Journal of
Modern Chemistry &
Chemical Technology

ISSN: 2229-6999 (Online)
ISSN: 2321-5208 (Print)
Volume 17, Issue 2, 2026
July–December
DOI (Journal): 10.37591/JoMCCT

https://journals.stmjournals.com/jomcct

Research JoMCCT

Analytical Examination on the Characterization of Wood Materials for Biohydrogen Production

Ukpaka, Chukwuemeka. Peter[1], Ikpe Otor Matthew[2], Victor Chukwuemeka Ukpaka[3], Joy Chukwuemeka Peter Ukpaka[4], Abraham Peter Ukpaka[5]*

Abstract

Investigation was carried out with the aim to characterized some of wood materials obtained in Rivers State of Nigeria. The wood samples considered are Agba, Mahogany and Ako, in which the obtained result demonstrates variation in the ultimate composition as well as relative hydrogen gas produced with the action of anaerobic organisms, especially, for the fermented process. The production of the biohydrogen gas from each of the wood material sampled is encouraging and increase in $BioH_2$ production is dependent of increase in biomass build-up and contact time. The research revealed that the concentration of the volatile matter is 69.8% and fixed carbon concentration is 20.4%. The characterization of the wood in the area of moisture content revealed Agbo > Aka > Mahogany, but in the case of volatile matter mahogany wood is equal to the Ako wood and both of them greater than Agba wood. Mahogany wood and in the area of Ash content is a contributing factor to the $BioH_2$ yield as well as other products such as Bio CH_4, Bio CO_2 and Bio H_2S. The application of ultimate analysis was carried out for the purpose of evaluating the weight (%wt) of some substance such as Carbon (C), Hydrogen (H), Oxygen (O) and Nitrogen (N) and the obtained values are 53.2 %wt, 6.1 %wt, 40.4 %wt, 0.2 %wt, for Agba wood, 48.7 %wt, 6.4 %wt, 44.5 %wt and 0.3 %wt for mahogany wood as well as 50.04 %wt, 6.2 %wt, 43.5 %wt and 0.22 %wt for Ako wood sample. The obtained values from the characterization of the three different wood samples revealed its contribution and potential to be used in the production of $BioH_2$.

Keywords: Biohydrogen production, wood biomass characterization, ultimate analysis, proximate analysis, anaerobic fermentation.

***Author for Correspondence**
Abraham Peter Ukpaka
E-mail:abraham.ukpaka@lpunetwork.edu.ph
upaksabraham24@gmail.com

[1]Professor, Department of Chemical/Petrochemical Engineering, Rivers State University Port Harcourt, Rivers State, Nigeria
[2]Research Student, Department of Chemical/Petrochemical Engineering, Rivers State University Port Harcourt, Rivers State, Nigeria
[3]Research Student, College of Engineering, Computer Studies and Architecture, Department of Industrial Engineering, Lyceum of the Philippines University Cavite, Philippines
[4]Research Student, Department of Pharmacy, MSB Medical School Berlin GmbH - Hochschule für Gesundheit und Medizin.
[5]Research Student, College of Engineering, Computer Studies and Architecture, Department of Computer Engineering, Lyceum of the Philippines University Cavite, Philippines

Received Date: June 17, 2026
Accepted Date: July 15, 2026
Published Date: August 17, 2026

Citation: Ukpaka, Chukwuemeka. Peter, Ikpe Otor Matthew, Victor Chukwuemeka Ukpaka, Joy Chukwuemeka Peter Ukpaka, Abraham Peter Ukpaka. Analytical Examination on the Characterization of Wood Materials for Biohydrogen Production. Journal of Modern Chemistry & Chemical Technology. 2026; 17(2): 59–64p.

INTRODUCTION

Green hydrogen is increasingly viewed as a keystone in the global transition towards decarbonized energy systems. Defined as hydrogen produced through water electrolysis powered entirely by renewable energy sources such as wind, solar, or hydro, green hydrogen stands apart due to its lack of greenhouse gas (GHG) emissions throughout the production process [1-2]. It contrasts with grey, blue, and brown hydrogen (Figure 1), which are derived from fossil fuels and are associated with considerable carbon emissions.

