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Analysis on mechanical properties of AA6061/Rice husk ash composites produced through stir casting technique

N.E. Udoye [a,*], O.J. Nnamba [a], O.S.I. Fayomi [a,c], A.O. Inegbenebor [a], K.J. Jolayemi [b]

[a] Department of Mechanical Engineering, College of Engineering, Covenant University, Ota, Lagos State, Nigeria
[b] Department of Civil Engineering, College of Engineering, Covenant University, Ota, Lagos State, Nigeria
[c] Department of Chemical, Metallurgical and Materials Engineering, Tshwane University of Technology, P.M.B, X680, Pretoria, South Africa

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ABSTRACT

Metal matrix composites have been utilized in the field of engineering and technology. In this study, fabrication was done by stir casting techniques and the mechanical properties of AA6061/rice husk ash were assessed. The cast were produced with liquid metallurgy route through the reinforcement of 2–8 weight percentages of particle sizes of 75 μm rice husk ash. The microstructural test like SEM/EDS and mechanical properties were studied. From the results, the mechanical properties were found to increase at 8% rice husk ash reinforcement. SEM images revealed that homogenous dispersal of particulates without voids occur in cast and an increase up to 8% rice husk ash revealed substantial blending of matrix and reinforcement as evidenced in the microstructure examination.

Selection and peer-review under responsibility of the scientific committee of the International Conference on Advanced Materials Behavior and Characterization.

1. Introduction

Metal matrix composite (MMC) is made up of a wide range of different materials that can be explained by the metal matrix, the geometry and the type of reinforcement [1]. MMCs are reinforced metals with fibres, particles or monofilaments as reinforcements. It is a structural material of light weight that can be used in the aerospace industry [2,3]. Aluminium based composites are always by far the most used materials [4]. AMMC has remained the best potential candidate for research in producing viable engineering components [5,6]. Aluminium 6061 is an alloy of aluminium that exhibits mechanical properties that make it wide used in industries. Some of its properties such as hardness and tensile strength may not be suitable for industries hence, the reason for reinforcement with a biodegradable, agro waste product such as rice husk ash (RHA) [7]. RHA particles are used for its large silica content, low cost and its availability. AMMCs exhibits several properties which includes high specific strength, low density, high damping capacity, high ability to conduct thermally, low expansion coefficient and high temperature resistance [8]. In the present research, aluminium alloy is reinforced with 2–8% of RHA to enhance the mechanical characteristics of AA6061/RHA composite. Rice husk is a low cost substance that can be used to manufacture silicon carbide whiskers, which is in turn utilized to reinforce cutting tools that are ceramic in nature [9].

2. Materials and methods

2.1. Selection of matrix and reinforcement

2.1.1. Matrix material

Al-Mg-Si metal matrix composite, known as AA6061 alloy originally called Alloy 61S is chosen because it exhibits superior mechanical properties, fine welding ability and extrusion property. The chemical properties of AA6061 is shown in Table 1.

The material used as reinforcement is selected based on its properties and individual applications. Rice husk ash was used in this work with particle size of 75 μm in the %wt of 0, 2, 4, 6 and 8. This was selected for use because it consists of up to 80–90% of amorphous silica that can be used in improving mechanical properties.

2.2. Preparation of aluminium matrix composite

The AA6061 aluminium alloy reinforced with 2%, 4%, 6% and 8 wt% RHA was produced by stir casting technique. At first, 3 kg of Aluminium 6061 was poured into a graphite crucible and melt

* Corresponding author.
E-mail address: nduka.udoye@covenantuniversity.edu.ng (N.E. Udoye).

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Table 1
Chemical properties of AA6061.

Composition	Al	Si	Mg	Cu	Cr	Mn	Ti	Zn	Fe
Weight (%)	97	0.5	1.0	0.3	0.25	0.14	0.13	0.22	0.5

ii. Reinforcement

at a temperature of 750 °C in a pit furnace. As the aluminium metal melted, 2 g of Mg was included to the melt as a wetting agent to reduce casting fluidity and surface tension of the molten aluminium. Rice husk ash particles were heated to 200 °C for 1 h to eliminate the moisture content. The graphite stirrer was lowered and the preheated RHA at a temperature of 600 °C was charged slowly into the melt for uniform distribution. Fig. 1 shows the stir casting fabrication set up.

