



Performance Evaluation of Hybrid Briquettes Produced from Carbonized Sawdust and Guinea Corn Straw Using Starch Binder in Rural Enugu State

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Abstract

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This study evaluates the performance of hybrid fuel briquettes produced from carbonized Saw dust and Guinea corn straw, using starch as a binder. The raw materials were mixed in ratios of 90:0:10, 75:15:10, 60:30:10, 45:45:10, 30:60:10, 15:75:10 and 0:90:10 (Saw dust: Guinea corn straw: Binder). Briquettes were produced via hydraulic pressing. Proximate, ultimate, and performance (boiling time, calorific value) analyses were conducted. Results indicated that increased carbonized Saw dust content enhanced fixed carbon and heating value. The 45:45:10 blend showed the best performance, with a heating value of 24.9 MJ/kg. These briquettes demonstrated improved combustion and lower emissions compared to uncarbonized counterparts, making them viable for rural energy needs.

KEYWORDS: Biomass carbonization, Mixing ratio, Energy fuel, Combustion Characteristics

1.0 INTRODUCTION

Sequel to the increasing adverse environmental impacts related to the use of local firewood and conventional fossil fuels for domestic cooking, also measures to limit indiscriminate disposal of agro waste and low greenhouse gas emissions are continuously sought (Ibitoye *et al.* 2021), there is a strong interest worldwide in the development of technologies that exploit sustainability, availability and renewable energy sources.

Recent researches have shown that over-utilization of non-renewable energy such as firewood and fossil fuel have contributed significantly to the global environmental challenges (Cheol *et al.*, 2021). This is because the conventional nonrenewable fuel are usually burned for energy to be released in several system for different applications. The combustion of fossil fuels leads to

the emission of carbon mono oxide and greenhouse gasses, which causes health hazard and global warming. With the raise in climatic issues, it is better to discourage the consumption of energy that leads to environmental degradation, thus, it is essential to seek alternative to conventional fuel such as firewood and fossil fuels for healthy living. Biomass is a renewable energy source that exhibits sustainable characteristics and promotes a green environment (Lubwama *et al.*, 2020). Previous studies have revealed that utilization of biomass such as agricultural residues, non-food crops, forest residues, and even algae for biofuel production could reduce global CO₂ emissions (Bhakta *et al.* 2020).

To solve the global energy issues, especially in developing nations like Nigeria where agro waste is abundant and clean, renewable, and sustainable energy is not accessible, decentralized approaches to energy will go a long way since raw material are almost at no cost (Ibitoye *et al.*, 2021). This is because biomass conversion techniques such as carbonization and densification are promising and favorable options for biomass fuel production. Carbonization is a thermochemical process where solid biomass is subjected to thermal treatment at a temperature between 350 – 500oC in an inert or oxygen-reduced environment (Atan, Nazari, & Azizan, 2018; Brachi *et al.*, 2019; Chen, Peng, & Bi, 2015) before they are crushed, and densified. Inert gases are employed to create an inert environment, but nitrogen is the commonly used carrier gas to create an inert atmosphere. Densification is the agglomeration of fine particles (different or same particle sizes) by applying pressure into various shapes with or without using a binding agent (Hu *et al.*, 2021; Ibitoye *et al.*, 2021a; Rabiou *et al.*, 2019). Pressure is applied on biomass in a mold so that the particles can articulate together stably for subsequent handling, storage, and transportation. Densification processes is either briquetting, pelletizing, bailing, and cubing. Densification will waive the challenges (transport, handling dumping, and burning, etc.) related to biomass utilization. Densification improves the fuel properties of the final products. Some of the benefits of biomass agglomeration include an increase in bulk density, improved storage, handling, and flow properties, enhanced homogeneity of blends, reduced dust formation, and improved particle bed heat transfer (Cong *et al.*, 2021; Riva *et al.*, 2021; Yang, Cooke-willis, Song, and Hall, 2021).

