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About the Nigerian Academy of Science

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- Providing advice on specific problems of scientific or technological nature presented to it by the government and its agencies, as well as private organizations
- Bringing to the attention of the government and its agencies problems of national interest that science and technology can help solve
- Establishing and maintaining the highest standards of scientific endeavours and achievements in Nigeria, through the publication of journals, organization of conferences, seminars, workshops, and symposia, recognition of outstanding contributions to science in Nigeria, and the development of a working relationship with other national and international scientific bodies and academies

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Regionally, the Nigerian Academy of Science is one of eight founding academies of the Network of African Science Academies (NASAC) and has served on its Executive Committee until date. The Academy has played a major role in the development and establishment of academies in Africa. In November 2012 and 2017, the Nigerian Academy of Science hosted the African academies for the 8th and 13th Annual Meeting of African Science Academies (AMASA), in Lagos and Abuja respectively. The Nigerian Academy has signed agreements with counterparts in many African countries (and beyond) to ensure scientific exchange and partnership.

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5. Conveying a media roundtable meeting to discuss issues of depression and suicide prevention,

6. Conveying a roundtable meeting to discuss the issues related to the Ebola Virus Disease epidemic that recently affected the country and the West African region,

7. Implementation of an intervention program to address the social and reproductive health issues of the youth in Ekiti and Nasarawa States of Nigeria,

8. The hosting of all African academies and other scientists at an international conference on STI education and man power development in Africa,

9. The organization of a summit to discuss the role of women in science and sustainable development in Nigeria,

10. The organization of a workshop to discuss the evolution of big data and artificial intelligence (AI), and the impact of education on training,

11. A consensus study on the evolving science advisory landscape in Africa.

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EDITORIAL

Science versus myths: the case of COVID-19 vaccine hesitancy

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The coronavirus disease 2019 (COVID-19), caused by a new strain of Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-COV-2) was first reported to the World Health Organization (WHO) from the first case in Wuhan, China on December 31, 2019. The WHO declared the disease a pandemic on March 10, 2020 due to the fast pace of its progression throughout the world. Given the high number of deaths and severe socio-economic consequences associated with the disease, and because of the limited uptake of public health measures designed to prevent the spread of the virus, it became evident that only the discovery of a vaccine would help prevent the community spread of the virus. In May 2020, the 73rd World Health Assembly issued a resolution recognizing the role of extensive immunization as a global public-health goal for preventing the transmission of SARS-COV-2 (WHO, 2020). Consequently, several scientific groups in various parts of the world began to work on developing vaccines against the virus. The first vaccines were introduced in September 2020, and since then the WHO has approved seven vaccines for use against COVID-19. These include 1) Biotech BBV152 COVAXIN vaccine, 2) Sinova-coronavac COVID-19 vaccine, 3) Pfizer BioNTech (BN T162 b2) COVID-19 vaccine, 4) Sinopharm COVID-19 vaccine, 5) Janssen Ad26.cov2.S COVID-19 vaccine, 6) the Oxford/AstraZeneca COVID-19 vaccine, and 7) the Moderna COVID-19 (mRNA-1273) vaccine.

The first dose of any COVID-19 vaccine was given in the United States in December 2020, with the goal to achieve widespread immunization against the disease within the shortest possible period. This was with the recognition that for a vaccine to effectively control the spread of COVID-19, herd immunity has to be reached with at least 67% of the global population vaccinated (Randolph et al 2020).

Consequently, several countries around the world have begun massive immunization of their citizens; however, with different levels of coverage. By December 2021, while countries such as the United States have attained 61% coverage with COVID-19 vaccination (CDC, 2021), a country like Nigeria has only succeeded in vaccinating less than 5% of its citizens (NCDC, 2021) (See figure).

While it is logical to suggest that the low level of vaccination in some low- and middle-income countries (LIMCs) may be due to paucity of vaccines, but the available evidence indicate that this may not be the case. To date, vaccines are being donated to LIMCs at no or limited costs, while the distribution chain has improved considerably as compared to those available to previously available vaccines.

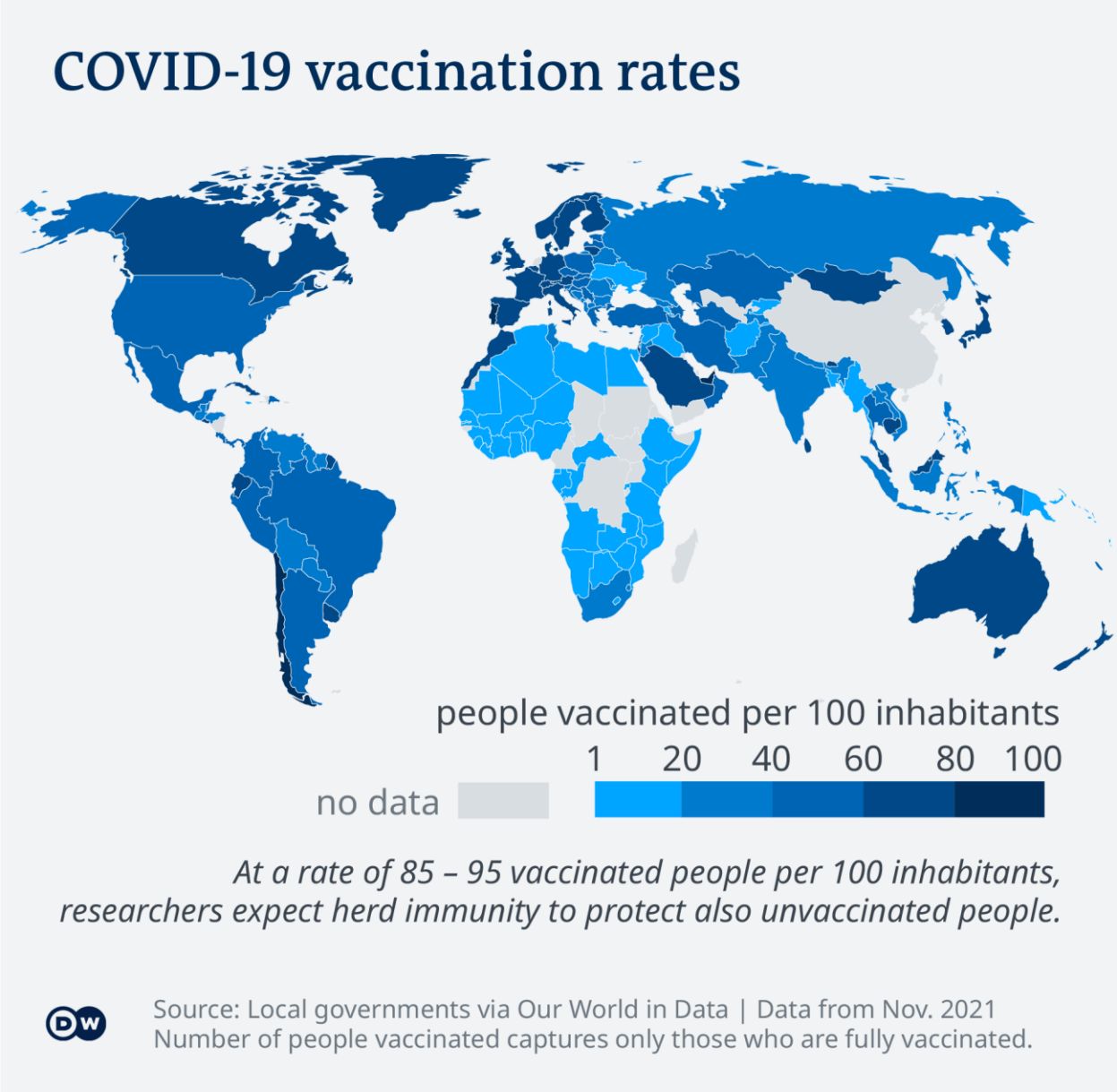

Figure 1: Worldwide COVID-19 vaccination rates – November 2021

The true reasons for the low COVID-19 vaccination rates in LMICs, especially sub-Saharan African countries appear to be vaccine hesitancy, the reluctance of individuals to accept the vaccination. The WHO defines "vaccine hesitancy" as "delay in acceptance or refusal of vaccines despite availability of vaccination services" (MacDonald et al, 2015). Although the reasons for vaccine hesitancy have not been systematically investigated, the emerging evidence suggests that this may be due to myths and make-believe doctrines that counter the evidence provided by scientific facts and research.

Interestingly, COVID-19 itself has been characterized by myths and folklores as to its origin, especially within the context of LMICs (Okunlola et al, 2020). Even the originally proposed treatment methods for COVID-19 in these countries were based on unfounded herbal medicines and allegories (Nugraha et al, 2020), which tended to counter the scientific recommendations on prevention and treatment. Some even proposed that the virus was manipulated to change the origin of humankind, and to alter genetic codes to favour a particular human species.

