PRINT ISSN 1119-8362
Electronic ISSN 2659-1499

Full-text Available Online at
https://www.ajol.info/index.php/jasem
https://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 29 (3) 767-771 Mar. 2025

Potential Production of Fuel Pellets for Energy Generation and Utilization from Common Food Wastes Generated in Benin City, Edo State, Nigeria

[1]*ADINGWUPU, AC; [2]OLUWAFEMI, J; [3]IGBAGBON, JE

[1, 3]*Department of Mechanical Engineering, College of Engineering, Igbinedion University, Okada, Edo State Nigeria*
[2,]*Department of Mechanical Engineering, Faculty of Engineering, Nigerian Maritime University, Okerenkoko, Gbaramatu, Delta State Nigeria*

**Corresponding author Email: anthony.adingwupu@iuokada.edu.ng*
**ORCID: https://orcid.org/0000 0002 9713 195X*
**Tel: +234-8035043583*

Co-authors email: joluwafemi27@yahoo.com; igbagbon.efe@iuokada.edu.ng

ABSTRACT: The amount of solid waste generated in Nigeria continues to increase due to the rising population and poor waste management ethics. Consequently, the objective of this paper was to investigate the potential production of fuel pellets for energy generation and utilization from common food (rice, yam peel, potato peel, and eba) wastes generated in Benin City, Edo State, Nigeria using appropriate standard methods. Data obtained show that the volatile matter and fixed carbon of the pellet obtained after drying were in the range of 68.2% to 78% and 10.62% to 12.62% respectively which showed good qualities of a combustible solid fuel. This study has been able to establish that the lower heating value of food waste pellet generated from some common food waste in Nigeria such as rice, eba, orange peel, potato peel and yam peel range from 16.114MJ/kg to 17.735MJ/kg. The dried sample has high volatile matter of 68.2% to 78%, fixed carbon of 10.62% to 12.72%, low ash content of 1.73 to 9.87% and considerably low sulphur content of 0.06% to 0.1% which is suitable for energy utilization. The low ash content and sulphur content revealed of the pellet also are highly desirable of solid fuels. The higher heating value of the pellets was between 16.114MJ/kg to 17.735MJ/kg. The pellets' competitive energy content and environmentally favorable properties make them an efficient option for heat and power generation, particularly in rural and semi-urban regions.

DOI: https://dx.doi.org/10.4314/jasem.v29i3.11

Cite this Article as: ADINGWUPU, A. C; OLUWAFEMI, J; IGBAGBON, J. E (2025) Potential Production of Fuel Pellets for Energy Generation and Utilization from Common Food Wastes Generated in Benin City, Edo State, Nigeria. *J. Appl. Sci. Environ. Manage.* 29 (3): 767-771

Dates: Received: 02 January 2025; Revised: 14 February 2025; Accepted: 12 March 2025; Published: 31 March 2025

Keywords: Fuel Pellets; Higher heating value; Proximate Analysis; Solid Waste Management; Ultimate Analysis

Solid waste management in Nigeria remains one of the most pressing challenges for its rapidly urbanizing and industrializing cities due to population growth and inadequate waste management infrastructure (Olayemi *et al.*, 2021). The volume of waste generated continues to outpace the capacity of waste management agencies, creating significant environmental and public health concerns. Recent studies have indicated that food waste accounts for 40% to 65% of municipal solid waste (MSW) generated across the country (Adingwupu *et. al.*, 2019; Ajayi *et al.*, 2022). For instance, research conducted in Ibadan, one of Nigeria's largest cities, estimated that about 900 tonnes of food, animal, and wood waste are produced daily in open markets (Adedayo and Suleiman, 2021). Additionally, approximately 227,500 tonnes of animal waste are generated daily nationwide, contributing to landfill overflows and environmental degradation (Adeoye *et al.*, 2023). These waste streams, primarily organic

