INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH AND ANALYSIS

ISSN(print): 2643-9840, ISSN(online): 2643-9875

Volume 07 Issue 07 July 2024

DOI: 10.47191/ijmra/v7-i07-12, Impact Factor: 8.22

Page No. 3150-3158

Characterization of Fuel Pellets Made From Rice Husk, Sawdust and Corncob Bond with *Cissus Populnea* and *Manihot Esculenta*

Comfort Akwonya Adadu[1], Dominic David Ekpo[2], Ekom Enefiok Okpo[3]

[1]Mechanical Engineering Department, Benue State University, Makurdi, Nigeria

[2]Mechanical Engineering Department, Akwa Ibom State University, Ikot Akaden, Nigeria

[3]Electrical and Electronic Engineering Department, Akwa Ibom State University, Ikot Akaden, Nigeria

ABSTRACT: There is growing interest in the production of biofuels from biomass wastes. The availability of biomass waste poses the need for technical assessment of pelletisation of biomass waste at industrial production level. The misuse of environmentally friendly and sustainable energy resources and lack of compressed biomass energy products that could enhance fuel quality needs to be addressed. This study intends to determine the energy output from tenary combination of the biomass fuel pellets consisting of rice husks, African birch sawdust, corncobs and their varying mixtures bond with aqueous extract of C. populnea (Cp) and M. esculenta (Me). The combustion characteristics of pellets produced from Rice Husk, African Birch Sawdust, Corncob and their blends (M, M1, M2, M3 and M4) were conducted by the development of an analytical protocol. Pellet admixtures were prepared at each binder ratio of 10% of bulk weight of RH, ABS, corncob and their various blends in the ratios 1:1:1 (M), 1:2:3 (M1), 2:1:3 (M2), 3:1:2 (M3) and 2:3:1 (M4), respectively. The Bulk Density (BD), Ash Contents (AC), Heat Release Rate (HRR) and Calorific Value (CV) of the pellets were measured using established procedures. The result revealed that combustion characteristics of fuel pellets made from Corncob and Blend ratio of 1:2:3 bound with Manihot esculenta gel were enhanced and the fuel pellets possessed sufficient calorific values suitable for energy applications. It was recommended that massive production of fuel pellets from biomass wastes for small and medium scale energy systems could give a positive development to agrarian and rural areas in Nigeria where there is a lot of these resources and lack of stable electrical supply.

KEYWORDS: Sawdust, Rice husk, Pelletisation, Biomass waste, Industrial waste

I. INTRODUCTION

Biomass refers to organic materials from plants and animals. Biomass is a renewable energy resource of high importance which is characterized as fuel of organic origin (Warajanont and Soponpongpipat, 2013). The materials include dedicated energy crops, aquatic vegetation, municipal wastes of organic type and agricultural crops and their residues such as crop residues and mill wastes, forestry trees and their wastes (Agbro and Ogie, 2012). The total standing biomass (including above ground and below ground) in Indian forests for the year 1992–93 was estimated using information on state and union-territory field inventory based growing stock volume and the corresponding area under three different crown density classes (very dense forests with crown cover 70 percent and above, dense forest with crown cover 40 percent but <70 percent and open forests with crown cover between 10 and 40 percent) grouped under four major forest categories (hardwood, spruce-fir, pine and bamboo) by Forest Survey of India (Chhabra et al., 2002).

Wastes is any item that is discarded or required to be disposed (Tumuluru and Wright, 2010). European Union classified wastes as gaseous, liquid, or solid (Okpo, et al 2021). Solid organic wastes referred to as biomass wastes are not free flowing unlike gaseous and liquid wastes. Main steps used in the management of Biomass wastes are the generation, transfer and discharging processes (Olatunbosun, et al 2014) (Udoh, et al., 2024). A one-year survey was conducted in the greater region of Crete (located at the lower region of the Aegean Sea) for the purpose of identifying waste composition (including chemical and physical characterization), as well as any seasonal variation. The results show that there has been a significant decrease of organic wastes during the last decade due to the increase of packaging materials, as a result of a change in consumption patterns. Three main waste categories were determined: organic wastes, paper and plastics, which combined represent 76% of the total waste in Crete (Gidarakos et al., 2006) (Ekpe et al., 2024).

Wastes can now be used in any of these four ways, which include recycling, landfilling, composting and densified waste-to-energy fuel products for example, briquettes and pellets. Oloronisola (2007), investigated the properties of fuel briquettes produced from a mixture of shredded waste paper and hammer milled coconut husk particles (Ekpo, et al., 2012). The briquettes were manufactured using a manually-operated closed –end die piston press at an average pressure of 1.2 x 103 N/m2 using four coconut husks: waste paper mixing ratios (by weight), that is, 0:100; 5: 95; 15: 85; and 25: 75. Results obtained showed that briquettes produced using 100% waste paper and 5:95 waste paper-coconut husk ratios respectively exhibited the largest (though minimal) linear expansion on drying (Diji, et al., 2013). there was no clearly discernible pattern in e.m.c variation with increase in coconut husk content. The mean durability rating of all the briquettes exceeded 95%. It was concluded that stable briquettes could be formed from waste paper mixed with coconut husk particles. Critical to the financial success of producing bio fuel is identifying the optimal location for the facility. Zhang et al. (2011) applied the methodology to the Upper Peninsula of Michigan to locate a biofuel production facility (Ekpo, 2012).

