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Research Article

Evaluation of Cassava Effluent as Organic Admixture in Concrete Production for Farm Structures

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ABSTRACT

This paper evaluated the influence of cassava effluent on the compressive strength of concrete for farm structures. Three sets of concrete cubes were produced with a concrete mix ratio of 1:2:4 (C 15) and a water to cement ratio (w c^{-1}) of 0.5. The 1st set was produced with 100% fresh water (tap water). The 2nd set was produced with 75% partial replacement of the fresh water with fresh cassava effluent, while the 3rd set was produced with 75% partial replacement of the fresh water with old cassava effluent. The density, water absorption rate and compressive strength of the concrete cubes was tested in accordance with ASTM International standards, at the end of 7, 14, 21, 28 and 56 curing days. The results revealed that, the cassava effluent slightly increased the cubes density; but reduced their water absorption rate. The study further showed that, concrete produced with fresh cassava effluent, developed the highest compressive strength (29.57 MPa) at the end of the 56th curing day. In contrast, concrete produced with old cassava effluent developed the lowest compressive strength (24.43 MPa) at day 56, which was lower than the compressive strength of 27.18 MPa developed by the concrete produced with fresh water (also at day 56). In addition, the cassava effluent retarded the initial rate of strength development, as such, increasing its prospect as an organic concrete admixture. This study will be helpful in mitigating the harmful effects of cassava effluent in the environment, since it can be utilized in concrete production.

RESEARCH ARTICLE

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INTRODUCTION

Concrete is produced by mixing cement, fine aggregate and coarse aggregate in a definite ratio. The cement acts as 'glue' that binds the aggregates together in the concrete. The mechanical properties of any concrete are highly dependent on the relative proportion of cement in the concrete (Shetty, 2001; FAO, 2011). During the construction of farm structures, fresh concrete is usually produced within the building site and poured into already prepared formworks, to produce the desired shapes and sizes. In some cases, the concrete is precast at other areas, and brought to the building sites for installation. A structure in engineering teams refers to the coupling of several independent members, in which each member is subjected to flexural or axial force (either tensile or compressive), and at times to both flexural and axial forces (Reynolds and Steedman, 1999; FAO, 2011). Concrete is one of the most expensive building materials used in the construction of farm structures; but it is more durable when compared with other building materials. Farm structures play a vital role in increasing agricultural productivity and overall production. Most of the farm storage and processing structures are made of concrete. Concrete has high compressive strength properties but very low tensile and flexural strength properties. The poor tensile and flexural strength properties of concrete can be improved by making appropriate changes in its constituents, or by adding special admixtures (Shetty, 2001; Yan and Chouw, 2014).

Admixtures are inorganic or organic chemicals that are added to concrete to improve some of its physico-mechanical properties, so that the concrete can meets its intended design target mean strength (Akpokodje and Uguru, 2019). The efficiency of any admixture is dependent on the nature of the admixture, the amount of the admixture added, the volume of the cement, the water-cement ratio, the nature of the aggregates, the environmental temperature, etc. According to the Portland Cement Association (PCA), the main functions of admixtures include; corrosion inhibition, shrinkage reduction, alkali-silica reactivity reduction, air entrainment and workability enhancement, bonding and strength development, damp proofing and coloring among others. Air-entraining admixtures are used to encourage the development of microscopic air bubbles in the concrete; while pozzolanic based admixture helps to prevent alkali-aggregate reactions and enhance further strength development in the concrete (PCA, 2019). Despite the numerous advantages of admixtures, they have some limitations. Some admixtures can increase the concrete's drying shrinkage and reduce the concrete's resistivity to sulphate attack (Mishra, 2019). Some inorganic admixtures contain formaldehyde, which is hazardous to the ecosystem, if discharged untreated into the environment (Akindahunsi *et al.*, 2013).

Numerous researchers have investigated the influence of admixtures in concretes. Dhir *et al.* (2009), reported that superplasticizing admixtures improved the mechanical properties of the concrete produced. A compressive strength of 42.59 N mm^{-2} was recorded in C35 concrete produced by partial replacement (0.05%) of the cement with cassava starch; as against the 39.51 N mm^{-2} recorded in the C35 control concrete (Abalaka, 2011). Likewise Okafor (2008) observed that cassava flour acted as a good set -retarding admixture; thereby, improving the quality of the concrete produced with it. Topçu and Atesin (2016) observed that the slump of concrete produced with naphthalenesulfonate-based admixture had a better flowability when compared with concrete produced with lignosulfonate-based admixture. Concretes produced from modified polycarboxylic ether polymer, were observed to have higher compressive strength properties, when compared with concrete produced from sulfonated polymer, after 28 curing days (Papayianni *et al*., 2005).