Several research efforts have developed solid fuel from biomass feedstock through thermal treatment and densification. Severy *et al.* (2018) carried out torrefaction and briquetting on a pilot-scale plant. Briquettes of high quality and optimal torrefaction conditions were obtained at residence time (RT), moisture content, temperature range of 10 min, < 11%, and 267-275 oC,

Anthony and Audu / Gregory University Uturu Journal of Engineering and Technology Vol. 1(1) 2025 pp. 20-33 respectively. An investigation was conducted on torrefied *Tectona grandis* in a tubular furnace at 240-300 °C, 30-60 min, and 2-6 mm torrefaction temperature (TT), RT, and particle size, respectively (Odusote *et al.*, 2019). A reduction in the volatile matter was reported with an increase in fixed carbon and calorific value. Though it was concluded that the fuel met the requirement for energy generation in thermal plants, there was no report on the physico-mechanical properties of the produced fuel.

A torrefaction study on agro-residues (rice straw, corncob, and cassava stalk) of Indonesia origin showed that the blending of feedstock does not significantly influence the product properties (Andini *et al.*, 2018). Fuel pellets were manufactured from food waste (paper cups, vegetable parts, rice, condiments, vegetables, fruit peels, woody chopsticks, noodles, and cooked meat) via hydrothermal carbonization by Zhai *et al.* (2018). Molasses and lime were utilized as binding agents. Carbonization was done at 3 °C/min heating rate using different temperatures and RT. Molasses only (20%) and a blend of 20% molasses and 5% lime were two binder compositions used for the study. Results revealed that pellets made from blends of molasses and lime exhibited good compressive strength, better resistance to impact forces, and improved density. (Song *et al.* 2021) submitted that a briquette of high calorific value and weather resistance could be produced from blends of thermoplastics and wood residues using a unique hot ejection method. A study on the effect of milling size on the pelletization process and pellet quality was conducted using a pilot-scale pellet production route (Pradhan *et al.* 2021). It was opined that milling sizes greatly influenced pellet quality.

Ohodo is a famous town in Enugu state, Eastern, Nigeria. The predominant occupation in Ohodo is farming, infact (Anthony *et al.* 2024) has it that they are one of the largest cultivator of guinea corn and due to farming activities and increasing deforestation, they also have very high timber product and residue. Due to the town's location and the high level of agricultural activity in the towns and villages surrounding it, the Ohodo market is usually dominated by agricultural products such as guinea corn, yam, maize, sweet potato, plantain, and banana, among other agricultural products. People come from far and near because things are available at a lower price. After the harvest time, the farm land and even the community is usually littered with agricultural residues such as rice chaff, guinea corn straw, saw dust, cassava peel, corncob, etc. Most time, these residues are disposed by dumping and burning in an open field, and these have constituted a nuisance and environmental pollution to the people living in the community.

In view of the foregoing, there is a need to seek a proper waste management method for the residue generated from farming activities in the Ohodo community and how these residues can be converted into usable products. It is essential to investigate the properties of solid fuel manufactured from blends guinea corn straw and saw dust which are biomass feedstock, specifically the physical, mechanical, and performance in stove. Therefore, this study aims to produce and characterize solid fuel briquettes from blends of carbonized saw dust and guinea corn straw as a waste management technique for people living in Ohodo community. The parameters considered for investigating the combustion properties are higher heating value, ultimate and proximate analyses. The physico-mechanical parameters include, density, shatter index, (Ajimotokan *et al.*, 2019a). This research would serve as an alternative to conventional fossil fuels and firewood. It would provide income for the people via employment generation. This study will advance renewable and sustainable energy generation from biomass for different applications. The outcome of this research can be applied in domestic and industrial settings for cooking and heating purposes.

2.0 Materials and Methods

2.1 Material

The raw materials used for this study were sawdust obtained from the Nsukka Timber Shed and guinea corn straw sourced from farmland in Ohodo. Starch purchased from the Ohodo Market served as the binder. The equipment used included a machete for cutting the straw, 2 mm sieves for particle size separation, and a digital weighing balance for measurements. Carbonization was carried out using a drum kiln, while briquettes were produced with a hydraulic briquetting machine. A mixing bowl, measuring cylinder, and water source were used for blending, and drying was done on a sun-drying platform or in a hot air oven. Performance evaluation involved a weighing balance for physical properties, a muffle furnace and oven for proximate analysis, a bomb calorimeter for calorific value, and a stove, stopwatch, thermometer, measuring cylinder, pot, and water for combustion testing.