The selection of agro-wastes for production of briquettes for domestic and industrial cottage applications depends on the fuel properties. Investigations were carried out on properties of briquettes produced from corncob and rice husk residues with a view to finding out which of the two residues examined can be used more efficiently and rationally as fuel (Dickson et al., 2023). Ultimate and proximate analyses were carried out to determine the average composition of their constituents (Okoro, et al., 2022). A simple prototype briquetting machine was fabricated to facilitate densification of these residues into briquettes (Dickson, et al., 2024). The results of this work indicate that briquettes produced from these two residues would make good biomass fuels (Ekpo, 2019). However, findings show that corncob briquette has more positive attributes of biomass fuel than rice husk briquette (Diji, et al., 2013). This study intends to determine the energy output from tenary combination of the biomass fuel pellets consisting of rice husks, African birch sawdust, corncobs and their varying mixtures bound with aqueous extract of C. populnea (Cp) and M. esculenta (Me) (Bassey, et al., 2024).

II. METHODOLOGY

The methodology is divided into two (2) stages, material selection and spot sampling stage and pellets formulation and characterisation stage. Figure 1 shows the first of the two stages.

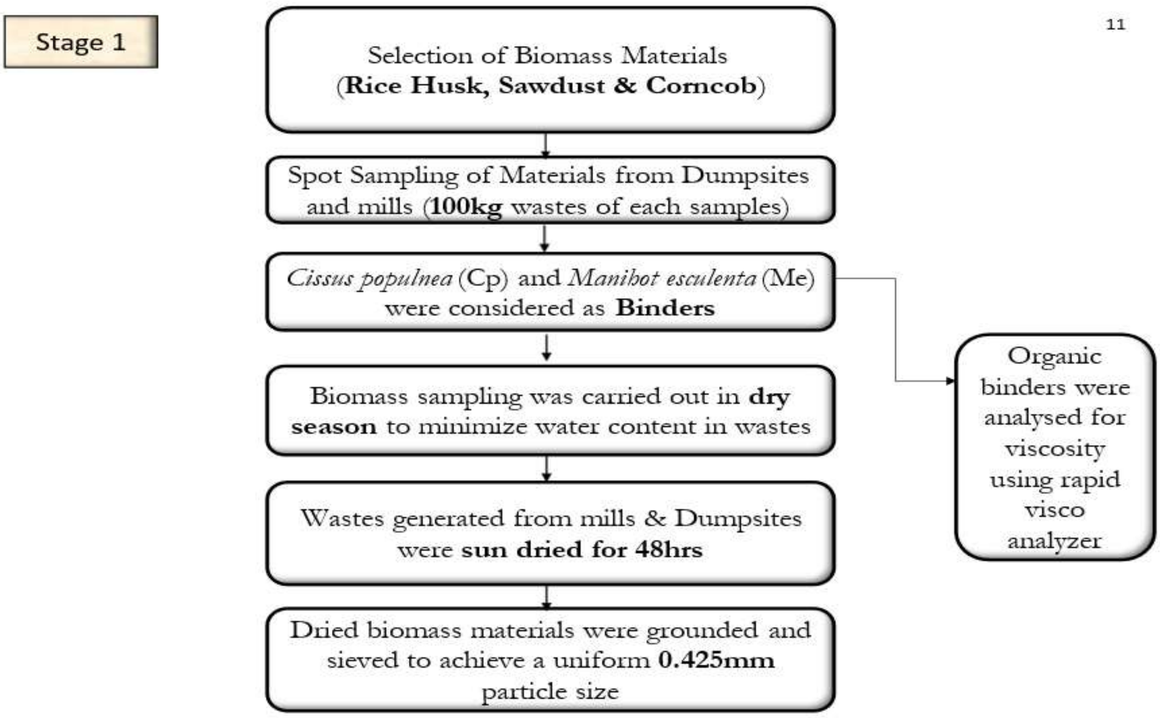

Figure 1: Material Selection and Spot Sampling Stage

In stage 2, pellet mixtures were prepared at each binder ratio of 10% of bulk weight of Rice Husk, RH, African Birch Sawdust, ABS, corncob, CC. Various blends in the ratios 1:1:1 (M), 1:2:3 (M1), 2:1:3 (M2), 3:1:2 (M3) and 2:3:1 (M4) respectively. Combustion characterization of the pellets were carried out using established procedures. This includes calorific value, burning rate, heat released rate and ignition time. The calorific value of mixed biomass waste in Makurdi metropolis is given by;

Summed product of the calorific value (MJ/kg) of dry matter

$$= \sum(A)x(B) = 18.21$$

$\sum(A)x(B)/C = 18.21/3 = 6.07$MJ/kg

where

A = components in the mixed solid biomass waste

B = calorific value in (MJ/kg) of dry matter

C = components with calorific value = 3

Pellets were combusted using a manually driven fan force air pellet stove. Data were analysed using IBM SPSS Statistics, version 2.0 for Windows, 2010. The differences were considered significant at $p < 0.05$.