2.3. Microstructural characteristics of AA6061/RHA

Microstructural examination was carried out for the produced composites with different percentages of reinforcement. To analyse the microstructure, a part of the surface was polished with different grade of emery papers to develop as a mirror surface. After the cleaning, the polished surface was kept in a crucible to protect it from atmospheric contact. The cast surfaces were examined using SEM/EDS at different magnifications and homogenous particle distribution was noticed in matrix composite with magnifying microstructures.

2.4. Mechanical properties

Mechanical properties for prepared composites of varying reinforcements were assessed in hardness and tensile properties. The Brinell hardness was measured at a load of 100 g for 15 s. The Brinell hardness number is gotten from equation 1. The universal testing machine (UTM) SM1000 was used in this work for testing the material tensile strengths. Percentage of elongation is calculated by using stress–strain curves for all the cast.

$$BHN = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)} \quad (1)$$

where
P = applied load (kilo Newton)
D = indenter diameter (square millimeters)
d = indentation diameter (square millimeters) [9,10].

Tensile test of prepared samples was estimated with SM1000 universal testing machine according to ASTM A370 standards. Fig. 2 shows the developed composite material before tensile test. The universal testing machine (UTM) was used in testing for the material tensile strength. The sample used were of diameter 10 mm and gauge length 170 mm which was machined from the cast composites with the gauge length of the specimen parallel to the longitudinal axis of the cast. The machine used a load capacity of 100kN to determine the strength of the developed material.

3. Results and discussion

3.1. Microstructure

The surface morphology of the composites was analysed using SEM/EDS to reveal the surface morphology of the different percentage reinforcement of the composite and the elemental composition of the constituents of the produced composites. Fig. 3 shows SEM/EDS of starting material in which EDS revealed aluminium as the major constituents in the sample. Fig. 4 shows the microstructure of AA6061 reinforced with 2% RHA. It shows equal distribution of the RHA and there is no sign of cracks and porosity in cast. The EDS analysis shows an improvement in the matrix ability to retain silica which confirms that there is abundance of SiO_2 in the RHA

Fig. 2. Tensile specimens.

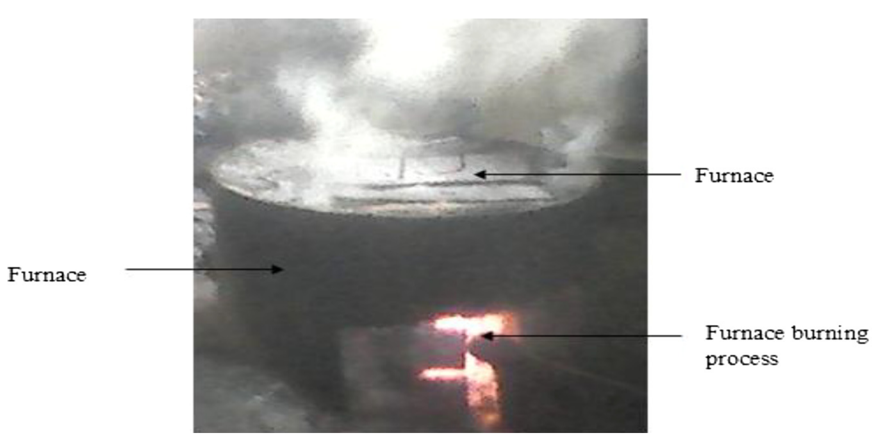

Fig. 1. Stir casting fabrication set up.