Therefore, it is not altogether unexpected that the vaccines designed to prevent the disease would be opposed with the same temerity with which the origin of the virus was debated. To date, COVID-19 vaccination appears to be the one single intervention that has reduced the incidence, severity, and death rates from the virus. While new variants of the virus such as Omicron have emerged (WHO, 2021), it is being argued that these may have developed from non-vaccinated individuals, while the possibly reduced severity of the new viral strain as compared to previous variants, may be due to the presence of herd immunity from extensive vaccination in several countries.

Given that vaccination holds the key to preventing, curtailing, and eliminating the virus on a sustainable basis, the relevant question is: how vaccine hesitancy can be managed in ways to promote the rational use of vaccines to prevent COVID-19 and possibly other future epidemics. In our view, the answer lies in the way and manner new vaccines are introduced, and how public oppositions to the vaccine are managed. In Nigeria, official response to non-acceptance of the vaccine has included threats of restrictions of movement to key places, removal of rights to access services, and public disagreement with opponents of the vaccine. By contrast, internationally accepted methods for managing vaccine hesitancy include health education (based on the provision of scientific facts), building community trust and transparency about the vaccine side effects, and addressing pain attributable to the vaccines (Arede et al, 2018). We believe strongly that the use of rights-based methods of vaccine introduction, while explaining the benefits and side effects of the vaccine in an easily understandable and scientific manner holds the key to vaccine acceptance in LMICs. Indeed, we recommend the same intensive scientific method used in discovering the vaccine, to be used in introducing the vaccine to communities, based on active community participation and ownership of the process.

We conclude that vaccine hesitancy is one of the most serious challenges that the elimination of COVID-19 currently faces in LMICs. The use of a rational and scientific process of introducing the vaccine rather than that based on the blame game will help sieve science from myths and facilitate the process of uptake of the COVID-19 vaccine and the eventual elimination of the virus.

Conflicts of Interest: None

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ORIGINAL RESEARCH ARTICLE

A checklist on the status of targeted fish species in selected communities of Ondo coastal waters, Nigeria.

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Abstract

The increased human activities resulting from industrialization and urbanization around the Ondo section of the coastal waters of the Atlantic Ocean have significantly affected the environment. To this end, the water quality, fish abundance and target status of fish species were identified, notwithstanding the influence of human activities on the water quality and its effects on fish abundance. Four fishing communities were purposively selected based on geographical location and accessibility along the coast; Ayetoro and Idi-Ogba communities on the eastern side and Eruna-Ero and Igbokoda on the western side. A total of 120 structured questionnaires were randomly administered using snowball technique at 30 per site. Erunna-Ero community measured the highest mean temperature, dissolved oxygen, salinity and conductivity with 29.39 ± 0.30 ^{o}C, 4.48 ± 0.06 mg/L,10.68 ± 0.39 ppt and 40.70 ± 0.18 µS/cm respectively, while pH was highest in Idi-Ogba community (6.47 ± 0.00). A total of 61.67% were within 21-40 age brackets; 69.17% were males, and 75% of the males engaged in fishing activities. Agricultural activities were high (97%) with most wastes emptying into the river (85.83%). A total of 27,622 fish individuals were identified across the fishing communities with Igbokoda having the highest abundance (38.13%) and *Cynoglossus browni* (75.18%) was the highest fish species. In the past, three (3) economically important fish species were of major target but a reduction to two (2) species was observed at the time of study which indicated a reduction in target fish species in Igbokoda community. An increase from three (3) to four (4) target species were observed in Ayetoro, Erunna-Ero, and Idi-ogba communities which indicated an increase in target fish species. The study showed the activities around the coastal water dictated the abundance of fish species and therefore essential to monitor the water quality parameters for the sustainability of fish species in the coastal water.

Keywords: *anthropogenic activities, coastal waters, fish abundance, sustainability water quality*

Introduction

Water is an indispensable resource on earth and all living organisms depending on it for their sustenance. Nigeria has 46,300km^2 maritime area and 125,470.82 km^2 inland waters which accommodate small-scale artisanal fishers estimated at over 6 million contributing 85% to domestic fish consumption in Nigeria (Fish for All Summit, 2005). Fish is a cheap source of protein (FAO, 1999) and its diversity has decreased over the years as a result of various factors such as overfishing, unregulated mesh sizes, climatic actions, and pollution (Ipinmoroti, 2013). In recent time, industrialization and rapid urbanization has affected fish species in Ondo coastal waters. It has the longest coastline in Nigeria (78 km) and accommodates diverse finfish and

shellfish species which contribute greatly to food and protein supply. The coastal environment like all others is exposed to various pressures from agricultural activities, construction, and oil exploration which results to pollution of the surrounding water bodies. Emmanuel (2012) reported that pollution can influence the abundance and choice of target fish species in a fishing community. There have been several reports on the anthropogenic activities and water quality in Ondo coastal area (Ipinmoroti *et al.,* 2018a; Adebowale *et al.,* 2008; Atobatele *et al.,* 2005) and the reports did not link the effect of the anthropogenic activities on the aquatic resources over time. As human population increases, the pressure by human activities on the natural resources also increases. Based on this, it is expected that the increase in population around the coastal area would impact on the type and number of fish species that form the target fishing groups in the study area. This study therefore investigates the present anthropogenic activities and their influence t on the fish species presently targeted in the coastal water as an important tool for necessary management procedures towards sustainability.

Materials and Methods

Study area

Ondo coastal waters lie within Latitude 5^{o} $5^{0'}$ N – 6^{o} 09' N and Longitude 4^{o} 45' E – 5^{o} 05 'E in Ilaje Local Government Area which is located in the Southern part of Ondo state (Figure 1). This area has the longest coastline in Nigeria with about 78 km and the inhabitants majorly engaged in fishing activities (Ipinmoroti *et al*, 2018a). The area consists of over 80 fishing communities with diverse fishing activities which contributes significantly to fish production in the state (Adebowale *et al*, 2008). The coastline has falls within the prospective oil producing areas referred to as the Niger-Delta regions and diverse wastes from land discharges into the ocean through this estuary (Olu-Owolabi *et al.,* 2013). Several trading and fishing activities are done around the coastline and these are the principal activities; and, transportation of goods and services was via motorboat which indirectly pollute the waterway. The fishing communities were purposively grouped into two based on geographical location (East and West). Two fishing communities were purposively selected from each of the locations for sampling based on accessibility and logistic characteristics. The communities selected are Igbokoda and Erunna-Ero on the western side and Ayetoro and Idi-Ogba on the eastern side. From each selected community, structured questionnaire were administered and personal interviews were conducted. Fish and water samples were collected monthly for a period of six months (January – June 2016).