III. RESULTS AND DISCUSSION

A. Particle size distribution of Rice Husk, Sawdust and Corncob

Grinds of sawdust were the finest with the least bulk density among the three grinds. Corncob grinds had the highest bulk density due to the particle size of the grind. Rice husk had more (18.22%) small particles (<0.212mm) than sawdust (4.03%) and corncob (8.47%). Sawdust had more (40.09%) larger particles (>0.850mm) than rice husk (25.25%) and corncob (6.67%). However, the medium particles (0.212 – 0.850mm) for the rice husks, sawdust and corncobs were, 56.49, 55.84 and 84.80%, respectively. In order to maintain uniform sizes, 0.425 mm particle size of the grinds was used with percentage weight of 5.31%, 5.81% and 12.58% for RH, ABS and CC respectively as shown in Figure 2.

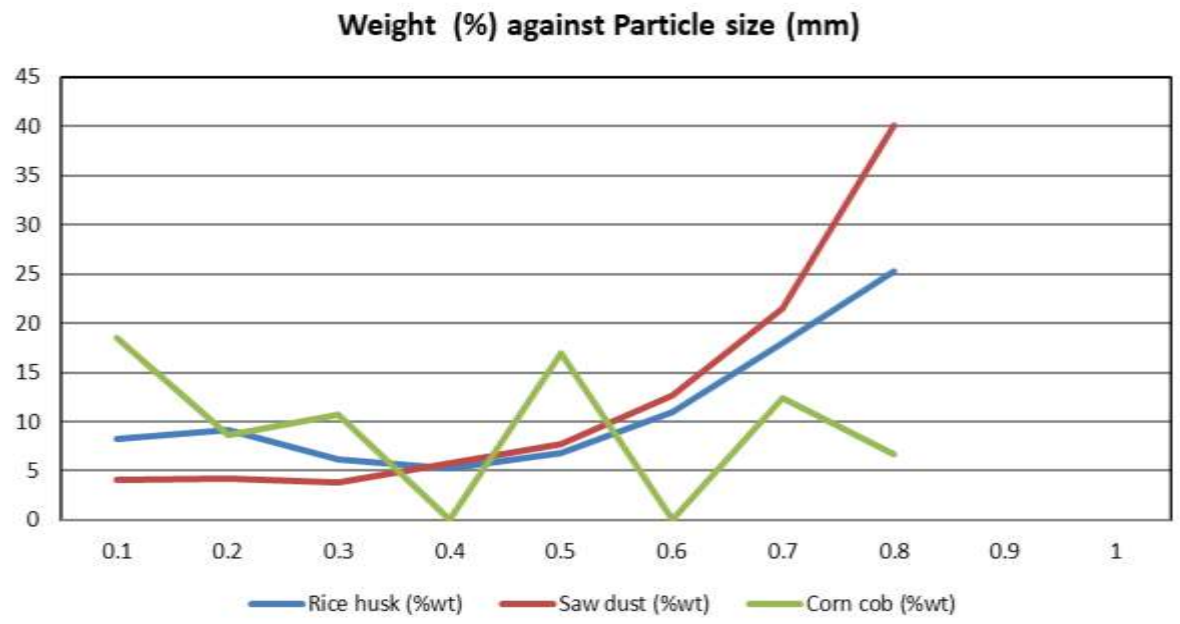

Figure 2: Particle size distribution of Rice Husk, Sawdust and Corncob

B. Proximate Composition of Cissus populnea and Manihot esculenta

Fat content and crude fibre are more in Cissus populnea (Cp) than in Manihot esculenta (Me) binder. Table 1 further revealed that Cissus populnea (Cp) constitute higher amount of protein. Low crude fibre impedes gelatinization which thereby lowers durability and compressive strength of the pellets.

Table 1: Proximate Composition of Cissus populnea and Manihot esculenta

Component	*Manihot esculenta* (Me) (%w/w)	*Cissus populnea* (Cp) (%w/w)
Fat	0.17±0.000	0.21±0.000
Crude Fibre	2.11±0.002	2.22±0.003
Protein	5.23±0.034	6.87±0.023

C. Viscosities of Manihot esculenta (Me) and Cissus populnea (Cp) Binders

At temperature above 64ºC, the viscosity of M. esculenta (Me) began to decline, which disagrees with Akpa and Dagde (2012). Figures 3 and 4 revealed that this variation may be due to the chemical modifications they made on natural Me while that of C. populnea continued to increase significantly.