2.2 Methods

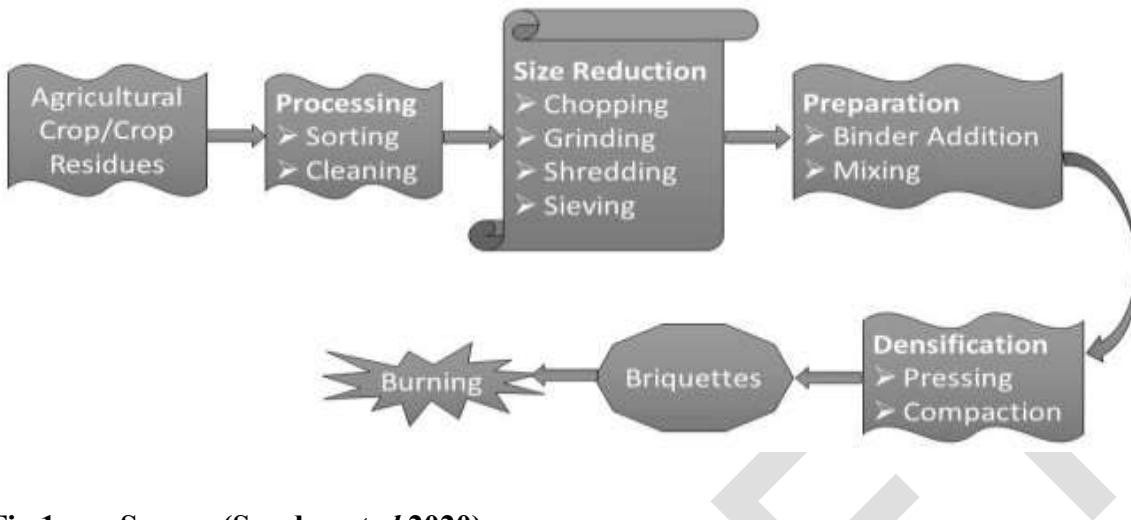


Fig 1. Source (Sunday *et al* 2020)

2.2.1 Sample Preparation and Carbonization

- i. **Collection and Pre-treatment:** Sawdust and guinea corn straw were collected. The guinea corn straw was first cut into smaller pieces (2-3 cm) using a machete.
- ii. **Drying:** Both raw materials were sun-dried for a period of 14 days to reduce their moisture content to a manageable level (below 15%).
- iii. **Milling and Sieving:** The dried sawdust and guinea corn straw were ground separately using a hammer mill to a particle size of 2mm to ensure homogeneity and proper binding.
- iv. **Carbonization:** The milled biomass was carbonized in a drum kiln. A controlled pyrolysis process was carried out by heating the materials to a temperature range of 400-500°C for a residence time of approximately 30-45 minutes. The resulting biochar was allowed to cool to room temperature.

2.2.2 Briquette Production

- i. **Binder Preparation:** Starch binder was prepared by mixing starch powder with water. A mixture of 10% (w/w) starch was prepared by dissolving 100g of starch in 1 liter of hot water to form a gelatinized paste.

- ii. **Mixing:** The carbonized sawdust and guinea corn straw bio char were mixed in various ratios (e.g., 90:0:10, 75:15:10, 60:30:10, 45:45:10, 30:60:10, 15:75:10, and 0:90:10 sawdust to guinea corn straw to binder) to determine the optimal blend.
- iii. **Compaction:** The mixed feedstock was fed into the briquetting machine. A compaction pressure of 5-10 MPa was applied to form solid, cylindrical briquettes. A standard briquette size (50mm diameter, 50mm height) was used for consistency and three (3) briquettes were produced from the seven (7) ratios
- iv. **Drying:** The briquettes were carefully removed from the mold and air-dried for 48 hours, followed by oven-drying at 105°C for 24 hours to reduce the moisture content to below 10% and improve their strength.