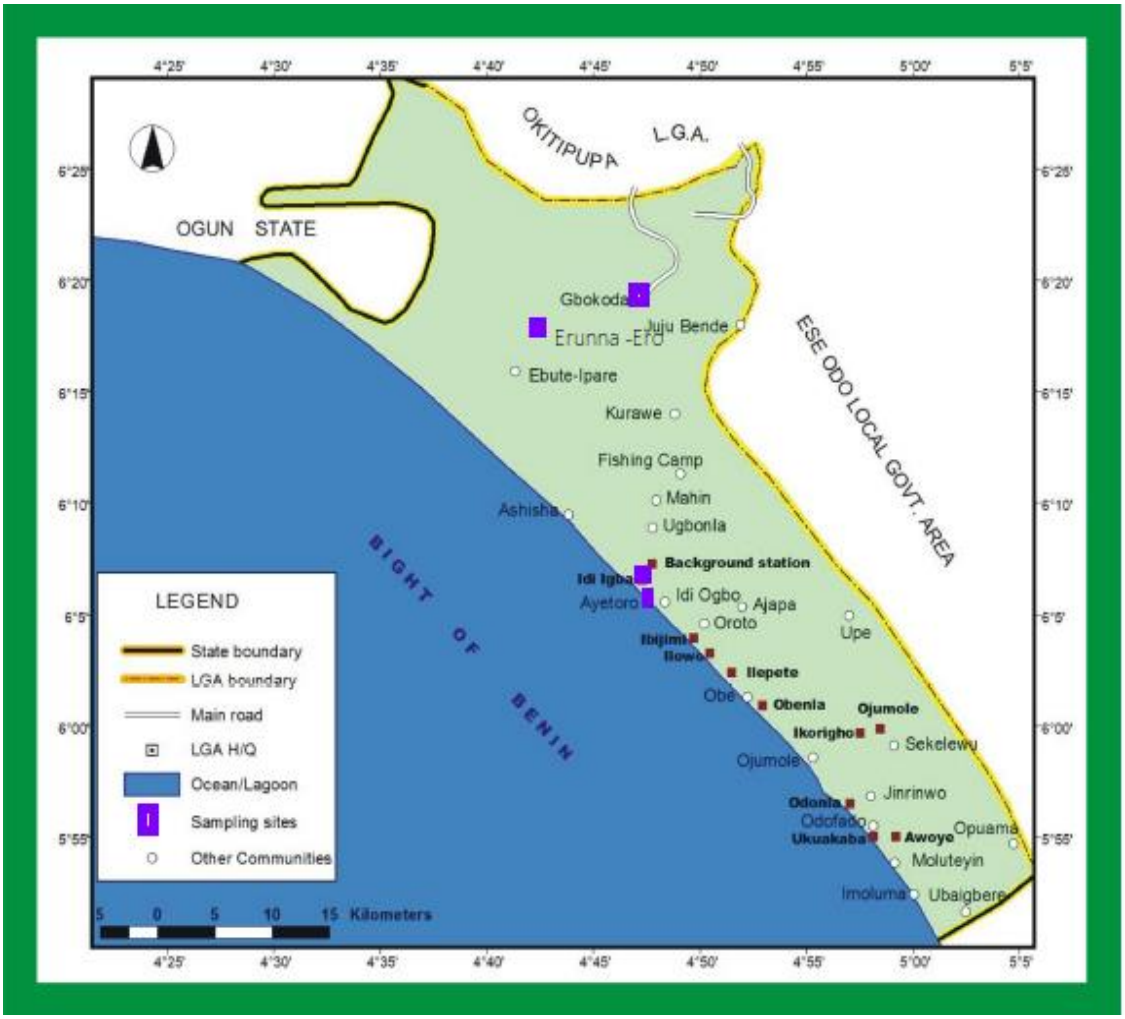

Figure 1: Map of the study area.

Source: Adapted from Olu-Owolabi *et al.*, (2013)

Water Quality analysis

Surface water samples collected fortnightly between the hours of 7.00am and 9.00am from the four sampling communities for a period of six months (January – June 2016). The samples were measured *in situ* for temperature, Dissolved Oxygen (DO), pH, conductivity and salinity.

Temperature and conductivity

These measurements were taken *in situ* using an hand-held Hanna Meter (Model HI98129) manufactured by Hanna Instruments, USA. It was determined by inserting the probe into the water body below the 1m depth and values for each parameter (temperature or conductivity) were taken by switching the mode on the meter. The measurement of each parameter was taken after at least five minutes of probe insertion and readings were taken after the meter values was steady and recorded in degrees Celsius (^{o}C) and parts per thousand (ppt) for temperature and conductivity respectively.

pH, salinity and DO

They were measured using a hand-held Hanna multi-parameter kit (Model HI9828) manufactured by Hanna Instruments, USA. The measurement of each parameter was taken by inserting the probe of meter into the water below the 1m depth and values for each parameter were taken by switching the mode on the meter to the appropriate parameter. The measurement of each parameter was taken

after at least five minutes of probe insertion and readings were taken after the meter values was steady and recorded in µS/cm and mg/L for conductivity and DO respectively.

Questionnaire administration

A total of 120 structured questionnaire at 30 per community were purposively administered using snowballing technique. The questionnaire was structured with both open questions which allowed respondents to express their opinions and close-ended questions. The questionnaire enquired from the fishermen about their demographic characteristics, anthropogenic activities and waste disposal systems, fishing practices, fish diversity, and targeted fish species. Personal interviews were conducted with the fishermen and some questions were interpreted into the local dialect with the assistance of a native interpreter for better understanding. This process was used to derive further information about their fishing activities and fish diversity.

Fish identification

Fish was sampled for six months (January –June, 2016) from the fishermen's landings and their abundance was recorded. Species were identified by their local and scientific names using the combined monographs by Olaosebikan and Raji (2013) and Froese and Pauly (2019).

Targeted Fish Species

From the questionnaire administered, the following information were derived about the status of fish targeted and were based on the following tags:

- TVO (Target Very Often) - describes fish species that are mostly purposively caught every fishing time. These fish species usually almost dominate the entire catch by the fisherman
- OT (Often Targeted) - describe fish species that are often purposively caught at every fishing period. These fish species usually form part of the entire catch.
- RT (Rarely Targeted) – describes fish species that are rarely purposively caught during the fishing time. These fish species may form very little part of the entire fish catch
- NT (Not Targeted) – describes fish species that are not intentionally caught during the fishing time.

Statistical analysis

The mean data on water quality from the sampling communities were separated using the Analysis of Variance (ANOVA) statistical tool and Descriptive statistics such as frequencies and percentages using Statistical Package for Social Sciences (SPSS) 23.0 while Microsoft Excel 2017 was used for graphical illustrations.

Results

Water quality parameters

The mean monthly water quality parameters measured from the sampling communities are presented in Tables 1 - 4. In Igbokoda community (Table 1), the mean temperature measured was 29.26 ± 0.32 ^{o}C with the highest in March (29.80 ± 0.01 °C) and least in May (28.95 ± 0.16 °C). The highest mean pH was measured in June (6.50 ± 0.01) and the least in January and March (6.10 ± 0.11) with an overall mean of 6.25 ± 0.13. DO was highest in May (3.50 ± 0.00 mg/L) and least in January and April with 3.10 ± 0.02mg/L respectively and an overall mean of 3.21 ± 0.04 mg/L. Salinity was highest in April (0.98 ± 0.01 ppt) and least in February (0.42 ± 0.00 ppt) and an overall mean of 0.68 ± 0.08 ppt was measured across the months. Conductivity was highest in April (13.21

± 0.11 µS/cm) and least in February (10.11 ± 0.02 µS/cm) and an overall mean of 11.77 ± 0.11 µS/cm was measured.

Table 1: The mean monthly values measured from Igbokoda fishing community

Months/ Parameters	Temperature (°C)	pH	DO (mg/L)	Salinity (ppt)	Conductivity (µS/cm)
January	29.10 ± 0.11 [a]	6.10 ± 0.11[a]	3.10 ± 0.02[a]	0.71 ± 0.02[a]	12.80 ± 0.05[a]
February	29.30 ± 0.18 [a]	6.30 ± 0.00[a]	3.30 ± 0.18[a]	0.42 ± 0.00[a]	10.11 ± 0.02[a]
March	29.80 ± 0.01 [a]	6.10 ± 0.11[a]	3.20 ± 0.00[a]	0.54 ± 0.02[a]	11.11 ± 0.22[a]
April	29.21± 0.12 [a]	6.30 ± 0.18[a]	3.10 ± 0.02[a]	0.98 ± 0.01[a]	13.21 ± 0.11[a]
May	28.95± 0.16 [a]	6.20 ± 0.12[a]	3.50 ± 0.00[a]	0.63 ± 0.00[a]	12.23 ± 0.01[a]
June	29.21 ± 0.00 [a]	6.50 ± 0.01[a]	3.10 ± 0.13[a]	0.81 ± 0.02[a]	11.18 ± 0.02[a]
Mean	29.26 ± 0.32	6.25 ± 0.13	3.21 ± 0.04	0.68 ± 0.08	11.77 ± 0.11

Values with the same superscript within the same column are not significantly different (P>0.05)

In Erunna-Ero community (Table 2), the mean temperature measured was 29.39 ± 0.30 °C with the highest in February (30.10 ± 0.11 °C) and the least in June (28.11 ± 0.00 °C). The highest mean pH was measured in April (6.42 ± 0.31) and the least in February (6.11 ± 0.01) with an overall mean of 6.29 ± 0.76. DO was highest in January (4.60 ± 0.03 mg/L) least in February and April with 4.40 ± 0.02 mg/L and 4.40 ± 0.01 mg/L respectively and an overall mean of 4.48 ± 0.06 mg/L. Salinity was highest in May (11.90 ± 0.11 ppt) and least in February (9.10 ± 0.02 ppt) and an overall mean of 10.68 ± 0.39 ppt was measured across the months. Conductivity was highest in May (41.20 ± 0.00 µS/cm) and least in April (40.50 ± 0.01 µS/cm) and an overall mean of 40.70 ± 0.11 µS/cm was measured.