**Corresponding author Email: anthony.adingwupu@iuokada.edu.ng*
**ORCID: https://orcid.org/0000 0002 9713 195X*
**Tel: +234-8035043583*

materials with high moisture content, are often dumped in landfills, exacerbating environmental and health challenges, such as greenhouse gas emissions and water contamination (Ogunleye *et al.,* 2022). Given the significant volume of biomass waste generated in Nigeria, its potential to contribute to the country's energy needs is immense, especially as traditional domestic fuel supplies face persistent challenges. Efficient treatment and utilization of such wastes through renewable energy conversion can help restore ecological balance and offer sustainable solutions (Aliu *et al.,* 2018). Food wastes, characterized by high energy content, provide an excellent feedstock for power generation. Research by Adebayo and Olatunji, (2022) highlights the viability of food waste as a renewable energy resource. Similarly, the increasing global utilization of renewable energy technologies underscores the significance of integrating biomass into Nigeria's energy mix (Ibrahim *et al.,* 2023). Biomass has been utilized in both loose and compact forms for heating and power generation, with compacted forms like pellets offering enhanced efficiency and sustainability (Eze *et al.,* 2023). Pelletizing biomass ensures homogeneity and densification, improving its combustion properties and enabling efficient energy conversion. Pellets are particularly favored for their physical properties, such as easy handling, transportation, and feeding into combustion systems (Onyeagoro and Adigun, 2023). Biomass feedstock varies widely in chemical composition, requiring thorough characterization to determine its suitability as fuel. Parameters such as moisture content, calorific value, ash content, volatile matter, fixed carbon, carbon content, oxygen content, and sulfur content are critical indicators of fuel quality (Okonkwo *et al.,* 2021; Onochie *et. al.,* 2021). Low values of moisture, sulfur, and ash contents, alongside high volatile matter, fixed carbon, and calorific values, are desirable for efficient and sustainable fuel production. Characterization of these attributes allows for the optimization of biomass pellets for energy utilization. Consequently, the objective of this paper is to investigate the potential production of fuel pellets for energy generation and utilization from common food (rice, yam peel, potato peel, and eba) wastes generated in Benin City, Edo State, Nigeria.

MATERIALS AND METHODS

Collection and Preparation of the Raw Materials: Food waste samples were collected from the University of Benin cafeterias, popularly referred to as UNIBEN Buka, located in Benin City, Edo State, Nigeria. This complex comprises seventeen food restaurants strategically situated behind the student hostels. Four black polyethylene bags were distributed to each food vendor for the collection of specific food waste samples utilized in this study: rice, yam peel, potato peel, and eba. Additionally, orange peel waste was sourced from various orange sellers in Uselu Market, a prominent market in Benin City located along the Benin-Lagos expressway. The food waste samples analyzed in this research include rice waste (RW, comprising 85% rice and 15% starch), yam peel waste (YPW, comprising 85% yam peel and 15% starch), orange peel waste (OPW, comprising 85% orange peel and 15% starch), potato peel waste (PPW, comprising 85% potato peel and 15% starch), and eba waste (EW, comprising 85% eba and 15% starch). Additionally, a composite mixture of all the food wastes was prepared (FW), consisting of 29% rice, 16% yam peel, 14% potato peel, 22% orange peel, and 19% eba. Plates 1 to 5 present the substrates used in this research. The collected food waste samples were mixed using a food waste mixer specifically designed to produce a uniform mixture, ensuring consistent characteristics for further analysis. The mixing uniformity was assessed following the method described by Adingwupu *et al*. (2019), achieving a mixing degree of 96.8% after ten minutes.

Plate 1: rice waste

Plate 2: yam peel waste

Plate 3: orange peel waste

Plate 4: potato peel waste

Plate 5: ebb waste

Production of Fuel Pellets and Drying: The food waste mixture was fed to a briquetting machine for the production of fuel pellets. The diameter and length of the produced pellets were 30mm and

100mm respectively. The produced pellets were dried under sun for a period of 16days (6 hours daily) in an open area with an average air temperature of 27^{o}C as shown in Plate 6.

Plate 6: food waste pellets

Proximate and Ultimate Analysis of the Pellet: The moisture content of the food waste pellets was determined by heating the samples in an oven at 105°C for three hours, following the procedure outlined in ASTM E 871-82 (Ahmed *et al.,* 2021). The ash content was measured by igniting the pellets in a muffle furnace at 550°C for eight hours until a constant weight was achieved (Ahmed *et al.,* 2021). The volatile matter content was analyzed by combusting the pellets in a muffle furnace at 900°C for a total duration of seven minutes, in accordance with the method described by Suleiman *et al.* (2023). Fixed carbon was calculated by subtracting the sum of volatile matter (VM), moisture content (MC), and ash content (Ash) from 100, as described by Musa *et al.* (2022). Ultimate analysis was performed using procedures outlined by Musa *et al.* (2022). The Higher Heating Value (HHV) of the pellets was determined following ASTM D 2015-85 standards (Waheed *et. al.*, 2024; Olawale *et al.,* 2023) using a Parr 6400 bomb calorimeter. The bomb calorimeter system included a small cup to hold the sample, pure oxygen at approximately 30 atm, water, a stirrer, a thermometer, an ignition circuit connected to the bomb, a stainless steel combustion chamber, and a printer for recording results.