The definition has now been widely standardized, particularly in leading economies such as China and the European Union, where specific metrics for lifecycle emissions are used to certify hydrogen as green [4-5].

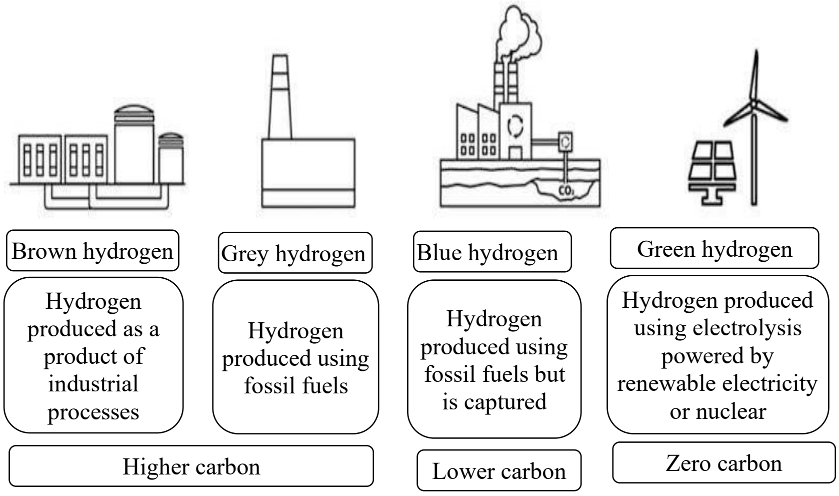

Figure 1. Hydrogen Production Technologies [3].

Green hydrogen can be produced via several pathways, including electrolysis of water using electricity from renewable sources, photoelectrochemical (PEC) water splitting, bio photolysis, and biological methods such as dark fermentation and photo fermentation [6-7]. Electrolysis is currently the most mature and commercially scalable method, particularly through proton exchange membrane (PEM) and alkaline electrolyzers, although newer technologies like solid oxide electrolysis cells (SOECs) are gaining momentum for their high efficiency and potential for integration with industrial heat sources [8-9]. Biological routes, especially dark fermentation offers the advantage of utilizing organic waste or lignocellulosic biomass as feedstocks, aligning with circular economy principles [10]. This aligns well with the broader vision of green hydrogen as a decarbonization tool that does not compete with food resources or require intensive land use [11]. Nonetheless, biological routes often suffer from lower yields and limited technological maturity compared to electrochemical processes [12]. The advantages of green hydrogen are both environmental and strategic. From an environmental perspective, the most significant benefit is its near-zero carbon footprint, particularly when the full hydrogen value chain from electricity production to end-use is powered by renewable sources [13]. This makes green hydrogen a critical enabler of sectoral decarbonization, particularly in hard-to-abate sectors such as steel manufacturing, aviation, shipping, and chemical industries [14-15].

From a geopolitical and economic standpoint, green hydrogen also promises energy independence for countries that are heavily reliant on fossil fuel imports. Research conducted by Panchenko and others have highlighted the potential for countries like Chile, Australia, Namibia, and Saudi Arabia to become net exporters of green hydrogen due to their vast renewable energy resources and favourable solar irradiance [16]. In this context, green hydrogen is not only an energy vector but also a geoeconomic asset, likely to redefine global energy trade dynamics over the coming decade [17].

Furthermore, green hydrogen's versatility enhances its strategic importance. It can be used as a fuel, a feedstock in ammonia and methanol production, a storage medium for excess renewable electricity, and a means for grid balancing through power-to-gas systems [18-19]. Such applications align with national and regional climate strategies aimed at achieving net-zero emissions by mid-century [20].

However, the challenges associated with green hydrogen production and deployment remain substantial. The most pressing issue is the high cost of production, driven by the capital-intensive nature of electrolyser technology, operational inefficiencies, and the cost of renewable electricity [21]. Current estimates place green hydrogen production at two to three times the cost of grey hydrogen, making it economically uncompetitive without substantial policy support or carbon pricing mechanisms [22].