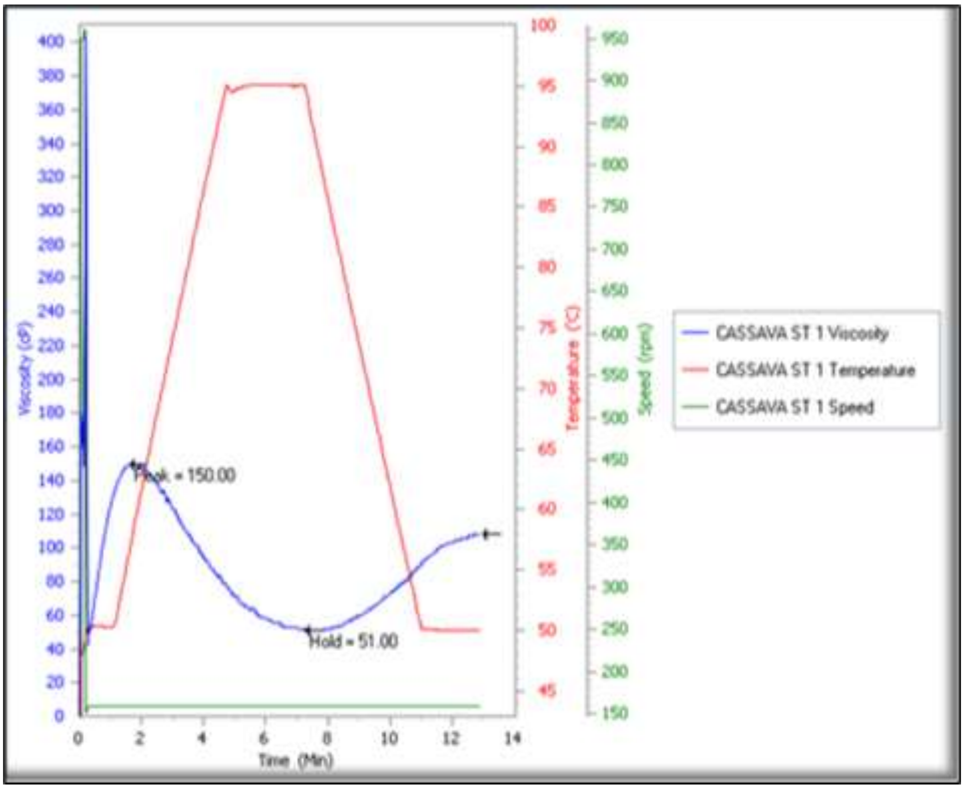

Figure 3: Rate of Viscosity of M. esculenta against Temperature

(Me = 150 centipoise at 64°C for 2mins)

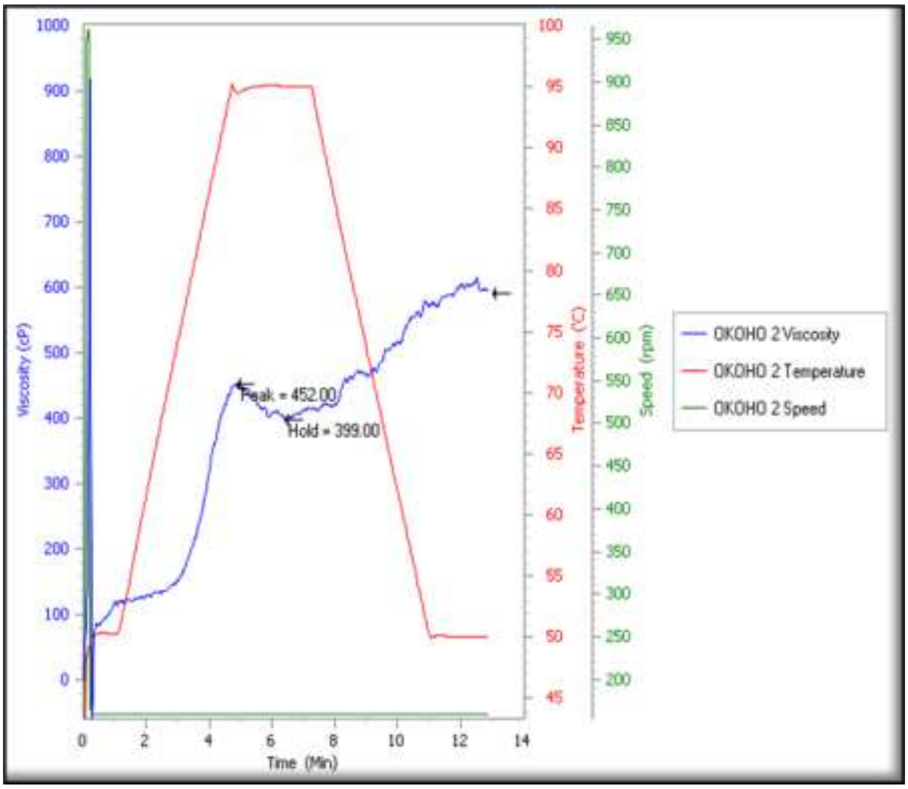

Figure 4: Rate of Viscosity of Cissus populnea against Temperature

(Cp = 452 centipoises at 78°C for 5 mins)