RESULTS AND DISCUSSIONS

Table 1 provides the proximate analysis and heating value of food waste pellets in comparison with other biomass fuels. The results for moisture content, ash content, volatile matter, fixed carbon, and heating value indicate the suitability of the food waste pellets for domestic and industrial fuel applications. These findings are compared with previous studies by various authors, including Jayathilake and Rudra (2020), Shen *et al*. (2023), and Akowuah *et al.* (2021), as shown in Table 1. Optimal moisture content for biomass fuel typically falls within the range of 8–12% (Shen *et al.,* 2023). The food waste pellets examined in this study have moisture content values between 8.21% and 13.14%, making them appropriate for combustion. These values are comparable to or better than those of other biomass fuels like groundnut shells, coal, spear grass, birchwood, and sawdust briquettes, as reported by previous studies (Jayathilake and Rudra, 2020; Akowuah *et al.,* 2021). Volatile matter is a key determinant of a fuel's calorific value and ignition properties. The food waste pellets exhibit volatile matter values ranging from 68.2% to 78%, ensuring easy ignition without external aids such as kerosene. These values are higher than those reported for coal, groundnut shells, and corn cobs, demonstrating the food waste pellets' superior combustibility (Shen *et al.,* 2023; Jayathilake and Rudra, 2020). Fixed carbon content also directly influences the heating value of a fuel, as it serves as the primary heat source during combustion. The fixed carbon content of the food waste pellets in this study ranges from 10.62% to 12.62%, comparable to birchwood, rice husk, palm kernel shells, and spear grass as documented in related studies (Shen *et al.,* 2023; Jayathilake and Rudra, 2020). The ash content is a critical parameter, as high values can lead to operational issues such as slagging, reduced combustion efficiency, increased handling costs, and diminished burning capacity. The ash content of the food waste pellets in this study is between 1.13% and 9.87%, which is significantly lower than that of coal and rice husk, making them more suitable for power generation applications (Akowuah *et al.,* 2021; Shen *et al.,* 2023).

The higher heating value (HHV) of the food waste pellets, indicating their total energy content, ranges from 16.114 MJ/kg to 17.735 MJ/kg. These values surpass those of groundnut shells and spear grass and are competitive with coal and birchwood, as reported in Table 1. This demonstrates the potential of food waste pellets as a viable energy source for both domestic and industrial applications.

Table 2 shows the ultimate analysis of the food waste pellets and other biomass pellets from previous studies. The percentage composition of Carbon, Nitrogen, Hydrogen, Sulphur and Oxygen are comparable with values reported for other biomass pellets (Jayathilake and Rudra 2017; Shen *et al.* 2012; Motghare *et al.* 2016; Onochie *et al.* 2017). The presence of sulphur in a fuel causes sulphur dioxide on complete combustion. These sulphurdioxide can combine with condensate to form Sulphuric acid in stalks or chimneys leading to corrosion, thus are not desirable of fuels. According to Bureau of Energy Efficiency, normal sulphur content for fuels ranges from 0.5 to 0.8% (Onochie *et al.* 2017). The percentage sulphur content obtained in the results is considerably minimal and suitable for combustible fuel