Table 2: The mean monthly values measured from Erunna-Ero fishing community

Months/ Parameters	Temperature (°C)	pH	DO (mg/L)	Salinity (ppt)	Conductivity (µS/cm)
January	29.01 ± 0.02[a]	6.21 ± 0.00[a]	4.60 ± 0.03[a]	11.10 ± 0.11[b]	41.10 ± 0.00[a]
February	30.10 ± 0.11[a]	6.11 ± 0.01[a]	4.40 ± 0.02[a]	9.10 ± 0.02[a]	40.10 ± 0.02[a]
March	29.91 ± 0.01[a]	6.31 ± 0.03	4.50 ± 0.00[a]	9.90 ± 0.01[a]	41.10 ± 0.04[a]
April	29.21 ± 0.04[a]	6.42 ± 0.31[a]	4.40 ± 0.01[a]	10.60 ± 0.00[b]	40.50 ± 0.01[a]
May	30.02 ± 0.02[a]	6.40 ± 0.01[a]	4.50 ± 0.20[a]	11.90 ± 0.02[b]	41.20 ± 0.00[a]
June	28.11 ± 0.00[a]	6.30 ± 0.03[a]	4.50 ± 0.00[a]	11.50 ± 0.03[b]	40.20 ± 0.00[a]
Mean	29.39 ± 0.30 [a]	6.29 ± 0.76 [a]	4.48 ± 0.06	10.68 ± 0.39	40.70 ± 0.18

Values with the same superscript within the same column are not significantly different (P>0.05)

In Ayetoro community (Table 3), the overall mean temperature measured was 29.20 ± 0.31 °C with the highest in February (29.30 ± 0.00 °C) and the least in April (29.00 ± 0.20 °C). The highest mean pH was measured in April (6.40 ± 0.10) and the least in (6.10 ± 0.00) with an overall mean of 6.25 ± 0.23. DO was highest in March (4.30 ± 0.00 mg/L) and least in June (3.95 ± 0.20mg/L) and an overall mean of 4.11 ± 0.06 mg/L. Salinity was highest in May (10.90 ± 0.11 ppt) and least in March (10.00 ± 0.21 ppt) and an overall mean of 10.35 ± 0.38 ppt was measured across the months. Mean values of salinity in January, March and April were significantly different (P<0.05) from other months during the study period. Conductivity was highest in March (41.40 ± 0.05 µS/cm) and least in January, February and June with 40.20 ± 0.06 µS/cm, 40.20 ± 0.02 µS/cm 40.20 ± 0106 µS/cm respectively. An overall mean of 40.52 ± 0.11 µS/cm was measured across the months.

Table 3: The mean monthly values measured from Ayetoro fishing community

Months	Temperature (ºC)	pH	DO (mg/L)	Salinity (ppt)	Conductivity (µS/cm)
January	29.20 ± 0.01[a]	6.20 ± 0.02[a]	4.10 ± 0.04[a]	10.20 ± 0.21[a]	40.20 ± 0.06[a]
February	29.40 ± 0.00[a]	6.30 ± 0.03[a]	4.10 ± 0.00[a]	10.30 ± 0.31[b]	40.20 ± 0.02[a]
March	29.10 ± 0.40[a]	6.10 ± 0.00[a]	4.30 ± 0.10[a]	10.00 ± 0.21[a]	41.40 ± 0.00[a]
April	29.00 ± 0.20[a]	6.40 ± 0.10[a]	4.00 ± 0.03[a]	10.10 ± 0.01[a]	40.10 ± 0.04[a]
May	29.30 ± 0.40[a]	6.30 ± 0.05[a]	4.20 ± 0.02[a]	10.90 ± 0.11[b]	41.00 ± 0.21[a]
June	29.20 ± 0.00[a]	6.20 ± 0.06[a]	3.95± 0.20[a]	10.60 ± 0.28[b]	40.20 ± 0.10[a]
Mean	29.20 ± 0.31	6.25 ± 0.23	4.11 ± 0.06	10.35 ± 0.38	40.52 ± 0.51

Values with the same superscript within the same column are not significantly different (P>0.05)

In Idi-Ogba community (Table 4), the overall mean temperature measured was 29.11 ± 0.33 ºC with the highest in March (29.60 ± 0.01 °C) and the least in April (28.90 ± 0.06 °C). The highest mean pH was measured in March (6.80 ± 0.04) and the least in January and April with 6.20 ± 0.02 respectively with an overall mean of 6.47 ± 0.00. DO was highest in January and June with 4.60 ± 0.01 mg/L) and least in April (4.00 ± 0.01 mg/L) and an overall mean of 4.30 ± 0.04 mg/L. Salinity was highest in January, April and June with 10.40 ± 0.21 ppt, 10.40 ± 0.32 ppt and 10.40 ± 0.02 ppt respectively. The mean values in February and March were significantly different (P<0.05) from other months. Conductivity was highest in May (41.11 ± 0.00 µS/cm) and least in January (40.00 ± 0.11 µS/cm) with overall mean value of 40.57 ± 0.26 µS/cm.

Table 4: The mean monthly values measured from Idi-Ogba fishing community

	Temperature (ºC)	pH	DO (mg/L)	Salinity (ppt)	Conductivity (µS/cm)
January	29.10 ± 0.02[a]	6.20 ± 0.02[a]	4.60 ± 0.01[a]	10.40 ± 0.21[b]	40.00 ± 0.11[a]
February	29.10 ± 0.21[a]	6.60 ± 0.03[a]	4.20 ± 0.02[a]	10.30 ± 0.01[a]	41.10 ± 0.12 [a]
March	29.60 ± 0.01[a]	6.80 ± 0.04[a]	4.30 ± 0.00[a]	10.00 ± 0.11[a]	40.98 ± 0.11[a]
April	28.90 ± 0.06[a]	6.20 ± 0.01[a]	4.00 ± 0.01[a]	10.40 ± 0.32[b]	40.12 ± 0.01[a]
May	28.95 ± 0.04[a]	6.60 ± 0.02[a]	4.20 ± 0.03[a]	10.10 ± 0.01[b]	41.11 ± 0.00[a]
June	29.00 ± 0.00[a]	6.40 ± 0.10[a]	4.60 ± 0.01[a]	10.40 ± 0.02[b]	40.10 ± 0.02[a]
Mean	29.11 ± 0.33	6.47 ± 0.00	4.3 ± 0.01	10.26 ± 0.36	40.57 ± 0.26

Values with the same superscript within the same column are not significantly different (P>0.05)

Demographic and Anthropogenic Characteristics of Fishers

The demographic characteristics and activities of the fishermen in the fishing communities are presented on Table 5. In terms of age, 61.67% of the total respondents were within between 21-40 years while the 17.23% were less than 20 years of age. The population was male-dominated (69.17%) while females were 30.83%. Most of the males (79%) were engaged in fishing activities while most females (89%) were involved in processing activities. As total of 81.67% of males were engaged in mechanic activities, 97% of males were engaged in agricultural activities as secondary sources of income. Only 31% use the designated waste area for their refuse, 69% dumped their wastes indiscriminately.

Table 5: Demographic and activities of respondents in the fishing communities.

Parameter	Range	Mean
Age	< 20 years	17.23%
	21 – 40 years	61.67%
	41 – 60 years	21.10%
Sex	Male	69.17%
	Female	30.83%
Fishing activities	Males	79%
	Females	21%
Processing activities	Males	11%
	Females	89%
Mechanic activities	Males	81.67%
	Females	18.33%
Agricultural activities	Males	97%
	Females	3%
Crop production	Males	85.3%
	Females	14.7%
Waste Disposal	Indiscriminately	69%
	Refuse dumps	31%

Fish species

The mean fortnight relative abundance of fish species identified in the four fishing communities are presented in Table 6. A total of 10,532 individuals belonging to 33 species were identified with *Cynoglossus browni* the most abundant (78.34%) and the least was *Drepane africana* (0.03%) in Igbokoda community. At Ayetoro community, a total of 4783 individuals belonging to 33 species were identified with *Cynoglossus browni* the most abundant (67.28%) and *Polycentropsis abbreviate* 0.02% as the least. At Idi-Ogba community, 5629 individuals belonging to 32 species were identified, *Cynoglossus browni* the most abundant (73.21%) and the least was *Synodontis melanopteron* (0.02%). While at Erunna -Ero community, a total of 6678 individuals belonging to 30 species were identified, *Cynoglossus browni* was the most abundant (77.60%) and *Ophisternon afrum* was the least (0.01%). *Cynoglossus browni*, a carnivorous species generally accounted for 75% of the numerical abundance of the total fish species sampled. Across the months, at Igbokoda and Ayetoro the highest occurrences were in the month of April (12.64% and 13% respectively) and the least were in October (5.99%, 4.56% respectively). While at Idi-Agba and Eunna-Ero the highest were in the month of March (11.72% and 13.33%) and the least were similarly October (4.85% and 4.37%).

