic) of the composite biomass briquettes

Mixed Ratio (SD:PKSP)	Mean initial mass g	Mean initial height cm	Initial handling property after production	Mean final mass g	Mean final height cm	Final handling property After drying
0:100	758.72	13.76	Break easily the first 24 hours	162.58	13.78	Strong and easy to handle
15:85	582.56	13.32	Very easy to handle	350.12	13.32	Very strong and easy to handle
25:75	565.22	13.4	Very easy to handle	334.28	13.48	Very strong and easy to handle
35:65	579.02	12.58	A little difficult to handle	318.94	13.06	Very strong and easy to handle
45:55	678.5	14.46	Easy to handle	363.26	14.2	Very strong and easy to handle
100:0	833.52	14.66	Slightly strong after 1 hour	167.12	15.2	Strong and easy to handle

The combustion properties of the sawdust briquette, palm Kernel Shell Powder briquette and composite biomass briquettes that was produced are shown in Table 3. The different mixing ratio had a significant effect on the combustion properties of the briquettes. The volatile matter recorded ranged from 62.82% to 90.63%. The lowest volatile matter content was recorded at 100% Palm Kernel Shell Powder briquette and this increases as the ratio of Sawdust increases in the mixed ratio. The ash content ranged from 0.56% to 19.21%. Ash content in briquettes normally causes increase in combustion remnant in the form of ash which lowers the heating value of briquettes; the lowest value was recorded at 100% Sawdust briquette. The calculated fixed carbon was highest at 100% Palm Kernel Shell Powder briquette with a value of 19.10%.

Table 3: Combustion Properties of Biomass Briquettes

Mixed Ratio (SD:PKSP)	Volatile Matter (%)	Ash Content (%)	Fixed Carbon (%)	Heating Value (MJKg^{-1})
0:100	62.82	11.75	19.10	27.60
15:85	77.95	11.66	10.39	29.68
25:75	74.08	12.21	13.71	29.52
35:65	90.63	1.56	7.81	33.04
45:55	79.35	13.05	7.61	29.19
100:0	76.23	1.49	14.04	30.35

The heating value is the most important combustion property for determining the suitability of a material as fuel. It gives the indication of the quantity of fuel required to generate a specific amount of energy. The heating value ranged from 27.60MJKg^{-1} to 33.04MJkg^{-1}. The highest value was recorded at the 35:65 mixing ratio of the composite biomass briquette and this could be due to the low ash content of 1.56%; and they were all significantly different from one another (Table 3). The low heating value at the 100% Palm Kernel Shell Powder. The range of heating value of 33.04MJKg^{-1} to 33.04MJKg^{-1} has obtained in this research work, was found to be higher than 18.89 MJkg^{-1} obtained in banana peel briquette [21] and 14.1 MJkg^{-1} obtained in maize cob briquette [22], 24MJKg^{-1} to 27MJkg^{-1} for lignite with bio-binder [23], and 12.60MJkg^{-1} for groundnut shell briquette [24]. This makes the 100% sawdust briquette; 100% Palm Kernel Shell Powder Briquette and composite biomass briquette a good potential fuel for domestic cooking. In the production of the sawdust briquette, Palm Kernel Shell Powder Briquette and composite biomass briquette; 1500cm^3 of water per kilogram was used in producing a good biomass-binder mix for briquetting.

The result obtained from the water boiling test is shown in Table 4. Although the briquettes did not ignite readily only a little quantity of kerosene was required. The initial little smoke observed during the combustion of the briquette probably may not be unconnected with the binder since the charcoal fines produced burnt without smoke.

Table 4: Water Boiling Test on the Produced Briquettes

Test	Data
Total weight of briquettes at the start of test	209.7g
Total number of briquettes at the start of test	6
Average weight of each briquette	34.95g
Total weight of Briquettes after water boil	104.3g
Initial weight of water in the pot	100g
Final weight of water after boil	70g
Physical appearance of the briquettes	The colour was brownish. It was firm at hand and took the cylindrical shape of the mould.
Compressed Density of the briquette	0.5932 to 0.8342g/cm^3
Heating value	27.60MJKg^{-1} to 33.04MJkg^{-1}
Moisture content	6.67%
Ignition	The kerosene burnt out in 5 minutes and the briquettes lumps turned reddish with a blue flame.
Smoke	It burnt with very low level of smoke. It was not confirmed whether the smoke emanated from the starch used as a binder or not
Odour	There was no odour from the combustion
Spark	The briquettes burned with no sparks.
Cleanliness	The cooking pot remained very neat all through the cooking period
Percentage Heat Utilized (P.H.U)	3.2%
Power Output (P)	1.26kW
Specific Fuel Consumption	0.7kg
Burning Rate	3.2g/min

Figure 4: *Blue Flame While Burning the Biomass Briquettes*

IV. CONCLUSION

This paper has brought out synergistic views on biomass and briquetting as a hybrid application on waste to heat generation for clean energy in developing countries by addressing the issues of utilizing the abundant quantities of agricultural wastes and residues which provide an enormous untapped fuel resource. With compressed density range from 0.5932 g/cm^3 to 0.8342g/cm^3, heating value range from 27.60MJKg^{-1} to 33.04MJkg^{-1}, fixed carbon content of 19.10%, and ash content of 1.56%; the produced briquettes are of better quality compare to other biomass briquettes () and are suitable in domestic applications such as cooking, heating, ironing etc., and small-scale industrial cottage applications. The materials and methods used can be adopted easily at the local communities as it does not require any special training. With proper energy conversion techniques such as Fluidized Bed Combustor (FBC) it can find useful application in power generation of up to 10-30MWh