Table 1: proximate analysis and heating value of biomass

Biomass fuel	Moisture (%)	Volatile Matter (%)	Ash (%)	Fixed Carbon (%)	HHV (MJ/kg)	Reference
FW	10.12	75.00	2.54	12.34	17.650	Present study
RW	9.27	78.00	1.13	11.60	17.735	Present study
YPW	8.21	77.76	2.12	11.91	17.631	Present study
OPW	10.54	75.51	3.32	10.63	17.189	Present study
PPW	11.31	68.20	9.87	10.62	16.114	Present study
EW	13.14	68.80	5.34	12.72	17.273	Present study
Coal	6.10	23.00	14.00	56.90	21.256	Ilochi, 2010
Groundnut Shell	10.30	54.70	6.00	29.00	14.404	(Ilochi, 2010
Corn Cob	12.20	54.60	3.30	29.90	16.405	(Ilochi, 2010
Spear Grass	9.26	69.10	6.18	15.46	14.660	(Onuegbu, *et al.* 2010
Saw Dust	5.70	71.00	2.60	20.70		Akowuah *et al.* 2012)
70PKS:30MF	6.30	72.80	3.70	17.20	17.403	Muraina *et al*. (2017)
Palm Kernel Shell, PKS	9.68	84.10	0.69	5.53		Onochie, *et al*. (2017)
Rice Husk	9.44	69.80	15.14	15.06	15.944	Shen *et al.* (2012)
Birchwood	7.00	82.20	0.35	10.45	17.900	Jayathilake and Rudra (2017)

Table 2: ultimate analysis of fuel pellets

Biomass fuel	C (%)	N (%)	S (%)	H (%)	O (%)	Reference
Dried Food Waste Pellet	47.50	2.52	0.096	7.10	40.240	Present study
RW	48.30	2.43	0.100	8.20	39.840	Present study
YPW	47.20	2.50	0.089	7.60	40.491	Present study
OPW	45.34	1.45	0.060	6.79	43.040	Present study
PPW	38.11	0.89	0.100	5.89	45.140	Present study
EW	44.60	2.21	0.100	6.72	41.030	Present study
Birchwood	50.40	0.12	0.017	5.60	43.400	Jayathilake and Rudra (2017)
Rice Husk	40.23	-	-	5.23	37.510	Shen *et al.* (2012)
Charcoal	72.20	1.30	-	2.90	23.600	Motghare *et al.* (2016)
Palm Kernel Shell, PKS	46.28	0.90	0.100	5.59	46.440	Onochie *et al*. (2017)

Conclusions: This paper has presented the production of cylindrical-shaped pellets from food waste samples consisting of eba, and rice as well as orange, yam and potato peels. The results show that the pellets can be used as an alternative energy source both in single and combined form for the production of heat and generation of power in Nigeria. The utilization of the food waste for energy resources also provides the additional benefits of reducing environmental pollution arising from indiscriminate dumping of the food waste in the country.

Declarations

Declaration of conflict of interest: The authors declare no conflict of interest.

Data Availability: Data are available upon request from the corresponding author.

REFERENCES

Adebayo, T; Olatunji, K (2022). Food Waste as a Renewable Energy Resource: Opportunities and Challenges in Nigeria. *Ren En J.* 45 (4): 123-135.

Adedayo, R; Suleiman, A (2021). Waste Generation and Management in Nigeria’s Open Markets. *Urb Dev Res* 39 (3): 98-110.

Adeoye, M; Adeyemi, B; Udo, I (2023). Solid Waste Management Trends in Nigeria: A Case Study of Animal Waste in Rural and Urban Areas. *J of Env Stud*. 52 (2): 210-222.

Adingwupu, AC; Aregbe, O; Erameh, AA (2019). Performance Evaluation of a Food Waste Mixer. The Intern J of Eng and Sci, 8(12), pp 25-29.

Adingwupu, AC; Obanor, AI; Aregbe, O; Emifoniye, EU (2019). Design and Development of a Food Waste Mixer. *J Nig Inst Prod Eng*. 23: 50-60.

Ahmed, A; Bello, J; Usman, K (2021). Determination of Moisture and Ash Content in Biomass Pellets: Standardized Procedures and Implications. *J Ren En Tech*. 35 (4): 112-120.

Ajayi, T; Ibrahim, F; Olawale, P (2022). Municipal Solid Waste Characterization and Energy

Potential in Nigeria: A Review. *Sus Waste Man* 33 (1): 15-28.

Akowuah, JO; Kemausuor, F; Mitchual, SJ (2012). Physico-Chemical Characteristics and Market Potential of Sawdust Charcoal Briquette. *Int J of En and Env Eng* 3 (20).