Table 6: Relative abundance of fish species identified in the fishing communities

	Species/months	Igbokoda	Ayetoro	Idi-Ogba	Erunna Ero	Total	Total (%)
1	*Arius gigas*	29	19	21	20	89	0.32
2	*Barbus stigmatopygus*	3	1	2	2	8	0.03
3	*Caranax hippos*	239	198	212	232	881	3.19
4	*Carcharihnus leucas*	2	3	5	2	12	0.04
5	*Clarias gariepinus*	129	101	99	123	452	1.64
6	*Coptodon gunieensis*	36	30	57	16	139	0.50
7	*Cynoglossus browni*	8249	3218	4121	5182	20770	75.19
8	*Drepane Africana*	3	10	7	8	28	0.10
9	*Ethmalosa frimbriata*	158	175	191	150	674	2.44
10	*Gnathonemus petersii*	7	2	5	4	18	0.07
11	*Gymnarchus niloticus*	99	68	61	76	304	1.10
12	*Hydrocynus forskahli*	6	1	5	0	12	0.04
13	*Ilisha Africana*	321	91	141	203	756	2.74
14	*Malapterurus electricus*	8	3	0	2	13	0.05
15	*Monodactylus sebea*	17	9	11	0	37	0.13
16	*Mormyrus rume rume*	79	71	43	52	245	0.89
17	*Ophisternon afrum*	8	2	4	1	15	0.05
18	*Ophisurus serpens*	13	21	18	12	64	0.23
19	*Oreochromis niloticus*	29	21	46	19	115	0.42
20	*Papynocranus afer*	8	12	4	0	24	0.09
21	*Parachanna obscura*	9	6	5	4	24	0.09
22	*Parauchenoglanis fasciatus*	51	25	39	27	142	0.51
23	*Pentanemus quinquarius*	123	83	92	105	403	1.46
24	*Polycentropsis abbreviate*	5	1	3	4	13	0.05
25	*Polydactylus quadrifilis*	28	51	28	60	167	0.60
26	*Pseudotolithus elongates*	657	410	287	270	1624	5.88
27	*Sarotherodon galileaus*	51	35	21	41	148	0.54
28	*Schilbe uranoscopus*	4	36	2	0	42	0.15
29	*Selene dorsalis*	78	6	28	25	137	0.50
30	*Synodontis melanopteron*	9	53	1	6	69	0.25
31	*Tilapia marie*	35	11	59	22	127	0.46
32	*Xenimystus nigri*	32	10	9	5	56	0.20
33	*Zanobatus atlanticus*	7	4783	2	5	14	0.05
	Total	10,532	4783	5629	6678	27622	
	Total (%)	38.13	17.32	20.38	24.18		

Fish species targeted in the past and present in Igbokoda community

The targeted fish species based on the responses in the Igbokoda fishing community in the past and present is presented in Tables 7 and 8. A total of nine (9) fish species: *Coptodon spp, Clarias gariepinus, Heterotis niloticus, Gymnarchus niloticus, Parachanna obscura, Gnathonemus petersii, Malapterurus electricus, Xenomystus nigri, and Hydrocynus forskahlii* were targeted at different levels in this community. *C. gariepinus, H. niloticus, and G. niloticus* had the highest percentage of fishers that Targeted them Very Often (TVO) in the past (100%) while *C. gariepinus*

and H. niloticus had the highest TVO fish species at the time of the study (100%) (Figure 2). *G. petersii* and *M. elecricus* had the highest target percentage of fish species Often Targeted (OT) in the past (56.67%) and present (93.33%) respectively (Figure 3). *X. nigri* and *G. petersii* were Rarely Targeted (RT - 33.33%) in the past and present (RT-53.33%) respectively (Figure 4). All the species enjoy one level of target or the other (Figure 4 and 5).

Table 7: Relative abundance of fish species targeted in the past by Igbokoda fishermen.

Fish species	TVO		OT		RT		NT	
	Number	%	Number	%	Number	%	Number	%
Coptodon spp.	19	63.33	8	26.67	3	10	nil	-nil
Clarias spp.	30	100	nil	nil	Nil	nil	nil	nil
H. niloticus	30	100	nil	nil	Nil	nil	nil	nil
G. niloticus	30	100	nil	nil	Nil	nil	nil	nil
P. obscura	23	76.67	5	16.67	2	6.67	nil	nil
G. petersii	10	33.33	17	56.67	3	10	nil	nil
M. electricus	11	36.67	13	43.33	6	20	nil	nil
X. nigri	7	23.33	13	43.33	10	33.33	nil	nil
H. forskahlii	10	33.33	14	46.67	6	20	nil	nil

Key: TVO- target very often; OT- often targeted; RT- rarely targeted; NT- not targeted; %- Relative abundance; Number- across the roles total adds up to 30 respondents.

Table 8: Relative abundance of fish species presently targeted by Igbokoda fishermen.

Fish species	TVO		OT		RT		NT	
	Number	%	Number	%	Number	%	Number	%
Coptodon spp	26	86.67	2	6.67	Nil	nil	2	6.67
Clarias spp.	30	100	Nil	nil	Nil	nil	nil	Nil
H. niloticus	30	100	Nil	nil	Nil	nil	nil	Nil
G. niloticus	29	96.67	1	3.33	Nil	nil	nil	Nil
P. obscura	2	6.67	23	76.67	5	16.67	nil	Nil
G. petersii	1	3.33	13	43.33	16	53.33	nil	Nil
M. electricus	1	3.33	28	93.33	1	3.33	nil	Nil
X. nigri	3	10	13	43.33	14	46.67	nil	Nil
H. forskahlii	4	13.33	24	80	2	6.67	nil	Nil

Key: TVO- target very often; TO- often targeted; RT- rarely targeted; NT- not targeted; %- Relative abundance; Number- across the roles total adds up to 30 respondents.