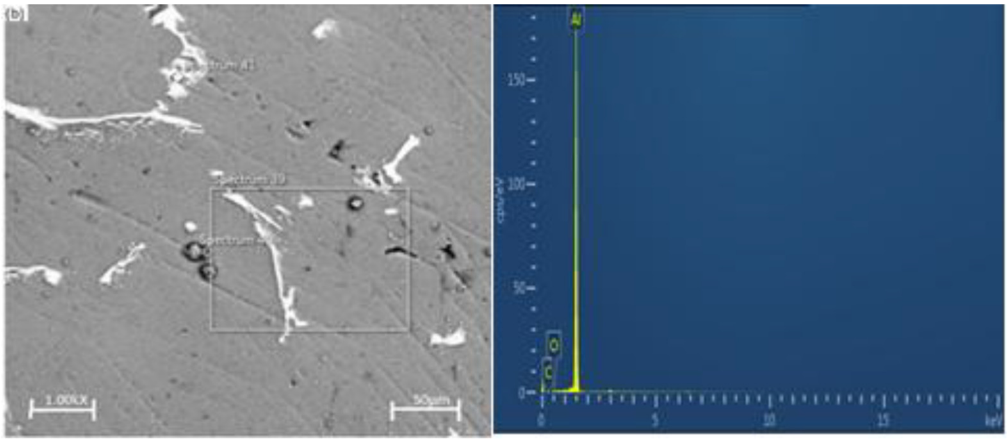

Fig. 3. SEM/EDS of starting aluminium.

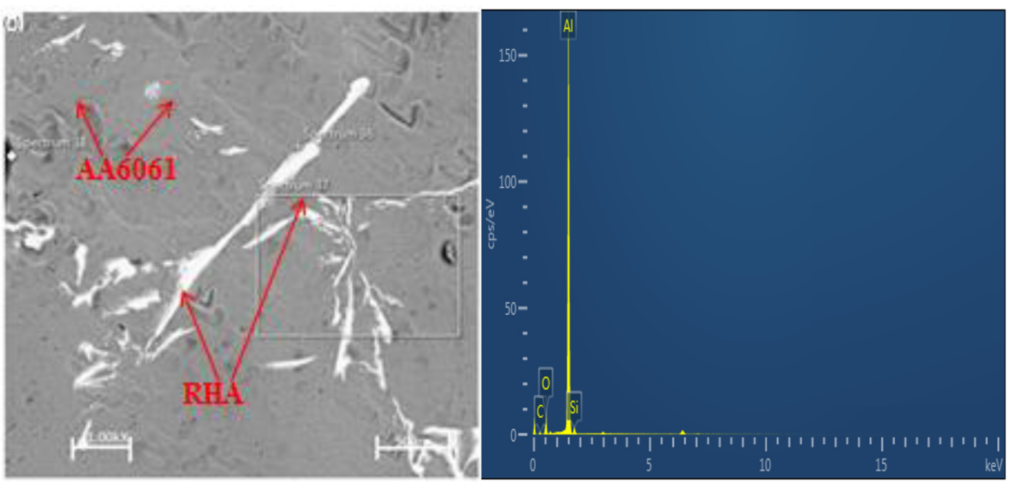

Fig. 4. SEM/EDS of 2% RHA reinforced AA 6061.

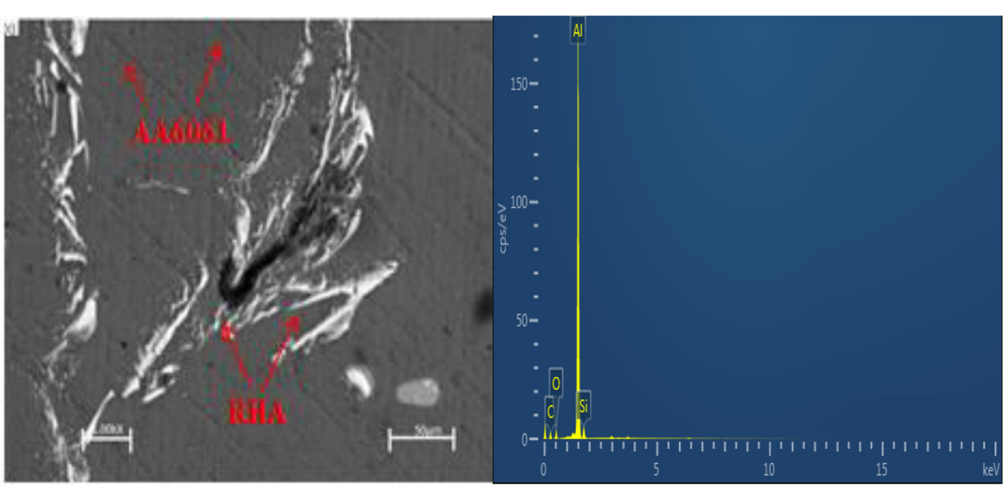

Fig. 5. SEM of 4% RHA reinforced AA 6061.

reinforcement. Fig. 5 shows the microstructure of AA6061 reinforced with 4% RHA. The EDS revealed existence of silica in the aluminium matrix. Fig. 6 shows the microstructure of AA6061 reinforced with 6% RHA. It was observed from the SEM images that there was a thorough dispersal of RHA particulates in the reinforced sample. Fig. 7 shows the microstructure of AA6061 reinforced with 8% RHA. The EDS revealed existence of silica from reinforcement of aluminium alloy with rice husk ash particulates.