D. Physical Characteristics of RH, ABS, CC, M, M1, M2, M3 and M4 Pellets

Only bulk densities of pellets produced from CC pellets and (M, M1and M2) meet the guiding value of >600 kg/m³ British code of good practice irrespective of the binder used. Bulk densities of the pellets influenced combustion behaviour positively. The denser pellets had longer burning rate as observed by Obernberger and Thek (2004). Bulk density of mill waste pellets obtained in this study ranged from 522-675kg/m³ and 518 – 671kg/m³ with respect to Me and Cp respectively as shown in Table 2

Table 2: Physical Characteristics of RH, ABS, CC, M, M1, M2, M3 and M4 Pellets

Physical Parameters	Units	Guiding Values ***	Binders	Pellets RH	ABS	CC	M	M1	M2	M3	M4
Bulk density (ρ)	Kg m^{-3}	>600	Me	524^{d}	522^{d}	650^{b}	642^{b}	673^{a}	675^{a}	580^{c}	534^{d}
			Cp	520^{d}	518^{d}	643^{b}	631^{b}	661^{a}	671^{a}	572^{c}	528^{d}
Porosity	%		Me	70.13^{d}	58.76^{e}	69.23^{d}	78.05^{a}	70.11^{d}	72.88^{c}	74.12^{b}	68.24^{d}
			Cp	73.15^{c}	59.70^{e}	72.20 ^{c}	79.12 ^{a}	71.21^{cd}	72.94 ^{c}	75.05^{b}	69.32^{d}

ratios 1:1:1 (M), 1:2:3 (M1), 2:1:3 (M2), 3:1:2 (M3) and 2:3:1 (M4)

*** refers to British BioGen/UK Code of Good Practice

E. Combustion Analysis of RH, ABS, CC, M, M1, M2, M3 and M4 Pellets

The means of the combustion analysis of ratios 1:1:1 (M), 1:2:3 (M1), 2:1:3 (M2), 3:1:2 (M3) and 2:3:1 (M4) RH, ABS, CC pellets are shown in Table 3

Table 3: Combustion Analysis of RH, ABS, CC, M, M1, M2, M3 and M4 Pellets

		Guiding Values			Pellets							
Combustion Analysis	**Units**	**British BioGen/UK Code of Good Practice**	**Pellet Fuel Institute Standard PFI (2010)**	**Binder**	**RH**	**ABS**	**CC**	**M**	**M1**	**M2**	**M3**	**M4**
Ignition Time (IT)	**Sec**			**Me**	23.33^{a}	19.24^{d}	21.10^{c}	22.12^{b}	19.33^{d}	21.58^{bc}	24.02^{a}	20.14^{c}
				Cp	22.01^{b}	15.02^{f}	20.86^{c}	19.30^{d}	17.11^{e}	20.36^{c}	23.22^{a}	19.88^{d}
Heat Release Rate (HRR)	**KJ/s**			**Me**	1.34^{d}	1.66^{c}	2.46^{a}	2.59^{a}	2.51^{a}	2.03^{b}	1.68^{c}	1.64^{c}
				Cp	1.46^{e}	1.83^{d}	2.80^{b}	3.07^{a}	2.84^{b}	2.15^{c}	1.82^{d}	1.80^{d}
Burning Rate (BR)	**KJ/s**			**Me**	0.10^{bc}	0.09^{c}	0.12^{b}	0.14^{a}	0.11^{bc}	0.10^{bc}	0.11^{bc}	0.09^{c}
				Cp	0.11^{ef}	0.10^{f}	0.14^{cd}	0.17^{a}	0.15^{bc}	0.13^{de}	0.12^{e}	0.14^{cd}
Calorific Value (CV)	**KJ/kg**	**<4.7**		**Me**	13.39^{d}	18.48^{b}	20.46^{a}	18.50^{b}	20.14^{a}	19.39^{b}	15.03^{c}	18.49^{b}
				Cp	13.31^{c}	18.30^{b}	19.97^{a}	18.05^{b}	19.95^{a}	19.87^{a}	14.98^{c}	18.38^{b}

Means along the row followed by different letter (s) differ at the 0.05 probability level according to Duncan Multiple Range Test (DMRT)

F. Burning Rate and Calorific Value

The burning rate of 23.33, 19.24, 21.10, 22.12, 19.33, 21.58, 24.02 and 20.14 seconds recorded for RH, ABS and M4 respectively produced with Me binder. This implies that sawdust burns slowest than the other pellets followed by pellets produced with tertiary combination M4. CC had the highest calorific value followed by M1 pellets. Figures 5 and 6, present burning rate chart and calorific values.