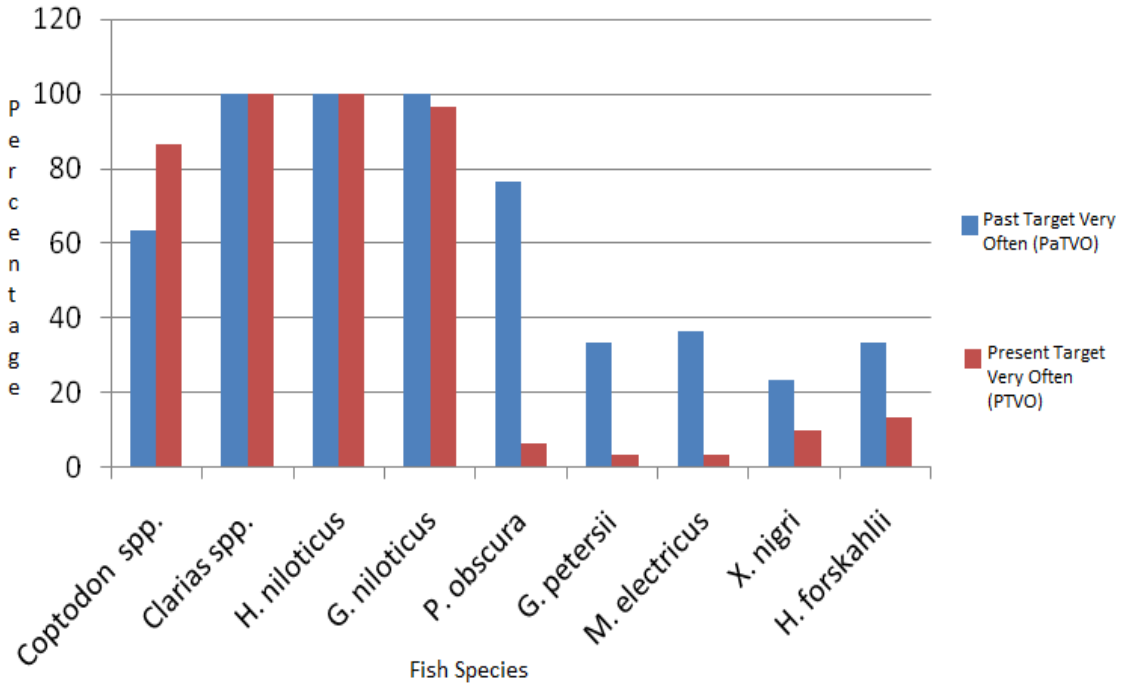

Figure 2: Fish species TVO in the past and present by Igbokoda fishermen

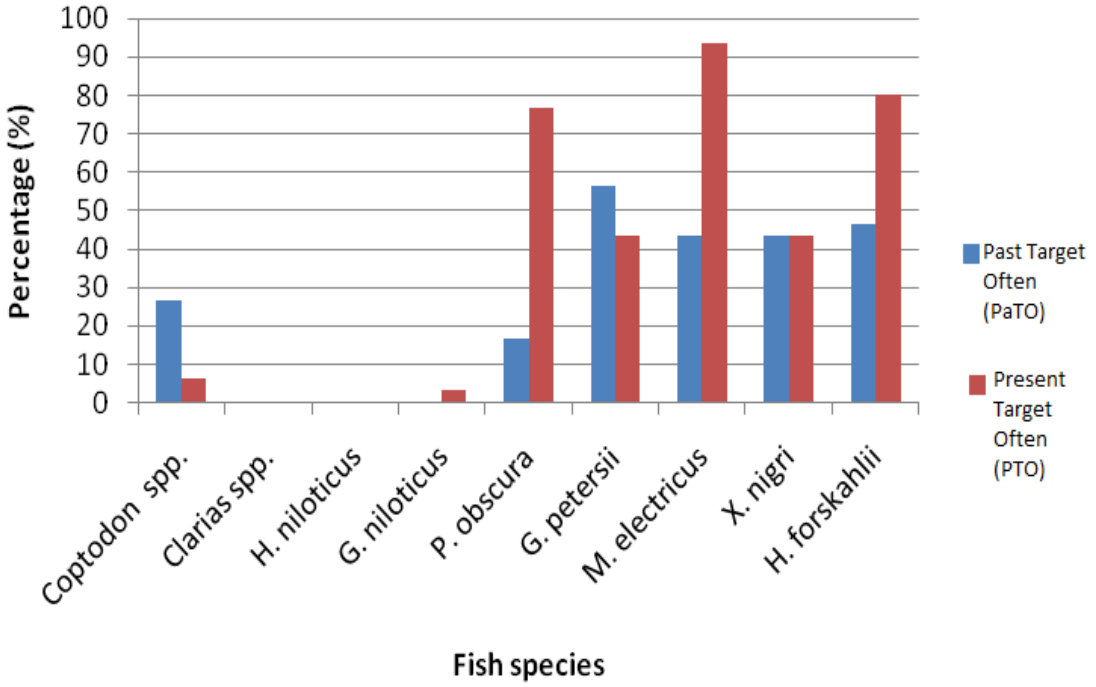

Figure 3: Fish species OT in the past and present by Igbokoda fishermen

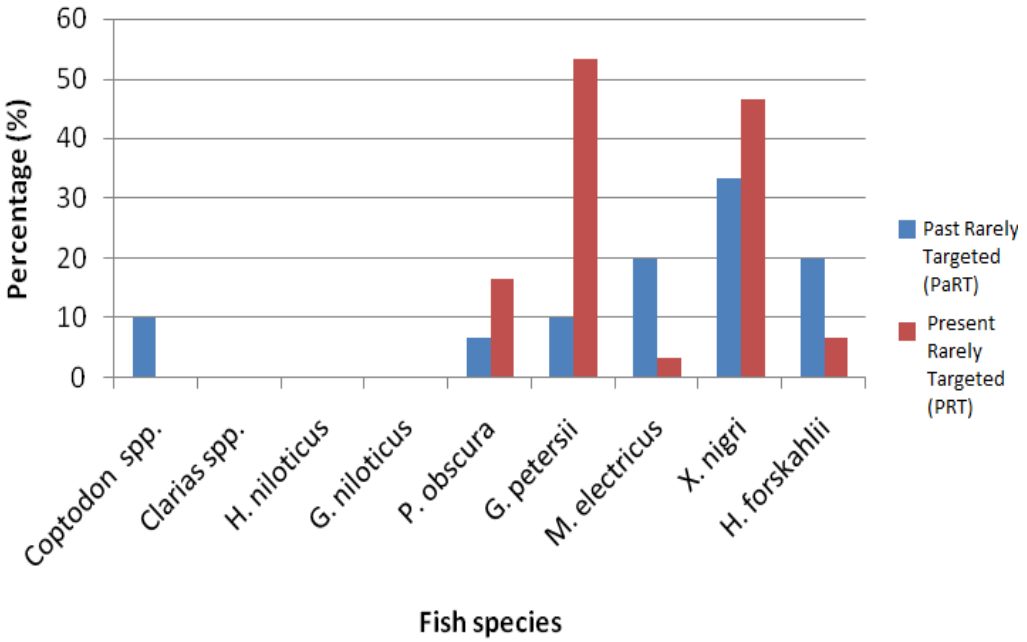

Figure 4: Fish species RT in the past and present by Igbokoda fishermen

Fish species targeted in the past and present in Ayetoro, Erunna-Ero and Idi-Ogba communities

The relative abundance of fish species targeted in the past and present in Ayetoro, Erunna-Ero, and Idi-Ogba fishing communities are presented in Tables 9 and 10. A total of nine (9) fish species, *Liza falcipinnis, Ethmalosa fimbriata, Pseudotolithus elongatus, Dalophis cephalopeltis, Illisa africana, Eleotris senegalensis, Sole sole, Carcharodon* carcharias, and *Carlarius* heudelotii. *I. africana, S. sole,* and *C. heudeloti* had the highest percentage of fish species TVO in the past (100%) while *E. fimbriata, P. elongates, I. africana and S. sole* were the highest occurring fish species TVO in the present (100%) (Figure 5). *L. falcipinnis* had the highest percentage of fish species OT in the past (62.22%) while *D. cephalopeltis* was OT in the present (58.89%) (Figure 6). There was no response for fish species RT and NT in the past and present in these communities.

Table 9: Relative abundance of fish species targeted in the past by Ayetoro, Eruna-Ero, and Idiogba fishermen.

Fish species	TVO		OT		RT		NT	
	Number	%	Number	%	Number	%	Number	%
L. falcipinnis	34	37.78	56	62.22	nil	nil	nil	Nil
E. fimbriata	88	97.78	2	2.22	nil	nil	nil	Nil
P. elongates	88	97.78	2	2.22	nil	nil	nil	Nil
D. cephalopeltis	40	44.44	50	55.56	nil	nil	nil	Nil
E. selengalensis	39	43.33	51	56.67	nil	nil	nil	Nil
I. Africana	90	100	Nil	nil	nil	nil	nil	Nil
S. sole	90	100	Nil	nil	nil	nil	nil	Nil
C. heudeloti	90	100	Nil	nil	nil	nil	nil	Nil
C. carcharias	42	46.67	48	53.33	nil	nil	nil	Nil

Key: TVO- target very often; OT- often targeted; RT- rarely targeted; NT- not targeted; %- Relative abundance; Number- across the roles total adds up to 90 respondents.

Table 10: Relative abundance of fish species presently targeted by Ayetoro, Eruna-Ero, and Idiogba fishermen

Fish species	TVO		OT		RT		NT	
	Number	%	Number	%	Number	%	Number	%
L. falcipinnis	42	46.67	48	53.33	Nil	Nil	nil	nil
E. fimbriata	90	100	Nil	nil	Nil	Nil	nil	nil
P. elongates	90	100	Nil	nil	Nil	Nil	nil	nil
D. cephalopeltis	37	41.11	53	58.89	Nil	Nil	nil	nil
E. selengalensis	41	45.56	49	54.44	Nil	Nil	nil	nil
I. Africana	90	100	Nil	nil	Nil	Nil	nil	nil
S. sole	90	100	Nil	nil	Nil	Nil	nil	nil
C. heudeloti	82	91.11	8	8.89	Nil	Nil	nil	nil
C. carcharias	45	50	45	50	Nil	Nil	nil	nil

Key: TVO- target very often; TO- often targeted, RT- rarely targeted; NT- not targeted; %- Relative abundance; Number- across the roles total adds up to 90 respondents.