2.2.3 Performance Evaluation

The performance of the briquettes was evaluated based on their physical, proximate, and combustion properties.

1. Physical Properties:

- **Bulk Density:** The mass and volume of each briquette were measured using a digital weighing balance and a Vernier caliper, respectively. The bulk density was calculated as the ratio of mass to volume.

$$(\rho = \frac{m}{v}).$$

- **Shatter Resistance/Durability:** This was determined by dropping the briquettes from a height of 1.8 meters onto a hard surface. The briquette's durability was assessed by the percentage of weight retained after the test.
- #### 2. Proximate Analysis:
- Standard ASTM methods were used to determine the following properties :
- **Moisture Content:** (according to ASTM-D3173-03) Briquettes were weighed before and after drying in an oven at 105°C until a constant weight was achieved. The moisture content was calculated as the percentage of mass lost.

- **Volatile Matter:** (according to ASTM-D3175-02) A known mass of the briquette was heated in a muffle furnace at 950°C for a 45 minutes. The percentage of weight lost was taken as the volatile matter.
 - **Ash Content:** (ASTM-D3173-04) the remaining residue after the volatile matter test was heated at 600°C for several hours until a constant weight of ash was obtained. The ash content was calculated as the percentage of the final residue weight.
 - **Fixed Carbon:** This was calculated by difference using the formula:
Fixed Carbon (%) = 100 - (Moisture Content (%) + Ash Content (%) + Volatile Matter (%))
3. **Combustion Test and Calorific Value:**
- **Calorific Value:** The heating value of the briquettes was determined using M39889 bomb calorimeter according to ASTM-D5865-13 standards. This measures the total energy released per unit mass of the briquette.
 - **Boiling Time and Fuel Consumption Rate:** 100g mass of briquette was ignited in a stove to boil 1 liter of water. The time taken for the water to reach its boiling point was recorded using a stopwatch. The weight of the briquette before and after the test was measured to determine the fuel consumption rate. The combustion efficiency and fuel efficiency were calculated based on the heat supplied and the energy used to heat the water.

3.0 RESULTS

The results of the performance evaluation is as shown in Table 1 with all value been the mean value since the experiment are repeated three times for accuracy and better presentation, Figure 2 is the bar chart showing the behavior for all properties of the various briquette made from various ratio of the biomass composition and binder.

Table 1 shows Performance Evaluation of the Briquettes (All figures in the table are mean value as three briquettes are produced from each sample for accuracy and consistency).

	Mass (%)	Ratio	Weight of Briquette (kg)	Bulk Density (kg/cm ³)	Moisture Content (%)	Ash content (%)	index	Calorific Value (MJ/Kg)	Burning Rate (g/min)	Boiling Time (min)
1	S90G0B10		68.5	0.7	21	3	89	13.9	1.2	30.5
2	S75G15B10		64.0	0.64	19	4	90	14.3	2.2	25.2
3	S60G30B10		65.5	0.65	18.3	5	89	14.5	2.8	23.8
4	S45G45B10		65.6	0.62	12	7	92	24.9	3.2	23.4
5	S30G60B10		67.4	0.65	15	5	89	15.8	3.8	22.8
6	S15G75B10		63.3	0.63	13	11	88	16.5	5.5	18
7	S0G90B10		68.2	0.69	13.4	13	90	15.3	7.1	16.5