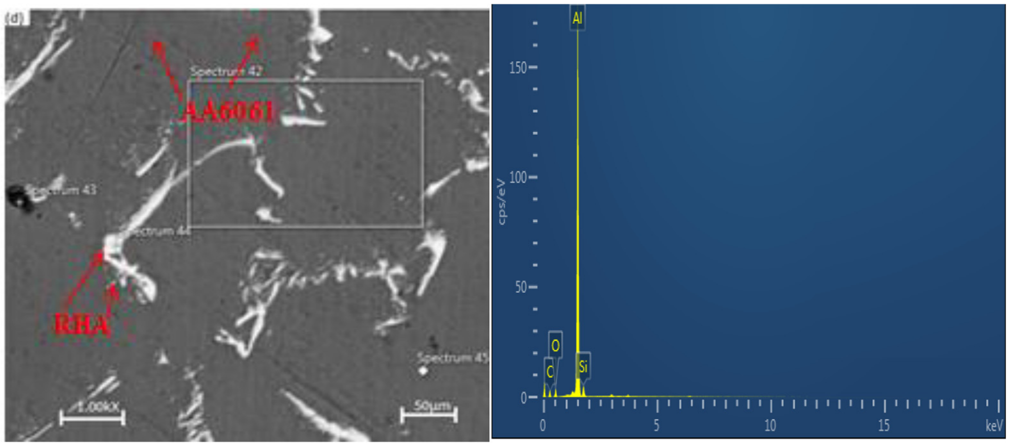

Fig. 6. SEM/EDS of 6% RHA reinforced AA 6061 sample.

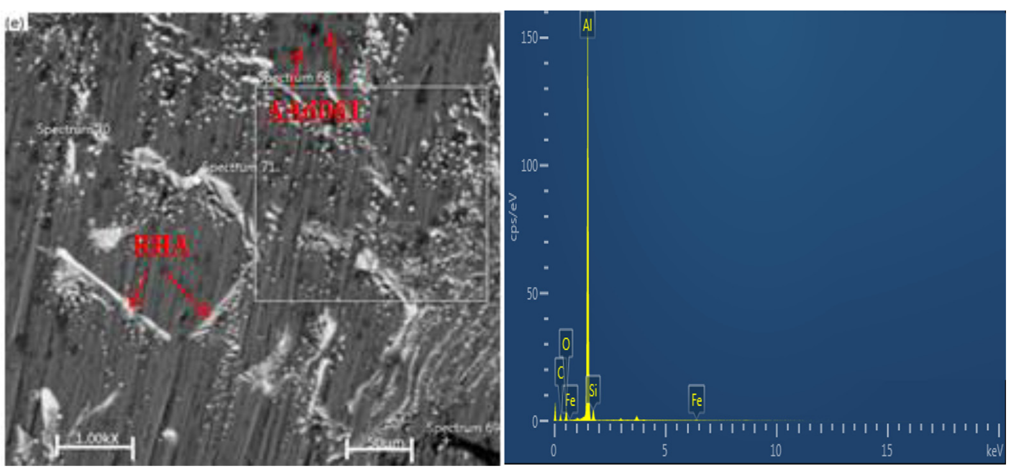

Fig. 7. SEM/EDS of 8% RHA reinforced AA 6061 sample.