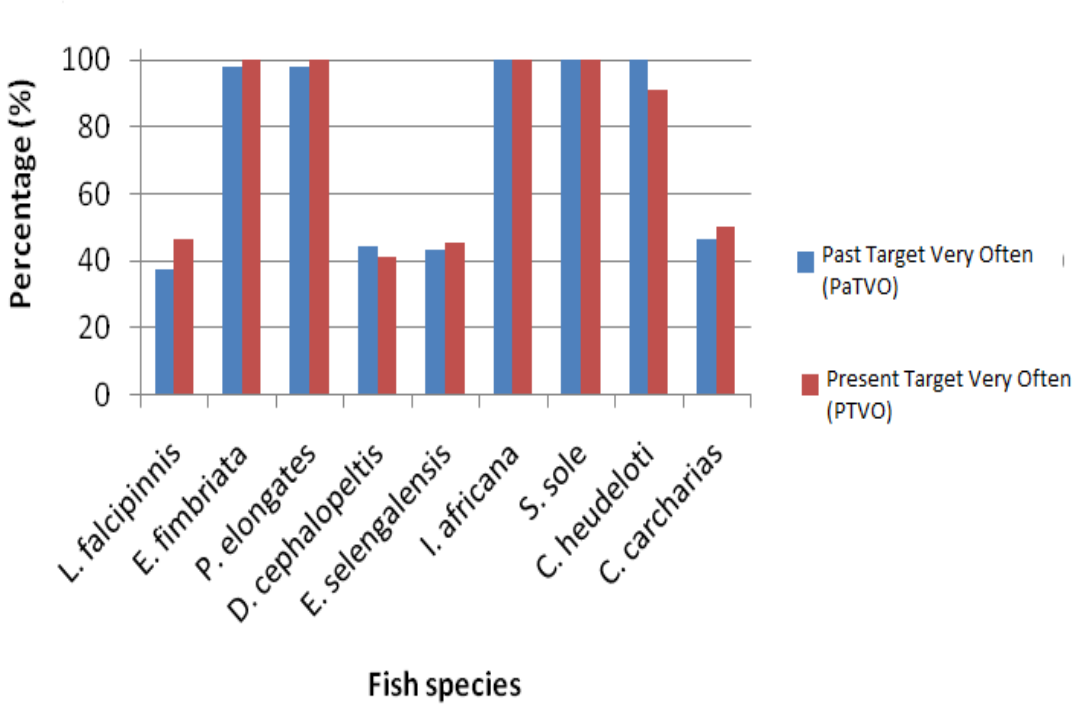

Figure 5: Fish species TVO in the past and present by Ayetoro, Erunna-Ero, and Idi-Ogba fishermen

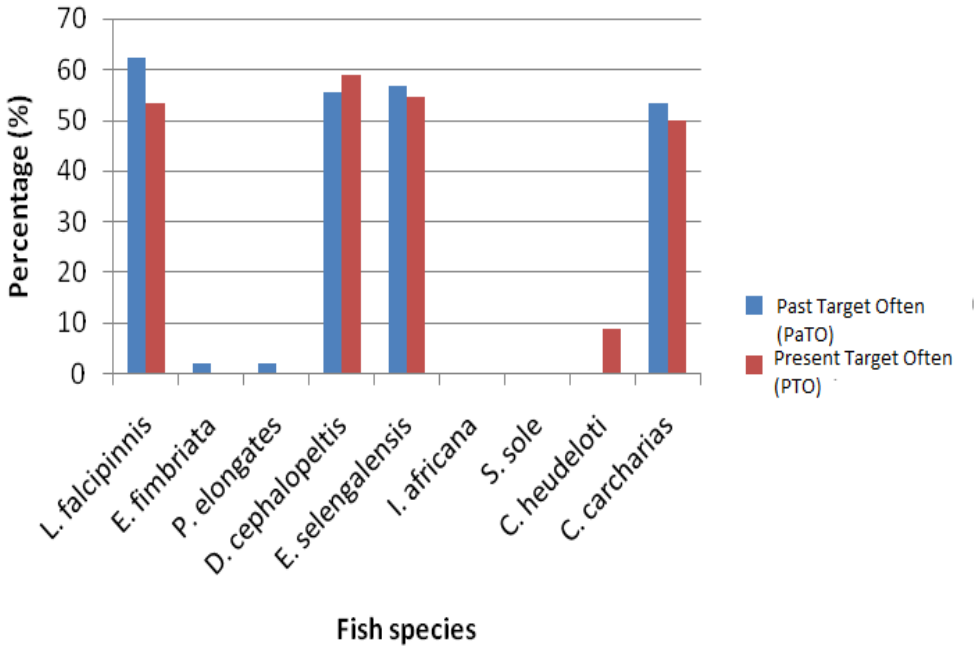

Figure 6: Fish species OT in the past and present by Ayetoro, Erunna-Ero, and Idi-Ogba fishermen

Discussion

Water Quality Parameters

The mean temperature (29.15 ± 0.29 °C) measured from the fishing communities were within the recommended range of 25 - 32°C as stated by Viveen *et al.,* (1985). Most of the mean pH values and the overall mean value measured across the communities were below the recommended range of 6.5 to 8.5 which implied that the water was acidic in nature and may be a function of the agricultural and industrial activities peculiar to these communities. Igbokoda and Ayetoro communities had the least concentration of pH and can be attributed to the mining and explorative activities which releases chemicals to the environment (Bolarinwa *et al.*, 2015). Fish processing activities and craft mending jetties were also observed to be on the rampant in these areas (Olu-Owolabi *et al.*, 2013). The mean concentration of DO was observed to be above the recommended level of 4 mg/L as reported by Boyd (2010) except for the mean values in Igbokoda community which was below the recommended level. The nature of wastes discharged which resulted to the acidic nature of water inhibited the dissolved oxygen concentration which resulted to a reduction below the recommended level in Igbokoda community. Dissolved oxygen is very crucial in aquatic systems and when concentration is beyond an organism's threshold, their abundance and biodiversity is affected (Makori *et al.*, 2017). Therefore, the increased nature of wastes in Igbokoda community as a result of the rapid industrialization and urbanization (Adebowale *et al.*, 2008) poses a serious threat to aquatic resources (Emmanuel, 2012). The water in Igbokoda community during the study period was observed to be fresh water as measured in the salinity level of 0.68 ± 0.08 ppt. Boyd (2010) stated a mean salinity level of < 1 as fresh water, between 1 – 34 ppt as brackish and above 34 as marine waters. Based on this description, it can be said that the waters in Igbokoda were fresh water and the other three communities were brackish water regions during the period of study. These salinity levels dictated the conductivity of these waters and this ability was low in Igbokoda (11.77 ± 0.11 µS/cm) when compared with Ayetoro (40.52 ± 0.51 µS/cm), Erunna-Ero (40.70 ± 0.18 µS/cm) and Idi-Ogba (40.57 ± 0.26 µS/cm) communities. These salinity and conductivity levels can also be dictated by tidal flows from the marine and freshwater environments (Adebowale *et al.*, 2008). Generally, the variations in water quality parameters were observed among the fishing communities which could be a result of factors such as climatic factors,

tidal activities, anthropogenic activities and the secondary use of water (Ipinmoroti *et al.,* 2018b, Olaoye *et al.,* 2013, Ipinmoroti, 2013).

Demographic characteristics of respondents

It was observed from these results that the four fishing communities were male-dominated and the most populous age range was 21 – 40 (61.67%). This result was corroborated by findings of Ipinmoroti *et al.,* (2018a), Nwabeze *et al.,* (2013), and Olaoye *et al.,* (2012) who reported the dominance of an active population force of young men in active fishing activities on the coastal waters of Ondo state while the females were into fish processing. It was observed that activities such as agriculture (97%), crop production (85.3%), mechanic activities (81.67%) which were male dominated disposed their wastes indiscriminately (69%) and end up directly or indirectly into the water, having a significant negative impact on the water quality (Emmanuel, 2012). Urbanization and industrialization also contributed to refuse and wastes generated in these communities, some of which are dumped uphill which eventually run off into the aquatic system when torrential rain occurs (Olaoye and Adedeji, 2005). Generally, a larger percentage of inhabitants (69%) dump the wastes from their various anthropogenic activities in locations where they find their way into the water system either directly or indirectly.

Fish species

The fishing communities were observed to have diverse fish species and targeted fish species by fishermen in the Igbokoda community were entirely different from those targeted by fishermen in Ayetoro, Erunna-Ero and Idi-Ogba fishing communities. The possible reasons may be the salinity level in which Igbokoda waters are more of fresh water and the other three communities' marine waters with salinity levels over 35ppt. The fish species abundance was highest in Igbokoda community (10,530 individuals) and this was expected because the area was larger than other commuities'. At the time of study, only two (2) fish species namely *C. gariepinus* and *H. niloticus* were presently TVO when compared with the three (3) fish species namely *C. gariepinus*, *H. niloticus* and *G. niloticus* which were TVO in the past at Igbokoda fishing community with a slight reduction in the target of *G. niloticus* when compared with the past. This may be linked with the reduction in the level of abundance of these target fish species which has also reduced drastically (Table 7). Igbokoda community is a large fishing community that is faced with rapid urbanization and the advance of oil exploration in the area has impacted the community (Akegbejo, 2005). These indicators could be the cause of a drastic reduction in the very frequent target of other fish species in the present when compared with the target in the past (Adebowale *et al.,* 2008).

The reverse was the case at Erunna-Ero, Idi-Ogba, and Ayetoro fishing communities which are smaller in population size when compared to the Igbokoda community. The targeted species increased from three (3) in the past namely *I. africana, S. sole*, and *C. heudeloti* to four (4) in the present namely *E. fimbriata, P. elongates, I. africana, and S. sole.* The possible reason for this increase in target species could be as a result of migration by fish species to new locations (Erunna-Ero, Idi-Ogba, and Ayetoro fishing communities) due to the negative effects of the anthropogenic activities at the Igbokoda community which is becoming urbanized. As a means of survival, fish species will normally migrate for various reasons, one of which is the search of better water conditions for their survival when the current state of water is not conducive. This migration was observed to result into increased fishing activities at Erunna-Ero, Idi-Ogba, and Ayetoro fishing communities and this was evident by the increase number in target species in these communities. *S. sole* was the only fish species targeted in the past and present and a possible reason for this increase in target could be based on the high market value, the availability of fish species, and consumer preferences in these three communities (Ipinmoroti *et al.,* 2018a).