This cost differential is partly due to electrolyzer inefficiencies, which range between 60–80% depending on the technology and operational conditions. Moreover, the intermittent nature of renewable

ISSN: 2229-6999 (Online), ISSN: 2321-5208 (Print)

energy sources poses challenges for electrolyzer operation, requiring complex integration with storage systems to ensure stable production [23]. Advanced control systems, real time demand matching, and hybrid power systems are being explored as solutions, but these further increase capital and operational expenditure [24]. Another challenge is scalability and infrastructure. While small-scale pilot projects have proliferated across Europe, Asia, and the Americas, few green hydrogen facilities have reached industrial scale. Massive investment is needed in electrolyzer manufacturing capacity, hydrogen transport pipelines, storage infrastructure, and refuelling stations [25-26]. In the absence of such infrastructure, the promise of a hydrogen-based economy risks remaining theoretical.

MATERIALS AND METHODS

For characterization of wood materials (Mahogany and Ako wood), this research explored proximate analysis and ultimate analysis, this will help to better understand the substrate.

Sample collection and Preparation

The sawdust used for this research was obtained from Mill Workshop, Oyigbo Road Port Harcourt in Rivers State. It was dried outdoors at an average temperature of about 30ºC to lower moisture content. This was followed by milling to 1.00mm, 2.00mm and 3.00mm particle size. The dried and milled Sawdust was preserved in a desiccator prior to analyses.

Proximate Analysis

This provided information required for moisture, volatile matter, and ash as well as fixed carbon contents of sawdust. These properties are relevant to the thermal conversion of biomass material. This research will follow the procedure described by Abdolvand & Sadeghiamirshahidi, 2024 [27].

Analysis

This analysis will provide information on the elemental components of sawdust both in qualitative and quantitative terms. A Thermos Quest CHNS elemental analyzer was used for this purpose. The proportion of carbon (C), hydrogen (H), sulphur (S), and nitrogen (N) were determined, while Oxygen (O), was obtained by difference. This research will follow the procedure described by Abdolvand & Sadeghiamirshahidi, 2024 [27].

RESULTS AND DISCUSSION

The characterization results of the three wood materials (Table 1): Agba, Mahogany, and Ako, reveal clear differences in their proximate and ultimate compositions, and these differences help explain their relative biohydrogen gas yields during anaerobic fermentation. Agba shows a slightly higher moisture content than the Mahogany and Ako, which diluted the concentration of fermentable organic matter available for microbial conversion. However, its volatile matter (69.8%) and fixed carbon (20.4%) values indicate a balanced distribution of readily degradable and stable carbon fractions. The moderate volatile matter suggested the reason Agba released high fermentable compounds at a reasonable rate during hydrolysis, supporting steady hydrogen production.

Its lower ash content (0.6%) also provides a cleaner substrate environment with minimal mineral interference, enhancing microbial performance during dark fermentation.

Mahogany, on the other hand, exhibits the highest volatile matter (72.2%) among the three materials, which generally indicates a higher proportion of thermally degradable organic fractions capable of supporting microbial hydrogen generation. This implies that Mahogany should theoretically produce more readily available substrates that can be converted into hydrogen. However, its relatively higher ash content (1.2%) introduces more inorganic impurities, which can inhibit microbial activity by buffering pH or adsorbing essential enzymes. Additionally, Mahogany's lower fixed carbon content (18.4%) suggests reduced long-term carbon availability, limiting sustained hydrogen generation over prolonged retention times. While the higher hydrogen content in its ultimate analysis (6.4%) is favourable, the relatively low carbon content (48.7%) reduces the overall energy density and may limit total hydrogen yield.

Table 1: Characterization of wood materials.

Parameter	Agba (nigerian cedar) (%wt)	Mahogany wood (%wt)	Ako wood (%wt)
Proximate analysis			
Moisture content	9.2	8.2	8.4
Volatile matter	69.8	72.2	72.2
Fixed carbon	20.4	18.4	18.6
Ash content	0.6	1.2	0.8
Ultimate analysis			
Carbon (C)	53.2	48.7	50.04
Hydrogen (H)	6.1	6.4	6.2
Oxygen (O)	40.4	44.5	43.5
Nitrogen (N)	0.20	0.30	0.22
Sulphur (S)	0.10	0.10	0.04

Ako wood presents a proximate profile similar to Mahogany, with a volatile matter of 72.2% and a slightly higher fixed carbon value (18.6%), which indicates moderate stability and good fermentable potential. Its ash content (0.8%) is lower than Mahogany's, creating a more favourable environment for microbial metabolism. The ultimate analysis shows a relatively higher carbon fraction (50.04%) compared to Mahogany, meaning Ako has a slightly richer organic matrix favourable for hydrogen production. Meanwhile, its hydrogen and oxygen contents (6.2% and 43.5%) maintain a balanced elemental composition that supports efficient fermentation. The relatively low sulphur content (0.04%) also minimizes the risk of generating inhibitory compounds such as hydrogen sulphide during fermentation.