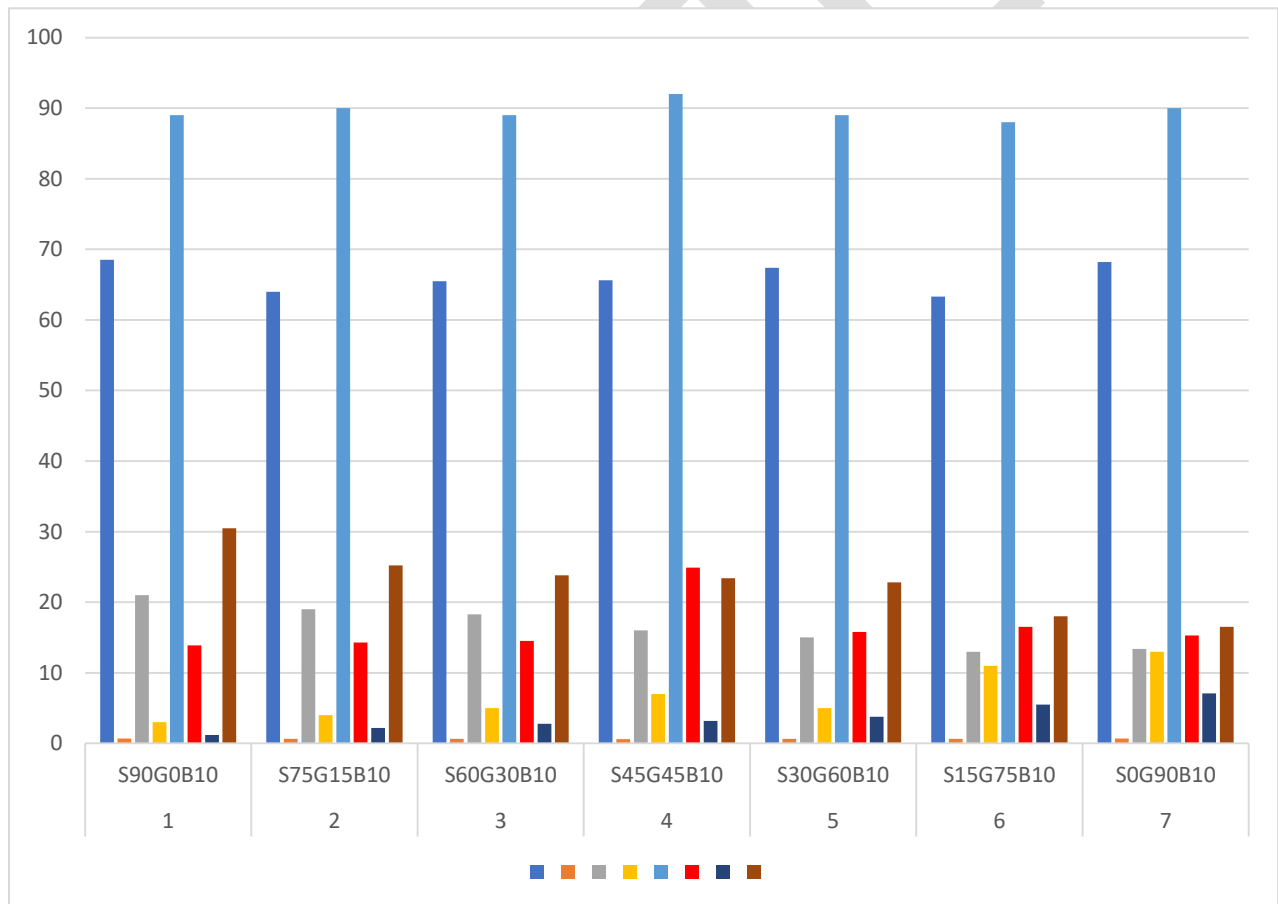


Figure 2: A bar chart of characteristics and properties briquette made from various ratio of the biomass material and the binder.

4.0 DISCUSSION

4.1 Properties of the Hybrid Briquettes

4.1.1 Bulk Density

From Table 1, the produced briquettes bulk density value are within the typical and acceptable range for biomass briquette reported in previous work and by the Food and Agriculture Organization (FAO) which states that bulk density of 0.6 g/cm^3 to 0.7 g/cm^3 are usual for briquettes since high bulk density is desire to reduce transportation and storage cost. According to (Waheed *et al.* 2022) a high bulk density significantly improves the economics and practicality of using briquettes as it directly addresses the low energy density of raw biomass. Also high bulk density implies that higher energy content per unit volume with slower burning time.