Cassava (*Manihot esculenta*) is a perennial crop with edible roots that is cultivated widely, both in the tropical and subtropical regions of the world. The roots are processed into various value-added products, such as; *garri*, statch, *fufu*, sweeteners, glues, etc. Cassava has become a staple food for over 300 million people globally (IITA, 2019). According to IITA, in 2017 about 291 million metric tons of cassava roots were harvested globally, of which Nigeria accounts for about 59 million metric tons; amounting to approximately 20%. Large quantity of effluent is discharged during the processing of cassava roots into its useful products. This effluent contains vary concentrations of hydrocyanic acid and starch; the concentration of hydrocyanic acid and starch in the cassava effluent depends on the cassava cultivar, age, farming method, etc. (FAO, 2001). Although, several researches have been done on remediation and the industrial applications of cassava effluent, very few literatures have been reported on the utilization of cassava effluent in the concrete production industry. Therefore, the objective of this study is to evaluate the effect of cassava effluent, on some physcio-mechanical properties of concrete, as may be applied in the construction industry and farm structures. The results obtained will help in the evaluation of cassava effluent as potential organic admixture.

MATERIALS and METHODS

Materials

Water

Borehole water obtained from the premises of the School of Engineering, Delta State Polytechnic, Ozoro, Nigeria, was used for the concrete production. The water was free from aquatic plants, foreign materials, oil contamination, suspended solids, pH of 7.2 and an electrical conductivity of 62 µS cm^{-1}.

Cement

Dangote Ordinary Portland Cement (OPC) was used for the concrete production. The cement was manufactured in compliance with Nigeria Industrial Standard (NIS), and has the standard cement grade of 42.5. Generally, cement grade 32.5 produces concrete with lower compressive strength than cement grade 42.5 (NIS 444-1, 2003). According to FAO (2011) concretes produced with OPC tend to have low resistivity to acids and sulphates.

Fine aggregate

Natural riverbed sand (Sharp sand) obtained from River Ase in Delta State, Nigeria was used as the fine aggregate. The sand was dried in the laboratory for two weeks, in order to appreciably reduce its moisture content. According to FAO (2011), sand with high moisture content is not preferred for concrete production; this is because it will alter the water-cement ratio, which will in turn reduce the quality of concrete produced.

Coarse aggregate

Crushed granite was used as the coarse aggregate in the concrete production. The granite was sieved with a 20 mm gauge sieve and only aggregate passing though was used, while the retained material was discarded. Furthermore, the granite was washed, decanted and dried. This was done to remove all amounts of dirt and other organic deleterious matter present in the granite, which can reduce the compressive strength of the concrete produced.

Preparation of cassava effluent

The cassava (cv. TME 419) roots were harvested from the research farm of Delta State Polytechnic, Ozoro, Nigeria. They were peeled manually, washed and grated using a cassava grating machine. The grated cassava roots were bagged in jute sack, and the cassava effluent was extracted by using a manual press, to expel the effluent. The cassava effluent obtained was filtered with a 150 μm gauge stainless steel sieve, to remove all solid particles.

The prepared cassava effluent was then divided into two parts; one part was used immediately for the concrete production, while the other was left to ferment to seven days before it was used.

Preliminary Tests

The physical characteristics of both the coarse and fine aggregates were determined in compliance with ASTM International procedures. The grading curves of the fine and coarse aggregates were determined by using the British Standard (BS) sieves; while some geotechnical properties of the coarse and fine aggregates were determined in compliance with ASTM International procedures. Likewise, the physiochemical properties of the cassava effluent were determined using the APHA approved procedures (APHA, 2005).