CONCLUSION

The analytical examination of the selected wood materials demonstrated their significant potential as renewable feedstocks for biohydrogen ($BioH_2$) production through anaerobic digestion in a biodigester. The study confirmed that the three different wood species possess suitable physicochemical characteristics that support microbial degradation and subsequent gas generation. Besides biohydrogen, the anaerobic digestion process also resulted in the production of other gaseous by-products, including methane (CH_4), carbon dioxide (CO_2), and hydrogen sulphide (H_2S), indicating the active biodegradation of lignocellulosic biomass. These findings highlight the suitability of wood biomass as a sustainable substrate for renewable energy generation while also demonstrating its potential contribution to integrated bioenergy systems.

The results further revealed that the efficiency of biohydrogen production is strongly influenced by the intrinsic properties of wood materials. Parameters such as moisture content, ash content, volatile matter, and fixed carbon play critical roles in determining the biodegradability of the biomass and the overall gas yield. Appropriate moisture levels facilitate microbial activity, whereas volatile matter provides readily degradable organic compounds that enhance hydrogen generation. In contrast, excessive ash content and higher fixed carbon may reduce substrate conversion efficiency, thereby affecting the overall productivity of the biodigester.

Furthermore, the characterization of wood materials before their utilization provides valuable information for optimizing biodigester operating conditions. Knowledge of the physicochemical composition enables the adjustment of process parameters such as substrate loading, retention time, temperature, and microbial inoculum, thereby promoting greater biomass accumulation and improved hydrogen production within the bioreactor. This preliminary assessment also supports the selection of the most suitable wood species for efficient biohydrogen generation. Overall, the characterization approach enhances process efficiency, improves the operational performance of the biodigestion system, and contributes to the development of sustainable and economically viable biohydrogen production technologies. The findings of this study emphasize the importance of biomass characterization as a fundamental step toward maximizing renewable hydrogen production and advancing clean energy technologies based on lignocellulosic feedstocks.