4.1.2 Moisture Content

From Table 1, the values fall within the acceptable range as reported by (Tumuluru *et al.* 2015). The lowest moisture content was observed for the briquette made with ratio 45:45:10 at 12% which also give the highest heating value of 24.9 MJ/kg which is attributed to a desirable morphology and good porosity that facilitated the air circulation needed for optimal combustion. In this study, the moisture content increase with an increase in the saw dust and decrease with increase in guinea corn straw clearly seen in Figure 2. (Yusuf *et al.* 2023) suggest that for low-lignin materials, a moderate to high moisture level is essential for proper compaction and binding since moisture act as natural binding agent. The briquettes produced in this study has relatively high moisture content range from 12% - 21% although the presence of the right amount of moisture reduces the internal friction between biomass particle which enhance their fluidity and promotes sliding and tight fitting under pressure (Udo *et al.* 2018).

4.1.3 Ash Content

The briquettes produced in this study exhibit relatively low ash content ranging from 3%-13% which directly correlates with higher concentration of combustible materials leading to higher energy yield per unit mass as evident in Table 1. The ash content range is similar to that of (Sanchez *et al.* 2022) which is substantially less than coal thereby lessening the environmental burden of ash disposal, low release of toxic chemical like sulfure dioxide (SO_2) responsible for acid rain.

4.1.4 Calorific Value

From Table 1, it is evident that the briquette produced from the sample with ratio 45:45:10 exhibited the highest calorific value of 24.9 MJ/kg. This range of energy content is shown to be a reliable and affordable fuel for domestic and industrial use, comparable to energy value of sub-bituminous coal in the range of 20-24.73MJ/kg (Sanchez *et al* 2022;Sam *et al.*, 2023).

4.1.5 Shatter Index

In this study, the produced briquettes exhibit shatter index in the range of 89%-92%as in Table 1. The briquettes considered durable, often those with a shatter resistance above 90% (Olugbade and Ojo, 2021; Tembe *et al.* 2014) are suitable for both domestic cooking and larger industrial applications like steam generation in boilers. The shatter index reported in this work indicate a good mechanical durability and integrity during handling, transporting or storage. This result is in line with that reported in a study involving Saw dust-charcoal composites (Owino *et al.*, 2020).

4.1.6 Burning Rate

In this study, the burning rate is in the range of 1.2-7.1 g/min which indicate a moderate combustion rate and is desirable for domestic cooking application as it reduce cooking time (Udechukwu and Oti, 2022). This range is efficient compare to briquettes with less burning rate as reported by (Ismail and Yaakob, 2017)

4.1.7 Boiling Time

The burning time reported in this study ranges from 16min-30min which aligns well with standards for efficient solid fuels (Agunwamba *et al.*, 2017). Is recommended for domestic cooking, offering a sustained heat output for long cooking process without frequent refueling.

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This study successfully demonstrated the viability of producing an efficient fuel briquettes from composite blend of carbonized sawdust and guinea corn straw utilizing starch binder. By providing a detailed characterization of a specific, effective waste to energy formulation, this study offer a pathway for sustainable agro waste management practices and production of renewable energy in rural community of Enugu State. It showcase the potential of converting underutilized biomass waste (saw dust and guinea corn straw) into valuable energy commodities, thereby mitigating environmental pollution resulting from indiscriminate dumping and burning of agro waste and reducing reliance on fossil fuel and traditional firewood sources. This work broadens the scope of materials considered viable for briquetting, adding empirical data to the growing body of knowledge on biomass densification.

5.2 RECOMMENDATION

Despite these milestone, further improvement is required to explore the impact of varying the binder ratio, which might further optimize shatter index. Additionally, investigating in depth analysis of the emission during combustion to comply with air quality standard.

Finally, impact of varying particle size of both feedstock on the briquette properties to also be investigated. The production of briquettes from carbonized Sawdust and Guinea corn straw represents a viable and sustainable strategy for renewable energy generation. The process not only converts agricultural and forestry waste into a valuable fuel source but also addresses environmental concerns related to waste disposal and air pollution. Further research is needed to optimize the carbonization process, time stayed in the farm and cost-effectiveness.