The physical characteristics of the fine and coarse aggregates used for concrete production were well graded and met the NIS and ASTM International standards (Table 1). As shown in Table 1, the moisture content of the fine and coarse aggregate was relatively low, and were within NIS specifications. Figure 1 shows the gradations of the fine aggregate, which revealed that the fine aggregate was well graded and satisfied ASTM International requirements. According to ASTM D2487-11, any fine aggregate having uniformity coefficient (Cu) less than 6 ($Cu < 6$), and fines particles less than 5% (fines < 5%), is considered Poorly Graded, and not preferable for concrete production (USCS, 2015).

Table 1. Physical characteristics of the aggregates

Aggregate	Specific gravity*	Absorption capacity (%)*	Moisture content*
Fine	2.53±0.05	2.14±0.04	3.82±0.29
Coarse	2.65±0.02	3.24±0.11	2.05±0.19

Values are means ± standard deviation, *Average value of triplicate results

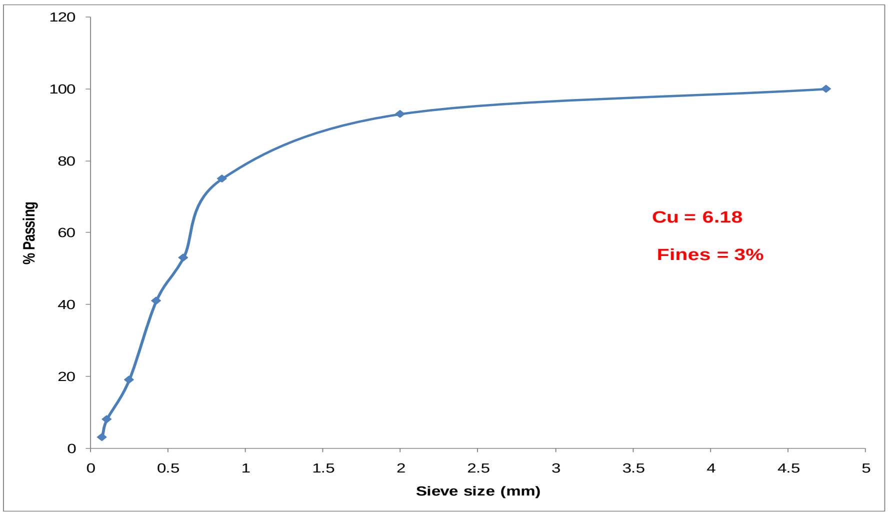

Figure 1. Particle size distribution of fine aggregates used for the concrete production

Methods

Mix design

Batching was done by volume for the concrete production. A concrete mix of 1:2:4 (C15) was adopted. A water to cement ratio (w c^{-1}) of 0.5 was generally employed, with the water content partially replaced with 75% (by volume) of cassava effluent, for the investigated cases.

Mixing

Mechanical mixing method as adopted for the concrete production. A tilting drum batch mixer was used to mix all the concrete constituents to achieve a homogenous mixture. Before the cassava effluent was introduced in the concrete production, it was stirred vigorously for five minutes, so that a fairly homogenous mixture can be attained. This is because starch and other components of cassava effluent have the tendency of settling within short period of time under tranquil conditions.

For the purpose of this study, three sets of concrete cubes were produced. The first set of concrete cubes was produced with 100% fresh water (tap water). They were tagged "Control".

The second set of concrete cubes were produced with 75% (by volume) of fresh cassava effluent, and they were tagged "CE-D1".

The third set of concrete cubes were produced with 75% (by volume) of seven-day old cassava effluent, and they were tagged "CE-D7".

Concrete cubes production

All the concrete cubes were produced with standard dimensions of 150 mm x 150 mm x 150 mm. During the production; the freshly mixed concrete was poured into a standard steel mould in three equal layers, and then rammed thirty-five times per layer. The cast concrete cubes were then covered with a black polyethylene sheet and left inside the concrete laboratory for twenty-four hours, after which they were de-moulded, and were cured by total submersion in clean water.