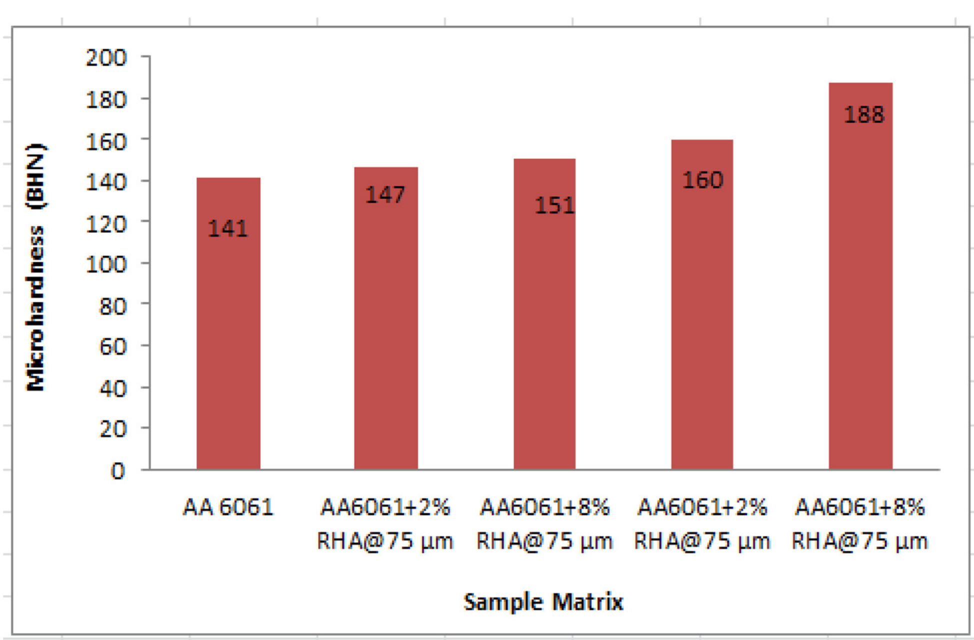

Fig. 8. Effect of RHA content on Microhardness.

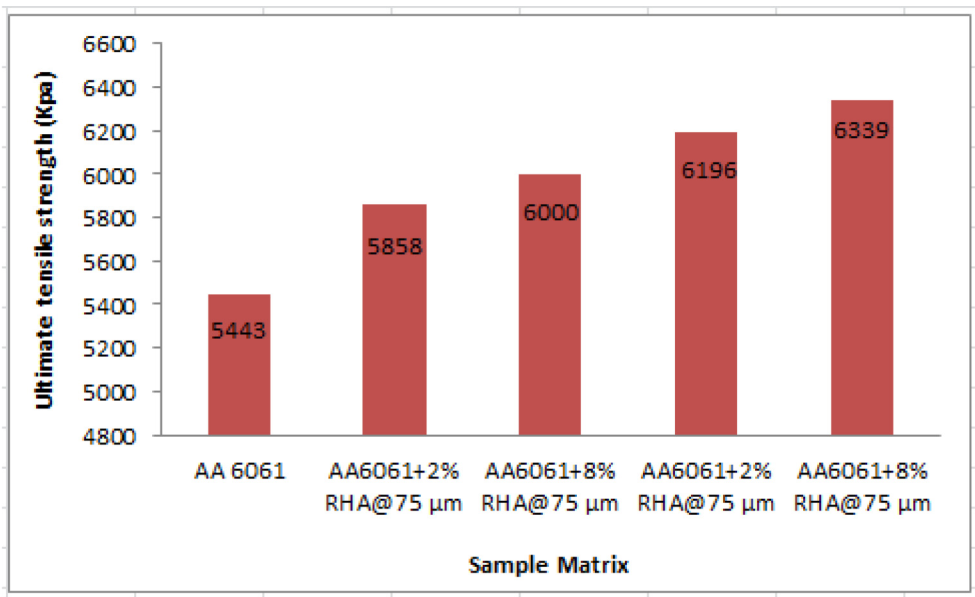

Fig. 9. Effect of RHA particles on tensile strength.