6.0 ACKNOWLEDGMENT

I wish to acknowledge TETFUND for providing the resources used in this entire research work, this has not only boost my moral but has also help to educate the peasant farmers in Ohodo and its environ that saw dust and guinea corn straw are not a waste but raw materials that can generate clean and sustainable alternative fuel and can create job for the teaming youth.

Not forgetting the Management of Federal Polytechnic Ohodo who have establish entrepreneur Centre to put this research and other to practice which will in turn boost internally generated

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revenue, show student a promising job opportunity and bring to light an alternative cheaper
cooking fuel.

REFERENCES

- Ibitoye, Segun E, Jen, T-C., Mahamood, R. M., & Akinlabi, E. T. (2021). Generation of Sustainable Energy from Agro-Residues through Thermal Pretreatment for Developing Nations : A Review. *Advanced Energy and Sustainability Research*, 2100107, 1–15. <https://doi.org/10.1002/aesr.202100107>
- Cheol, K., Kim, J., Yong, S., Jun, S., Hoon, L., Geon, C., ... Hyun, D. (2021). Development and validation of torrefaction optimization model applied element content prediction of biomass. *Energy*, 214, 1–11. <https://doi.org/https://doi.org/10.1016/j.energy.2020.119027>
- Lubwama, M., Andrew, V., Muhairwe, F., & Kihedu, J. (2020). Physical and combustion properties of agricultural residue bio-char bio-composite briquettes as sustainable domestic energy sources. *Renewable Energy*, 148, 1002–1016. <https://doi.org/https://doi.org/10.1016/j.renene.2019.10.085>
- Bhakta, H., Sarmah, A. K., & Dubey, B. (2020). Hydrothermal carbonization of renewable waste biomass for solid biofuel production: A discussion on process mechanism, the influence of process parameters, environmental performance, and fuel properties of hydrochar. *Renewable and Sustainable Energy Reviews*, 123, 1–22. <https://doi.org/10.1016/j.rser.2020.109761>
- Brachi, P., Chirone, R., Miccio, M., & Ruoppolo, G. (2019). Fluidized bed torrefaction of biomass pellets : A comparison between oxidative and inert atmosphere. *Powder Technology*, 357, 97–107.
- Atan, N. A., Nazari, M. M., & Azizan, F. A. (2018). Effect of torrefaction pretreatment on physical and combustion characteristics of biomass composite briquette from rice husk and banana residue. *MATEC Web of Conferences* 150, 150.
- Rabiu, A. B., Lasode, O. A., Popoola, O. T., Babatunde, O. P., & Ajimotokan, H. A. (2019). Densification of Tropical Wood Residues for the Development of Solid Fuels. *The IAFOR International Conference on Sustainability, Energy & the Environment*, Hawaii 2019, 1–11.
- Hu, X., Liu, Y., Zhao, Z., Liu, J., & Yang, X. (2021). Real-time detection of uneaten feed pellets in underwater images for aquaculture using an improved YOLO-V4 network. *Computers*