Laboratory tests

(a) Physical characteristics

Concrete water absorption rate test

The water absorption rate of the various concrete sets was determined in compliance with B.S 1881- 122 recommended procedures. During the test, three concrete cubes from each experimental set were taken from the curing tank and dried in a laboratory oven pre-set at 110±5⁰C for 48 hours. The dried concrete cubes weight was taken with digital weighing balance and were tagged W_1. There freshly dried concrete cubes were then immersed in fresh water for 24 hours. At the end of the 24 hours, they were taken out of the water, dried with paper towel. After which, the concrete cubes were weighed again, and the new weight was tagged W_2. The water absorption rate of concrete cubes was calculated using (Equation 1).

$$\text{Water absorption rate } (\%) = \frac{W_2 - W_1}{W_1} \times 100 \tag{1}$$

Concrete density determination

The density of the concrete produced was determined in compliance with ASTM C138 / C138M (2017) recommended procedures. Each concrete cube was weighed with an electronic digital weighing balance, with 0.01 Kg accuracy. Then the three principal dimensions (length, width and height) of the cube were measured with an electronic digital caliper, with 0.01 mm accuracy. Density of each concrete cube was calculated as the ratio of the mass to the volume of the cube, as shown in Equation 2 (Esegbuyota *et al.*, 2019).

$$Density = \frac{Mass}{Volume} \tag{2}$$

The concrete cubes that were used for the density and water absorption rate tests were marked, and were not used for compressive test, sue to the distortion in the curing process.

(B) Compressive strength test

The compressive strength test for the concrete cubes was carried out in accordance with ASTM C109 / C109M (2020) standards. Compressive strength of a concrete cubes was determined using the concrete Compression Testing Machine (Model: STYE 2000), manufactured in China. During the test, individual concrete cube was clamped in between the platens in the compression chamber of the machine, and compressed axially, at a slow speed of 0.6±0.2 mm min^{-1}until the concrete cube failed under the increasing load. The force required to crush individual concrete cube, was read from the digital screen attached to the machine and recorded. Using the crushing force, the compressive strength of the concrete cube was calculated by dividing the crushing force, by the effective surface area of the concrete cube on which the loading was applied (Equation 3).

$$Compressive\ strength = \frac{Crushing\ force}{Effective\ surface\ area\ of\ cube} \tag{3}$$

All the laboratory tests were done at the Department of Civil Engineering Technology, Delta State Polytechnic, Ozoro, Nigeria, at ambient temperature (27±3⁰C). Four cubes per sample set were tested and the average value recorded. The concrete cubes were tested at the end of 7, 14, 21, 28 and 56 curing days.

RESULTS and DISCUSSION

Physicochemical properties of the cassava effluent

The physicochemical properties of the cassava effluent used for the concrete production are presented in Table 2. The results revealed that the fermented cassava effluent was more acidic than the fresh cassava effluent. In addition, the starch content of the cassava effluent declined with the aging of the effluent; while the Total dissolved solids generally increased, as the cassava effluent gets aged (from Day 1 to Day 7).

Table 2. Physicochemical properties of cassava effluent

Parameter	Fresh cassava effluent*	Old cassava effluent*
pH	5.12±0.19	3.15±0.23
Hydrocyanic acid (mg l^{-1})	10.62±1.12	22.74±1.52
Starch (m^3 t^{-1})	34.5±3.22	22.1±4.19
Total dissolved solids (mg l^{-1})	2,432±44.91	4,428±65.22
Electrical conductivity (µS cm^{-1})	1712±20.44	3512±32.29

Values are means ± standard deviation, *Average value of triplicate results

Concrete water absorption rate

The water absorption rate of the concrete cubes is presented in Table 3. The study revealed that the water absorption rate of the concrete generally declined with aging of the concrete. Declining trend of the water absorption rate of the concrete with age, observed in this study is in agreement with previous study results of Akindahunsi *et al.* (2012). From the results, it was observed that control concrete cubes recorded the highest 56 day water absorption rate (4.9%); concrete produced with old cassava effluent recorded 56 day water absorption rate of 4.3%; while concrete produced with fresh cassava effluent recorded the least 56 day water absorption rate (3.2%). This signified that concrete produced with fresh cassava effluent absorbed lesser water than those concretes produced with fresh water. Lower water absorption rate recorded in the concrete produced with cassava effluent, could be attributed to the starch content of the effluent, which acts as an admixture.

Similar results were reported by Akindahunsi and Uzoegbo (2015), where concrete incorporated with cassava starch had lower water absorption rate, when compared with control concrete (concrete produced without cassava starch). In addition, Akpokodje and Uguru (2019) observed that cassava effluent was able to reduce the water absorption rate of sandcrete blocks by approximately 45% after 28 curing days. According to ASTM C1585 (2013), concrete water absorption rate is highly influenced by the concrete mix ratio, addition of admixtures, amount of entrained air, curing method adopted, age of the concrete, etc.