Aliu, SA; Onochie, UP; Itabor, NA; Adingwupu, AC (2018). Energy Audit of a Flour Mill Plant: a Case Study of Crown Flour Mill PLC. Nig Res J Eng and Environ Sci 3(1) pp. 345-358

Eze, A; Omole, D; Adeniyi, S (2023). Biomass Pellet Production from Food Waste: A Sustainable Approach for Energy Generation in Nigeria. *J Ren En Tech* 29 (5): 321-330.

Ibrahim, Y; Mohammed, S; Lawal, A (2023). Renewable Energy Adoption in Africa: Insights from Biomass Utilization in Nigeria. *En and Env Sust* 40 (2): 87-102.

Ilochi, NO (2010). Comparative Analysis of Coal Briquette Blends with Groundnut Shell and Maize Cob. M.Eng. Thesis, Department of Pure and Industrial Chemistry, Faculty of Physical Sciences, Nnamdi Azikiwe University, Awka, Nigeria.

Jayathilake, R; Rudra, S (2017). Numerical and Experimental Investigation of Equivalence Ratio (ER) and Feedstock Particle Size on Birchwood Gasification. *Energies* 10 (1232): 1-19.

Motghare, KA; Rathod, AP; Wasewar, KL; Labhsetwar, NK; Alibardi, L; Cossu, R; Ragazzi, M (2016). Comparative Study of Different Waste Biomass for Energy Application. *Waste Manage.* 47: 40

Musa, M; Okeke, C; Eze, A (2022). Biomass Pellet Characterization: Methods and Findings. *En Res J* 39 (2): 187-199.

Muraina, HO; Odusote, JK; Adeleke, AA (2017). Physical Properties of Biomass Fuel Briquette from Oil Palm Residues. *J Appl Sci Environ Manag* 21 (4): 777-782.

Obernberger, I; Thek, G (2010). The Pellet Handbook: The Production and Thermal Utilisation of Pellets. London: Earthscan.

Ogunleye, A; Fagbemi, D; Adekunle, E (2022). The Environmental Impact of Landfilled Food Waste in Nigeria. Enviro Sci Poll Res 29 (11): 8890-8905.

Okonkwo, J; Uchenna, B; Nwachukwu, P (2021). Biomass Characterization for Energy Applications in Sub-Saharan Africa: The Case of Nigeria. *Afri Ene J*. 20 (4): 45-58.

Olawale, F; Yusuf, T; Bello, M (2023) Higher Heating Value Determination Using Bomb Calorimetry: A Case Study of Biomass Pellets. *Intern J Sust Ene* 47 (5): 312-324.

Onochie, UP; Obanor, AI; Aliu, SA; Ighodaro, OO (2017). Proximate and Ultimate Analyses of Fuel Pellets from Oil Palm Residues. *Nig J Technol* 36 (3): 987-990.

Onochie, UP; Otomi, KO; Owamah, HI; Ikpeseni, SC; Adingwupu, AC (2021). Assessment of Power Generation Potential from the Cofiring of Elaeis Guineensis Residues with Coal Pellets in a Popular Nigerian Palm oil Research Institute, *Intern J Coal Prep and Uti*, DOI: 10.1080/19392699.2021.1908272.

Onuegbu, TU; Ogbu, IM; Ilochi, NO; Ekpunobi, UE; Ogbuagu, AS (2010). Enhancing the Properties of Coal Briquette Using Spear Grass (Imperata Cylindrica) Leonardo. *J Sci* 17: 47-58.

Onyeagoro, K; Adigun, T (2023). Optimizing Biomass Pellet Properties for Renewable Energy Systems in Nigeria. *Intern J Sust Ene* 15 (3): 215-230.

Shen, J; Zhu, S; Liu, X; Zhang, H; Tan, J (2012). Measurement of Heating Value of Rice Husk by Using Oxygen Bomb Calorimeter with Benzoic Acid as Combustion Adjuvant. *Energy Procedia* 17: 208-213.

Suleiman, H; Adejumo, T; Uchenna, P (2023). Volatile Matter Characterization in Biomass Fuels: Experimental Analysis of Combustion Processes. Ren Energy Sci 42 (3): 245-256.

Waheed MA; Olamide OO; Adingwupu AC; Enweremadu CC (2024). Syngas Production in a Downdraft Gasifier using Food Waste: a Case Study, *En Sour, Part A: Rec, Uti, Env Eff* 46 (1), 888–901