- Anthony and Audu / Gregory University Uturu Journal of Engineering and Technology Vol. 1(1) 2025 pp. 20-33
and Electronics in Agriculture, 185(September 2020), 106135.
<https://doi.org/10.1016/j.compag.2021.106135>
- Cong, H., Yao, Z., & Zhao, L. (2021). Co-combustion, co-densification, and pollutant emission characteristics of charcoal-based briquettes prepared using bio-tar as a binder. *Fuel*, 287(August 2020), 1–10. <https://doi.org/10.1016/j.fuel.2020.119512>
- Riva, L., Wang, L., Ravenni, G., Bartocci, P., Videm, T., Skreiberg, Ø., ... Kofoed, H. (2021). Considerations on factors affecting biochar densification behavior based on a multiparameter model. *Energy*, 221, 1–13.
- Yang, I., Cooke-willis, M., Song, B., & Hall, P. (2021). Densification of torrefied *Pinus radiata* sawdust as a solid biofuel: Effect of key variables on the durability and hydrophobicity of briquettes. *Fuel Processing Technology*, 214, 1–9.
<https://doi.org/10.1016/j.fuproc.2020.106719>
- Odusote, Jamiu Kolawole, Adeleke, A. A., Lasode, O. A., & Malathi, M. (2019). Thermal and compositional properties of treated *Tectona grandis*. *Biomass Conversion and Biorefinery*, March, 1–10. <https://doi.org/10.1007/s13399-019-00398-1>
- Andini, A., Bonnet, S., Rousset, P., Patumsawad, S., & Pattiya, A. (2018). Torrefaction study of Indonesian crop residues subject to open burning. 7th International Conference on Sustainable Energy and Environment: Technology & Innovation for Global Energy Revolution, (November), 28–31.
- Zhai, Y., Wang, T., Zhu, Y., Peng, C., Wang, B., Li, X., ... Zeng, G. (2018). Production of fuel pellets via hydrothermal carbonization of food waste using molasses as a binder. *Waste Management*, 77, 185–194. <https://doi.org/10.1016/j.wasman.2018.05.022>
- Pradhan, P., Mahajani, S. M., & Arora, A. (2021). Pilot-scale production of fuel pellets from waste biomass leaves effect of milling size on pelletization process and pellet quality. *Fuel*, 285, 1–7. <https://doi.org/10.1016/j.fuel.2020.119145>
- Ajimotoke, H. A., Ibitoye, S. E., Odusote, J. K., Adesoye, O. A., & Omoniyi, P. O. (2019a). Physico-Mechanical Characterisation of Fuel Briquettes made from Blends of Corncob and Rice Husk. *Journal of Physics: Conference Series*, 1378 02200, 1–12.
<https://doi.org/10.1088/1742-6596/1378/2/022008>
- ASTM D5865-04. (2004). Standard Test Method for Gross Calorific Value of Coal and Coke. Retrieved April 10, 2021, from ASTM International, West Conshohocken, PA website: www.astm.org

- Anthony and Audu / Gregory University Uturu Journal of Engineering and Technology Vol. 1(1) 2025 pp. 20-33
- ASTM D5373-16. (2016). Standard Test Methods for Determination of Carbon, Hydrogen, and Nitrogen in Analysis Samples of Coal and Carbon in Analysis Samples of Coal and Coke. Retrieved from ASTM International, West Conshohocken, PA website: www.astm.org.
- Chen, Y., Yang, J., Wu, W., & Li, R. (2017). Effects of carbonization temperature on physicochemical properties of biochar from cotton stalks. *Journal of Analytical and Applied Pyrolysis*, 124, 608-617.
- Demirbas, A. (2004). Combustion characteristics of different biomass fuels. *Progress in Energy and Combustion Science*, 30(2), 219-239.
- Ige, A. R., Nwadike, C. C., & Adegoke, B. (2021). Briquette production from guinea corn stalk and sawdust using cassava starch as binder. *International Journal of Research and Innovation in Applied Science*, 6(3), 20-25.
- Sengar, S., Singh, S., & Rawat, M. (2014). Production and characterization of fuel briquettes from agricultural residues. *International Journal of Modern Engineering Research*, 4(12), 43-47.
- Tumuluru, J. S., Sokhansanj, S., Lim, C. J., & Bi, X. T. (2011). A review on biomass feedstock properties, preprocessing and handling. *Journal of Biobased Materials and Bioenergy*, 5(2), 173-195
- Waheed, M.A., Lanjewar, H.A., & Sharma M.P. (2022). Biomass Briquetting: A training module for trainers and practitioners. CGIAR.
- Sam, O.J., Olotu, A.F., & Onukwube, E.C. (2023). Characterization of briquettes produced from blended biomass/coal for domestic energy used. *International Journal of Research and Publications Review (IJRPR)*, 4(6), 1884-1892.
- Sanchez, P.D.C., Gayo, V.S., Garcia, K. P.C., & Malingin, F.J. (2022). An overview on the production of bio-briquettes from agricultural waste: Methods, processes, and quality. *Journal of Agricultural and Food Engineering*, 1(1), 36-42.
- Olugbade, T.O., & Ojo, O.A. (2021). Characterization of Briquettes from forest wastes: Optimization approach. *Research in Agricultural Engineering*, 67(3) 112-120.