REFERENCES

1. Oliveira AM, Beswick RR, Yan Y. A green hydrogen economy for a renewable energy society. Current Opinion in Chemical Engineering. 2021 Sep 1; 33:100701.
2. Abad AV, Dodds PE. Green hydrogen characterisation initiatives: Definitions, standards, guarantees of origin, and challenges. Energy Policy. 2020 Mar 1; 138:111300.
3. Mohan, S.V.; & Pandey, A. (2021). Biohydrogen production: An introduction. In Biohydrogen; Elsevier: Amsterdam, The Netherlands; 1–24.
4. Lin YH, Zheng HX, Juan ML. Biohydrogen production uses waste activated sludge as a substrate from fructose-processing wastewater treatment. Process Safety and Environmental Protection. 2012 May 1;90(3):221-30.
5. Dong ZY, Yang J, Yu L, Daiyan R, Amal R. A green hydrogen credit framework for international green hydrogen trading towards a carbon neutral future. International Journal of Hydrogen Energy. 2022 Jan 5;47(2):728-34.
6. Osman SH, Mat Yatim NS, Jehan Elham OS, Shaari N, Zakaria Z. Three decades of hydrogen energy research: a bibliometric analysis on the evolution of green hydrogen technologies. Sustainable Energy & Fuels. 2025 Jun 10;9(12):3182-202.
7. Zhang YH. Hydrogen production from carbohydrates: a mini review. Sustainable Production of Fuels, Chemicals, and Fibers from Forest Biomass. 2011:203-16.
8. Wei J, Liu ZT, Zhang X. Biohydrogen production from starch wastewater and application in fuel cells. International Journal of Hydrogen Energy. 2010 Apr 1;35(7):2949-52.
9. Squadrito G, Maggio G, Nicita A. The green hydrogen revolution. Renewable Energy. 2023 Nov 1; 216:119041.
10. Boettcher SW. Introduction to green hydrogen. Chemical Reviews. 2024 Dec 11;124(23):13095-8.
11. Razmi AR, Sharifi S, Gholamian E, Arabkoohsar A, Shahbakhti M. Green hydrogen. InFuture grid-scale energy storage solutions 2023 Jan 1 (pp. 573-619). Academic Press.
12. Domalanta MR, Bamba JN, Matienzo DD, del Rosario-Paraggua JA, Ocon J. Pathways towards achieving high current density water electrolysis: from material perspective to system configuration. ChemSusChem. 2023 Jul 7;16(13): e202300310.
13. Olabi AG, Abdelkareem MA, Mahmoud MS, Elsaid K, Obaideen K, Rezk H, Wilberforce T, Eisa T, Chae KJ, Sayed ET. Green hydrogen: Pathways, roadmap, and role in achieving sustainable development goals. Process Safety and Environmental Protection. 2023 Sep 1; 177:664-87.
14. Ajanovic A, Sayer M, Haas R. On the future relevance of green hydrogen in Europe. Applied Energy. 2024 Mar 15; 358:122586.
15. Shan R, Kittner N. Sector-specific strategies to increase green hydrogen adoption. Renewable and Sustainable Energy Reviews. 2025 May 1; 214:115491.
16. Panchenko VA, Daus YV, Kovalev AA, Yudaev IV, Litti YV. Prospects for the production of green hydrogen: Review of countries with high potential. International Journal of Hydrogen Energy. 2023 Feb 8;48(12):4551-71.
17. Tian QN, Yao SQ, Shao MJ, Zhang W, Wang HH. Origin, discovery, exploration and development status and prospect of global natural hydrogen under the background of “carbon neutrality”. China Geology. 2022 Oct 1;5(4):722-33.
18. Schrotenboer AH, Veenstra AA, uit het Broek MA, Ursavas E. A Green Hydrogen Energy System: Optimal control strategies for integrated hydrogen storage and power generation with wind energy. Renewable and sustainable energy reviews. 2022 Oct 1; 168:112744.
19. Sikiru S, Oladosu TL, Amosa TI, Olutoki JO, Ansari MN, Abioye KJ, Rehman ZU, Soleimani H. Hydrogen-powered horizons: Transformative technologies in clean energy generation, distribution, and storage for sustainable innovation. International Journal of Hydrogen Energy. 2024 Feb 22; 56:1152-82.
20. Srivastava N, Srivastava M, Malhotra BD, Gupta VK, Ramteke PW, Silva RN, Shukla P, Dubey KK, Mishra PK. Nanoengineered cellulosic biohydrogen production via dark fermentation: a novel

approach. Biotechnology advances. 2019 Nov 1;37(6):107384.
21. Yang G, Wang J. Enhancing biohydrogen production from waste activated sludge disintegrated by sodium citrate. Fuel. 2019 Dec 15; 258:116177.
22. Farrell N. Policy design for green hydrogen. Renewable and Sustainable Energy Reviews. 2023 May 1; 178:113216.
23. Ma N, Zhao W, Wang W, Li X, Zhou H. Large scale of green hydrogen storage: Opportunities and challenges. International Journal of Hydrogen Energy. 2024 Jan 2; 50:379-96.
24. Raman R, Nair VK, Prakash V, Patwardhan A, Nedungadi P. Green-hydrogen research: What have we achieved, and where are we going? Bibliometrics analysis. Energy Reports. 2022 Nov 1; 8:9242-60.
25. Wappler M, Unguder D, Lu X, Ohlmeyer H, Teschke H, Lueke W. Building the green hydrogen market–Current state and outlook on green hydrogen demand and electrolyzer manufacturing. International Journal of Hydrogen Energy. 2022 Sep 15;47(79):33551-70.
26. Maka AO, Mehmood M. Green hydrogen energy production: current status and potential. Clean Energy. 2024 Apr;8(2):1-7.
27. Abdolvand Y, Sadeghiamirshahidi M. Soil stabilization with gypsum: A review. Journal of Rock Mechanics and Geotechnical Engineering. 2024 Dec 1;16(12):5278-96.