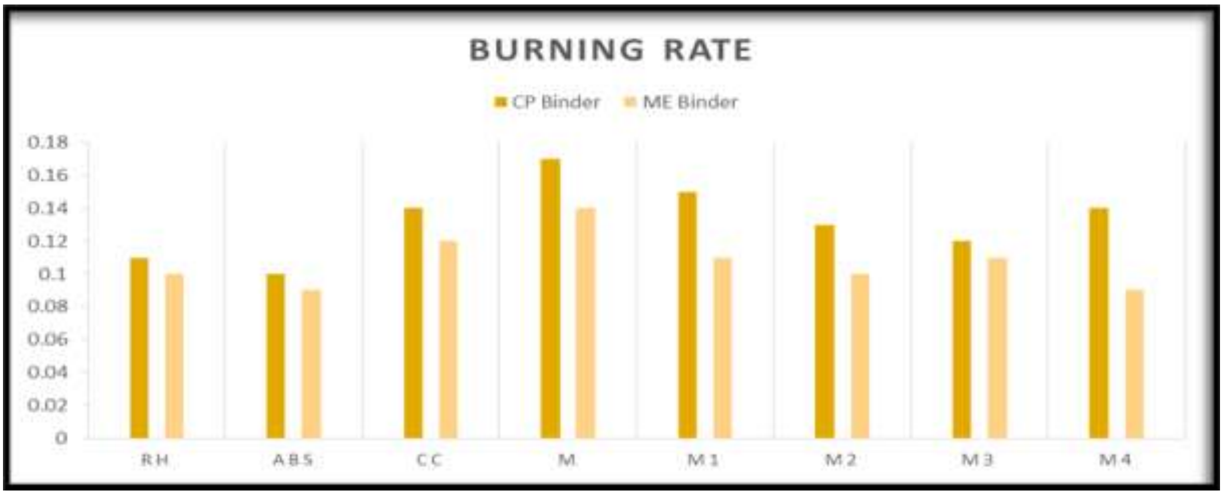

Figure 5. Burning Rate

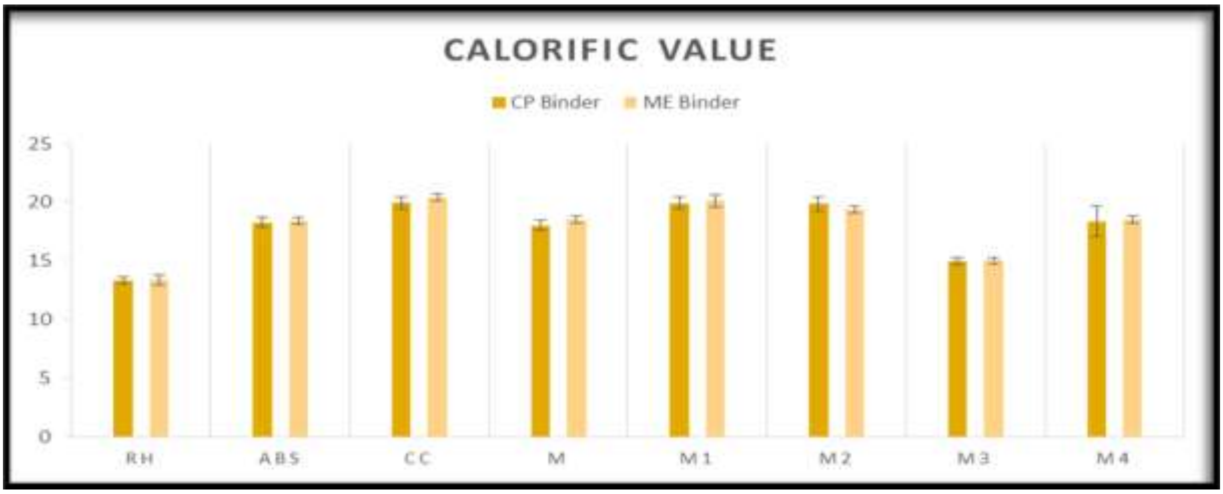

Figure 6. Calorific Value

G. Ignition Time and Heat Release Rate

The ignition time of 23.33, 19.24, 21.10, 22.12, 19.33, 21.58, 24.02 and 20.14 seconds recorded for RH, ABS, CC, M, M1, M2, M3 and M4 respectively produced with Cissus populnea binder as shown in Figure 7. This implies that sawdust ignites fastest than the other pellets followed by pellets produced with tertiary combination M1. The mixture, M1 shows optimum moisture content and ignition characteristics which could be due to the mixed compositions in the blend.