Furthermore, the study revealed that only concrete produced by fresh cassava effluent, was able to meet Pitroda and Shah (2014) assertion that, good quality concrete must not have water absorption rate greater than 5% at 28 days curing age. Concrete with high water absorption rate is not preferred in building construction. This is because their high permeability level will encourage the penetration of moisture, sulphate ions, chloride ions and other toxic substances that can caused negative chemical reactions (Alhozaimy *et al.*, 1996).

Table 3. Water absorption rate of concrete cubes produced with fresh water, fresh cassava effluent and old cassava effluent

Sample	Water Absorption rate (%) Curing days		
	Day 21*	Day 28*	Day 56*
Control	9.1±2.1	6.2±0.8	4.9±0.9
D1	6.8±1.4	4.3±0.7	3.2±0.8
D7	7.6±1.5	5.4±1.1	4.3±0.9

Values are means ± standard deviation, *Average value of triplicate results

Concrete cubes density

The density of the concrete cubes generally increased during curing (Table 4). The study showed that the increment in the concrete density during curing was generally low; 2.14% increment was recorded in the control concrete cubes, 6.83% was recorded with concrete incorporated with fresh cassava effluent, and 4.45% was recorded in the concrete incorporated with old cassava effluent. Concrete cubes produced with fresh water had the lowest density (2439.44 kg m^{-3}), at curing day 56; concrete incorporated with old cassava effluent recorded density of 2495.28 kg m^{-3} at the 56^{th} curing day; while concreted incorporated with fresh cassava effluent recorded the highest density (2568.36 kg m^{-3}), at curing day 56. This indicated that cassava effluent has the ability of influencing the weight and density of concrete, through its' (cassava effluent) starch content presented in Table 2. Okafor (2010) and Abd *et al.* (2016), stated that starch has the ability of influencing the density of concrete, as it can facilitates higher level of concrete compaction, which will result in increase in concrete density. Similarly, Okafor (2008) reported that density of concrete generally increases in an increased in the amount of cassava starch incorporated into the concrete. At 56^{th} curing day, the density of concrete incorporated with 0% cassava starch was 2542 kg m^{-3}; lower than 2573 kg m^{-3} and 2574 kg m^{-3} recorded for concrete incorporated with 3% and 10% cassava starch respectively.

Table 4. Concrete cubes density

Sample	Density (kg m^{-3}) Curing days			
	Day 7*	Day 21*	Day 28*	Day 56*
Control	2387.28±23	2405.17±31	2427.06±31	2439.44±29
D1	2392.93±31	2445.28±36	2517.87±34	2568.36±22
D7	2384.14±22	2411.27±28	2463.42±25	2495.28±25

Values are means ± standard deviation, *Average value of triplicate results

Concrete cubes compressive strength

The average compressive strength of the various sets of concrete cubes is presented in Table 5. The compressive strength development pattern of the concrete cubes during the curing period was fairly consistent with the recommendations of Reynolds and Steedman (1999). It was observed that the compressive strength was influenced by the presence of the cassava effluent, and the age of the effluent. The concrete cubes produced with fresh cassava effluent had the highest 56 day compressive strength (29.57 MPa), when compared with the concrete cubes produced with fresh water at 56 days (27.18 MPa), but displayed a less rapid strength development at the 7th day (14.65 MPa against 16.77 MPa recorded for fresh water). The improved quality of the concrete produced with the fresh cassava effluent beyond 21 days, can be attributed to the higher starch concentration and lower acidity (Table 2) of the fresh cassava effluent. Okafor (2010) reported that cassava starch (flour) acts as a water-reducing admixture in concrete; thereby increasing the compressive strength, when compared with concrete produced without the introduction of cassava flour admixture. Furthermore, the improved compressive strength of the fresh cassava effluent produced concrete, could be attributed to the better spreading of cement paste within the concrete. This is due to the adequate starch in the effluent, and a lower water to cement ratio, resulting in the production of a denser gel (Neville and Brooks, 1987). According to Dias *et al.* (2016), delays in strength development creates greater opportunity for the hydrated products to align and re-arrange themselves in the cement matrix, thereby producing a concrete with a higher compressive strength at the end.