REFERENCES

[1]. Christoph Frei et al. World energy council, (2013), world energy issues monitor report. Page 2

[2]. BP-Amoco, (2005). Statistical Review of World Energy

[3]. Oladeji1, J. T. and Enweremadu, C. C. (2012). The Effects of Some Processing Parameters on Physical and Densification Characteristics of Corncob Briquettes. International Journal of Energy Engineering, 2(1): 22-27.

[4]. Obi, O. F., Akubuo, C. O., Okonkwo, W. I., (2013), Development of an Appropriate Briquetting Machine for Use in Rural Communities, International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-2, Issue-4, April 2013

[5]. Mordi, F. A (2007), Production of Saw Dust/Charcoal Briquette for Export (www.groundreport.com).

[6]. Osarenmwinda J. O and Imoebe S (2006): Improved Sawdust Briquette: An Alternative Source of Fuel, Advanced Material Research. 62-64 :769- 773

[7]. Bindir, U.B (2009) Technology Acquisition and Promotion in the Power Sector, paper presented at the International Workshop on Promotion of Coal for Power Generation at Enugu in April, 2009.

[8]. Faborode, M. O. (1998). Rural Domestic and Agro-Industrial Energy from Biofuels. Proceedings of the CIGR Inter-Sections Symposium. National Center for Agricultural Mechanization, Ilorin, Nigeria, pp. 129 – 140.

[9]. Mohamed, F. M., Ahmed, Y. M. Z. and Shalabi, M. E. H. (2004). Effect of Organic Binders on the Quality of Manganese Ore Sinter Fines Briquettes. TESCE, Vol. 30, No.2, pp. 871 – 889

[10]. A.Olorunnisola (2007). “Production of Fuel Briquettes from Waste Paper and Coconut Husk Admixtures”. Agricultural Engineering International: the CIGR E-journal. Manuscript EE 06 006. Vol. IX. February, 2005.

[11]. Sotannde, O. A., Oluyege, A. O. and Abah, G. B. (2010). Physical and Combustion Properties of Briquettes from Sawdust of Azadirachta indica. Journal of Forestry Research, 21(1): 63 – 67.

[12]. Adapa, P., Tabil, L. and Schoenau, G. (2009). Compaction Characteristics of Barley, Canola, Oat and Wheat Straw, Biosystems Engineering (1 - 10).

[13]. Suparin, C., Suwit, S. and Prattana, K. (2008). Development of Fuel Briquettes from Biomass-Lignite Blends. Chiang. Mai. J. Sci., 35(1): 43 – 50.

[14]. Sah, P., Singh, B. and Agrawal, U. (1980). Compaction Behavior of Straw. Journal of Agricultural Engineering-India, 18(1), pp. 89 - 96.

[15]. Khankari, K. K., Shrivastava, M. and Morey, R. V. (1989). Densification Characteristics of Rice Husk. ASAE Paper No. 89-6093. St. Joseph, MI: ASABE.

[16]. Richards, S. R. (1990). Physical Testing of Fuel Briquettes, Fuel Processing Technology, 25: 89 - 100.

[17]. ASTM Standard E711-87 (2004). Standard Test Method for Gross Calorific Value of Refuse Derived Fuel by the Bomb Calorimeter. Annual Book of ASTM Standards, 11.04. ASTM International.

[18]. Yahaya B. S., and Adeleke A. A., Froth Flotation Upgrading of a Low Grade Coal, Pet Coal. 2014; 56 (1): 29-34.

[19]. Bailey, R.T. and Blankenhorn, P. R. (1982). Calorific and Porosity Development in Carbonized Wood. Wood Science, 15(1): 19 – 28.

[20]. Kuti, O.A (2009): Performance of Composite Sawdust Briquette fuel in a Biomass Stove under simulated condition. AU J.T. 12 (4) pp 284-288.

[21]. Wilaipon, P. (2008). Density Equation of Bio-coal Briquettes and Quantity of Maize Cob in Phitsanulok, Thailand. Am. J. App. Sci., 5(12): 1808−1811.

[22]. Wilaipon, P. (2007). Physical Characteristics of Maize Cob Briquette under Moderate Die Pressure. Am. J. Appl. Sci., 4, 995- 998.

[23]. Ivanov, I. P., Sudakova, I. G., and Kuznetsovv, B. (2003). Manufacture of Briquetted and Granulated Fuels from Lignite with Bio-Binders and Heated Die. Chem. Sustai. Devel., 11, 847 - 852.

[24]. Musa, N. A. (2007). Comparative Fuel Characterization of Rice Husk and Groundnut Shell Briquettes. NJRED. 6(4): 245-262

Yahaya Babatunde S, et. al. "Use of Composite Biomass Briquettes as Cleaner Energy Source.” *American Journal of Engineering Research (AJER)*, vol. 9(10), 2020, pp. 12-18.