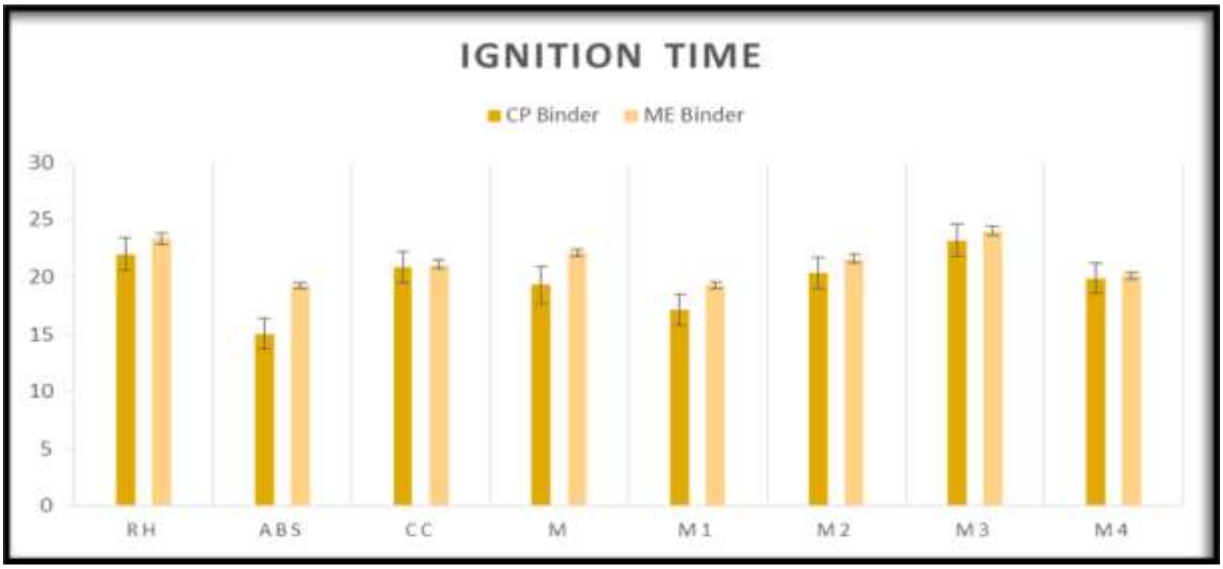

Figure 7. Ignition Time

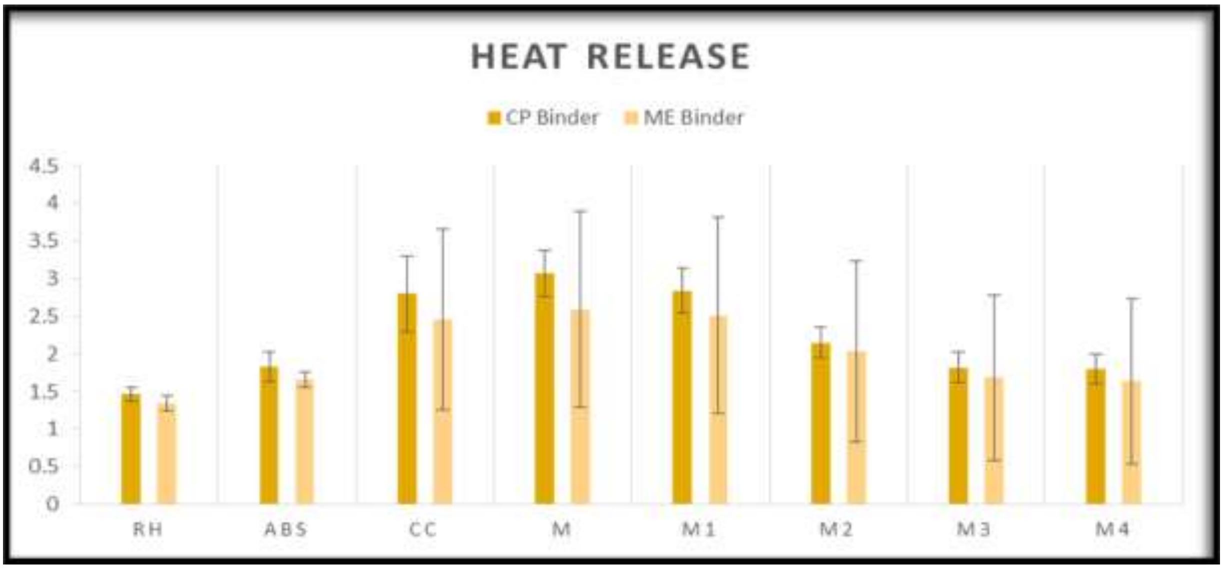

Figure 8. Heat Release Rate

V. CONCLUSIONS

Results from Plate revealed that M2 Pellet shows the least fuel consumption rate of 0.35kg/min, that is, little quantity of M2 will be required to cook thereby saving cost and fuel. This was followed by pellet made from corncob CC particles only (0.4kg/min). The binder effect is not significant at 95% probability level. The result of the water boiling tests showed that M2 pellets containing both M.esculenta (Me) and C. populnea (Cp) took the least time (18minutes and 20 minutes respectively) to boil one litre of water. Pellets made from rice husk (RH) with Me and Cp as included binders took the highest amount of time (28 minutes and 34 minutes respectively) to boil one litre of water. Ashes after combustion could be serve as a source of potash needed for the production of soap and other potassium-based materials. Pelletised biomass can serve as a potential renewable biofuel for cleaner energy production with a marked dependence of the thermochemical conversion processes.