In contrast, the concretes produced with the old cassava effluent had the lowest compressive strength, ranging from 10.51 MPa to 24.43 MPa. The poor physicochemical qualities of the old cassava effluent such as; high organic matters, low starch content and high acidity (Table 2), can be responsible for the poor compressive strength of the concrete produced with it. According to NIS, water with high organic matters content (Total dissolved solids) and high acidity, negatively affects the compressive strength of concretes, produced with it (NIS 554, 2007). In addition, Olusola and Opeyemi (2012) reported that high concentrations nitric acid, negatively affected the compressive strengths of concrete. A similar observation was made by Purnomo *et al.* (2019), where higher concentrations of citric acid reduced the compressive strength of the concrete bricks produced. According to Purnomo *et al.* (2019) concrete bricks produced with 0.15% citric acid (per wt. of cement) had a compressive strength of 46 MPa , at 28 curing days; while concrete bricks produced with 0.45% citric acid (per wt. of cement)developed a compressive strength of 29.70 MPa after 28 curing days. Thereby, the high concentration of the organic acid (Hydrocyanic acid) in the old cassava effluent (Table 2) will hinder the development of compressive strength of concrete. Adewumi *et al.* (2016) reported that the 28-day compressive strength of 1:2:4 concrete produced with cassava effluent was lower (13.5 MPa), compared with the concrete produced with fresh water (17.6 MPa) at 28 days. The differences in the compressive strength of concretes made with cassava effluent could be attributed to differences in age of maturity of the cassava roots, the age and concentration of the cassava effluent, the mix ratio and mixing methods, the properties of the other concrete constituents, etc.

The results further revealed a generally lower compressive strength of the concrete cubes produced with the cassava effluent during the first 14 curing days, when compared with the control concrete. This could be attributed to the slow setting time of the concrete produced with the cassava effluent. Similar results were reported by Okafor (2010) and Akpokodje and Uguru (2019). Delays in the setting time of concrete encourages the complete hydration of the cement; thereby, producing concrete with better qualities. This is beneficial in the hot tropical climates where normal setting time of concrete is reduced by higher ambient temperatures (Neville, 2006). According to FAO, cassava root processing produces large volume of effluent, which contains high concentration of organic compounds. Some of these compounds are not ecofriendly if not treated before they are discharged into the environment (FAO, 2001). Therefore, this study will help in mitigating the harmful effects of the cassava effluent, since it can be utilized in the concrete production industry.

Table 5: Compressive strength of concrete cubes

Sample	Compressive strength (MPa) Curing days				
	Day 7*	Day 14*	Day 21*	Day 28*	Day 56*
Control	16.77±2.3	22.28±1.7	25.92±1.2	26.54±1.3	27.18±2.1
CE - D1	14.63±2.1	19.83±1.5	27.31±1.4	28.69±1.9	29.57±1.7
CE - D7	10.51±1.7	14.66±1.6	22.09±1.8	24.11±2.2	24.43±1.5

Values are means ± standard deviation, *Average value of four results

CONCLUSION

This study looks into the utilization of cassava effluent as an admixture in concrete production. Mechanical properties of concrete cubes produced with cassava effluent, were tested in compliance with ASTM International standards. Based on the results, the density of the concrete increased marginally, by the addition of cassava effluent to the concrete; while the cassava effluent greatly reduced the water absorption rate of the concrete. In addition, the study revealed that the compressive strength of the concrete cubes was greatly influenced by the age and quantity of the cassava effluent, used for the production of the concrete. The highest compressive strength (29.57 MPa), was recorded in the concrete incorporated with fresh cassava effluent at day 56 of curing. While the concrete produced incorporating old cassava effluent recorded the lowest compressive strength (24.43 MPa), at day 56. This showed that fresh cassava effluent could serve as an organic admixture in concrete production, due to its' high starch content, which is able to retard the concrete setting time and increased its compressive strength in the process. The study will help in mitigating the harmful effects of the cassava effluent in the environment, since it can be adequately utilized in the concrete production industry.

DECLARATION OF COMPETING INTEREST

The authors declare that there are no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The authors declared that the following contributions are correct.
Goodnews Goodman Agbi: Literature review and methodology.
Ovie Isaac Akpokodje: Data analysis and review of the original draft.
Hilary Uguru: Design the research and writing the original draft.

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