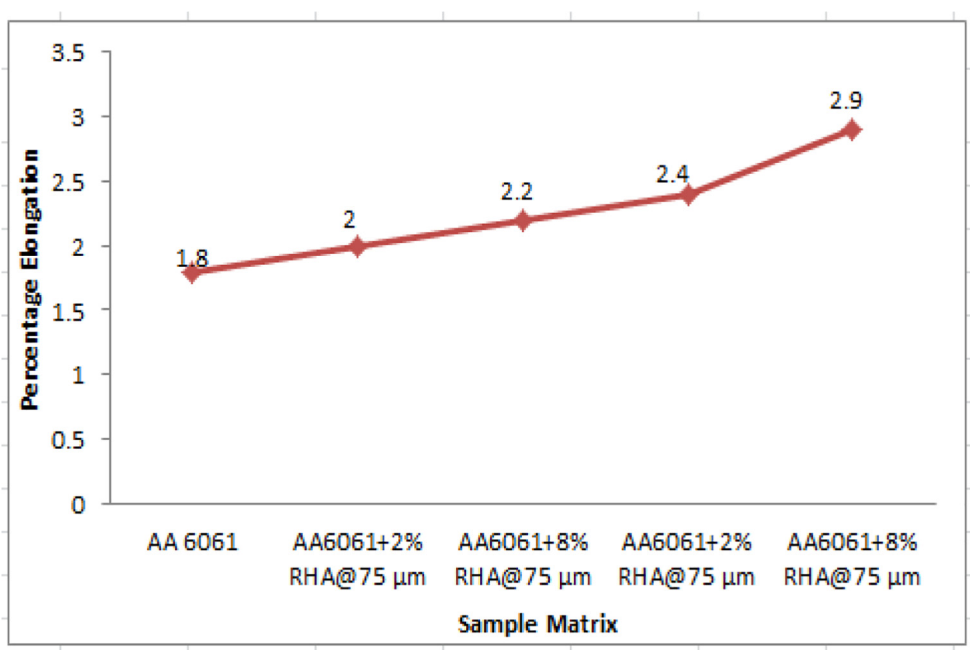

Fig. 10. Effect of RHA content on percentage elongation.

3.2. Mechanical properties

3.2.1. Hardness

Hardness tests were carried out on samples reinforced with 2–8 wt% RHA by means of Brinell hardness tester according to ASTM E10 standards. For the evaluation of hardness, 10 mm ball indenter was applied for 15 s on the cast. The result shows that the hardness is higher in the reinforced sample. The influence of a percentage of RHA particulate on the microhardness property of the AA6061/RHA alloy matrix composites is shown in Fig. 8. From the obtained data, the fabricated alloys increased geometrically in hardness from 141 BHN for the unreinforced composite to approximately 188 BHN at a percentage increment of 25%. The result of the hardness analysis shows that AA6061/8% RHA at 75 µm has higher hardness value therefore possesses a better hardness property. The increase in hardness was ascribed to the improvement in fraction of hard and brittle phase of the rice husk ash particulates in the aluminium alloy [11].

3.2.2. Tensile test

The effect of RHA particles on the tensile strength is displayed in Fig. 9. It was noticed that the strength was improved by the inclusion of RHA as reinforcing agent in comparison with the starting aluminium alloy. The result of the tensile strength shows that AA6061/8% RHA at 75 µm has higher strength value thereby possesses a superior tensile strength property. From the obtained data, the UTS of the reinforced aluminium metal matrix composites increased significantly from 5443 KPa starting aluminium alloy to approximately 6339 KPa for the developed alloy at a performance influence of 14.1%.

3.2.2.1. Percentage elongation. From previous research, it was observed that addition of RHA in aluminium matrix enhances the ductile nature of the aluminium, thereby enhancing its percentage elongation [12,13]. From the obtained data, the percentage elongation of the reinforced aluminium metal matrix composites increased intensely from 1.8% starting aluminium alloy to approximately 2.9% for the developed alloy at a performance influence of 37.9%. From this experiment and Fig. 10, there is increase in the percentage elongation of the reinforced sample in comparison with the starting material.

4. Conclusion

- AA 6061/RHA composite was successfully produced by stir casting technique with different percentage weight of reinforcements.
- There is a substantial improvement on the mechanical characteristics of the reinforced material than the aluminium alloy.
- The 8 wt% RHA reinforced AA6061 has good mechanical properties than other weight percentages of produced composites.
- SEM study revealed the surface morphology of the different percentage reinforcement of the composite and homogenous dispersal of reinforced particles.

CRediT authorship contribution statement

N.E. Udoye: Conceptualization, Methodology, Writing - original draft. **O.J. Nnamba:** Methodology, Validation. **O.S.I. Fayomi:** Data curation, Formal analysis, Investigation. **A.O. Inegbenebor:** Supervision, Validation, Writing - review & editing. **K.J. Jolayemi:** Data curation, Formal analysis, Investigation, Resources.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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