REFERENCES

1) Omoti, U., 2001. The future of the oil palm industry in Africa and strategies for Development. In The Nigerian situation". Paper prepared for the Africa Development Bank (ADB) workshop on the future of oil palm industry in Africa and strategies for Development Cote D'Ivoire.
2) Ekpo, D. D. (2019) Electricity Generation Potential from Municipal Solid Waste in Uyo Metropolis, Nigeria
3) Olatunbosun, D., Uguru-Okorie, B. E, & Ekpo D. C. (2014) A Comparison of Medical Waste Generated in Selected Private and Public Hospitals in Abeokuta Metropolis, Nigeria. International Journal of Scientific & Engineering Research pp 1441-1449
4) Diji, CJ, Ekpo, DD and Adadu, CA (2013) Design of a Biomass Power Plant for a Major Commercial Cluster in Ibadan-Nigeria the International Journal of Engineering and Science pp 23-29
5) Ekpo, D. D. (2012) Challenges of Municipal, Solid Waste Disposal A Case Study of Uyo Township. Education & Science Journal of Policy Review & Curriculum Development, Vol. 1 no 2, pp 110-116
6) Okoro, O. I., Abunike, C. E., Akuru, U. B., Awah, C. C., Okpo, E. E., Nkan, I. E., Udenze, P. I., Innocent, U. O., & Mbunwe, M. J. (2022). A Review on the State-of-the-Art Optimization Strategies and Future Trends of Wound-Field Flux Switching Motors. IEEE PES/IAS PowerAfrica, (pp. 1-5). Kigali, Rwanda.
7) Okpo, E. E., Nkan, I. E., Okoro, O. I., & Akuru, U. B. (2021). Winding Reconfiguration of 5.5 kW Three-Phase Induction Motor for Improved Performance. IEEE PES/IAS PowerAfrica, (pp. 1-4). Nairobi, Kenya.
8) Ekpo, DD, Diji, C and Offiong, A (2012) Environmental degradation and municipal solid waste management in Eket-Nigeria Pan African Book Company, ISSN: 2276-6138, pp 164-172.
9) Udoh, D. E., Ekpo, D. D., & Nkan, I. E. (2024). Design and Development of a Package Delivery Robot. International Journal of Multidisciplinary Research and Analysis, 7(6), 2504-2510.
10) Ekpe, M. V., Ekpo, D. D., & Okpo, E. E. (2024). Harnessing Biogas Resources for Production of Methane Gas. International Journal of Multidisciplinary Research and Analysis, 7(6), 2498-2503.

11) Abha Chhabra, Palria, S., Dadhwal, V.K. (2002) Growing stock-based forest biomass estimate for India Biomass and Bioenergy, 22(3), 187-194.
12) Agbro, E. B., & Ogie, N. A. (2012). A comprehensive review of biomass resources and biofuel production potential in Nigeria. Research journal in engineering and applied sciences, 1(3), 149-155.
13) Akpa, J. G., & Dagde, K. K. (2012). Modification of cassava starch for industrial uses. International Journal of Engineering and Technology, 2(6), 913-919.
14) Shah, A., Srinivasan, R., Suminto D., Filip T, Eugene P. (2010) Columbus, Performance and emissions of a spark-ignited engine driven generator on biomass-based syngas Bioresource Technology, 101(12), 4656-4661.
15) Zhang, F., Dana M. Johnson, J.W., Sutherland, A. (2011) GIS-based method for identifying the optimal location for a facility to convert forest biomass to biofuel Biomass and Bioenergy, 35(9), 3951-3961.
16) Gidarakos, E., Havas, G., and Ntzamilis, P. (2006). Municipal solid waste composition determination supporting the integrated solid waste management system in the island of Crete. Waste management, 26(6), 668-679.
17) Oladeji, J. T. (2010). Fuel characterization of briquettes produced from corncob and rice husk resides. The Pacific Journal of Science and Technology, 11(1), 101-106.
18) Obernberger, I., & Thek, G. (2004). Physical characterisation and chemical composition of densified biomass fuels with regard to their combustion behaviour. Biomass and bioenergy, 27(6), 653-669.
19) Olorunnisola, A. (2007). Production of fuel briquettes from waste paper and coconut husk admixtures.
20) Tumuluru, J. S., & Wright, C. T. (2010). A review on biomass densification technologie for energy application.
21) Warajanont, S., & Soponpongpipat, N. (2013). Effect of particle size and moisture content on cassava root pellet fuel's qualities follow the acceptance of pellet fuel standard. parameters, 3, 7-17.
22) Dickson, M. E., Akpan, O., Chuku, C. D., Bassey B. E., Ojie, P. A., Atairet, C. A., Ita, V. E., Umanah, I. J., Ibanga S. E., Umoren, P. E., Mark, J. O., Ekpo, D. D. (2023). Natural Resources, Resource Governance, and Insecurity in Developing Countries: Evidence from Nigeria's Niger Delta Region. African Journal of Peace and Conflict Studies. (12) 3, 49.
23) Bassey, J. B., Ekpo, D. D., Gentle, V. U. (2024). Computational Fluid Dynamics Analysis of Flow Characteristics in Convergent and Divergent Sections. International Journal of Science, Engineering and Technology (12) 2, 2395-4752.