Conclusion

The water quality parameters measured from the coastal waters present values which were within the recommended ranges for the sustenance of aquatic life although the anthropogenic activities affected the water quality at some periods most especially in Igbokoda community. The coastal area was male-dominated and majorly involved in fishing activities while the females engaged majorly in fish processing. It also revealed that the coastal water is rich in fish diversity and the past and present state of targeted fish species in Igbokoda, Ayetoro, Erunna-Ero, and Idi-Ogba fishing communities fluctuated over time and differently. These differences could be traced to anthropogenic factors most especially the oil exploration activities and transportation activities as such resulting in fish migration to a more conducive environment. The coastal water system can be classified as a good, stable, and healthy system; although there is need for decisive management to sustain the quality of the coastal water. Orientation is also needed on proper disposal of wastes and clean-up activities for the coastal inhabitants.

Conflict of Interest

The authors declare no conflict of interest exists

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ORIGINAL RESEARCH ARTICLE

Changes in serum brain derived neurotrophic factor following high intensity interval training among obese undergraduates

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Abstract

The study examined changes in Serum Brain Derived Neurotrophic Factor (BDNF) following High Intensity Interval Training (HIIT) programme among obese undergraduates. The pretest-posttest randomized experimental design was employed for the study. The population of the study comprised one hundred and twenty (120) obese undergraduates, out of which a total of twenty-four (24) obese undergraduates made up the sample for the study. Simple random sampling technique was employed to select the participants. The anthropometric profiles of the participants were descriptively analyzed using mean and standard deviation, while independent sample t-test was used to test the hypothesis. Statistical significance was accepted at p value of <0.05. The results obtained indicated an increase in Serum BDNF (1.05 ± 1.4 vs 1.42 ± 2.2) among HIIT group, with no statistical significant difference. It was therefore concluded that the HIIT protocol-initiated alterations in the serum BDNF concentration of the obese undergraduates. HIIT may represent an effective intervention for elevating BDNF levels, as well as potentially promoting brain health. It was recommended that further research with prolonged exercise duration and larger sample size is required to elicit statistical significance, as well as to confirm the finding that increased serum BDNF levels are associated with HIIT intervention among obese undergraduate population.

Keywords: *BDNF, Obese undergraduates and HIIT*

Introduction

Obesity is a serious health issue characterized by abnormal or excessive body fat accumulation. Empirical studies conducted among university undergraduates in Nigeria reflect a high prevalence of obesity (Obirikorang, *et al.*, 2017; Chukwuonye, *et al.*, 2013). A common way of measuring and classifying obesity is to use the Body Mass Index (BMI). In general, higher BMI values leads to increased risk of health complications. Increased body mass, excess weight and abdominal obesity have been associated with cognitive impairment across the duration of life (Prickett, *et al.*, 2015). Obesity is usually linked to poor cognitive state across lifespan with decline in daily functions and health as well as decline in motor control capabilities (Gunstad, *et al.*, 2006). An

evidence by Prickett, *et al.* (2015) showed a correlation between obesity and impaired brain functions, as well as obesity-related changes in brain plasticity. In an attempt to resolve this claim, Cherif, *et al.* (2016) asserted that exercises geared towards weight loss may improve cognitive functions. Although, the underlying mechanism which is biological in nature, as postulated from Cherif, *et al.* (2016) report is yet to be unraveled.

Growing evidence exist that Brain Derived Neurotrophic Factor (BDNF) is actively involved in facilitating the benefits of exercise on cognitive functions as well as mediating decreased food intake (Szuhany, *et al.,* 2015). BDNF is a protein grouped among the neurotrophin class. BDNF has expression in Central Nervous System (CNS) repair, as well as plasticity and linking of synapses. Furthermore, loss-of-function mutations in the BDNF receptor may lead to neurodegenerative disorders, depression, and obesity (Szuhany, *et al.,* 2015). Obesity-related health conditions including cognitive function may be moderated by physical activity. Physical exercise is a sub-class of the physical-activity domain. Physical exercises elicit impact on the brain anatomy and function in humans (Alberto, *et al*, 2018). During high intensity exercise (above 80% MaxVO_2), an increased neurotrophic factor was observed (Marston, et al., 2017).

High Intensity Interval Training (HIIT) is characterized by sessions of intermittent, relatively brief bursts of vigorous activity with intensity of above or equal to 85% Peak Oxygen Uptake (VO_2peak), intermixed by low intensity exercise or rest-phases for recovery. HIIT session takes 45 minutes with warm up and relaxation phases. The training bouts are usually executed at optimal effort with intensities at 80 to 100% of maximal heart rate (Saanijoki, *et al.,* 2018). The exertion is performed with a duration not longer than 60 seconds with recovery periods (rest or low-intensity exercise) of up to 4minutes.

Besides the protocol of Gibala (2015), several researchers have presented divergent high and low exercise bout durations (Stoggl & Bjorklund, 2017). Although, a duration of 30 minutes and above may be considered appropriate. HIIT can be performed while running, swimming, on cyclical exercises, and whole-body exercise (Schleppenbach, *et al.,* 2017). Connolly, *et al.* (2017) asserted that HIIT improves human physical performance. The attendant impact of HIIT on human brain-function exist; although, the available evidence appears to be scarce. Short-term HIIT has been shown to elicit improvements in intense exercise performance, and appear to be beneficial as an addition to an already high training volume (Chin, *et al.,* 2019). Marquez, *et al.* (2015) further opined that short bouts of HIIT are slightly more potent when compared to continuous HIIT in elevating serum BDNF. In contrast, the study conducted by Zhang, *et al.* (2015); and Nazari, *et al.* (2016) revealed that long term/chronic effect of 12-week HIIT protocol potentiated a significant increase in serum BDNF and anthropometric parameters, respectively. In this study, an acute bout/short term HIIT programme was adopted.

In light of the above, this study examined changes in the serum BNDF following High Intensity Interval Training (HIIT) among obese undergraduates of the University of Benin.

Hypothesis

An hypothesis was formulated to guide the study.

- There will be no significant difference in the Serum BDNF concentration of obese undergraduates following HIIT programme in the experimental and control groups.

Methodology

This study adopted the pretest-posttest randomized experimental design. A sample size of twenty-four (24) from a population of one hundred and twenty (120) obese undergraduates of the

University of Benin in the 2019/2020 academic session were selected. The cohort belonged to an Obesity Fitness Group (OFG), which regularly participate in exercise sessions at the University of Benin. The selected sample constituted 20% of the total population. The inclusion criteria for the study involved participants without any form of visible disability. An exclusion criterion of participants below the BMI categorization of 30 kg/m^2 was adhered strictly. The selection was through a simple random sampling technique. The sampled participants were then randomly assigned to the experimental and control groups. This involved serializing the 24 selected obese students and respectively assigning numbers to the participants and selecting the even numbers to the experimental and the odd numbers to the control group. This yielded 12 obese undergraduates in each of experimental and control group.

An ethical approval was obtained from the Ethics Board of University of Benin, Benin-City, Nigeria.

Anthropometric Measurements

The subjects were briefed on the study's objectives and familiarized with the anthropometric assessments and equipment. Data were collected by conducting pre-test measurements of anthropometric parameters before the commencement of the High Intensity Interval Training (HIIT) programme, which was in an acute form. Post-test measurements were conducted immediately after the intervention duration has elapsed using the same procedures.

Specifically, the participants' heights were measured while standing with bare foot using a calibrated stadiometer. The subject's percentage body fat and body weight indices were estimated using an Omron Body Composition Monitor (Omron Healthcare, 2019), wearing minimal clothing. Internal consistency type of reliability was adopted in the present study. A pilot study was carried out to confirm the suitability of the HIIT protocol and instrument, to which eight (8) independent subjects were selected, with four (4) each per group. The multilevel modeling method was adopted in obtaining the data that was subjected to Interclass Correlation Coefficient (ICC). A Correlation Coefficient of 0.75 was obtained and considered a high reliability. Hence, this justified the aptness of employing the instrument and protocol for this study.

Biochemical Analysis

The procedure for obtaining blood sample was in accordance with WHO (2010) standard. Blood sampling was obtained twice, pre-training and immediately after the acute training. Blood sampling were obtained from the antecubital veins of the overnight-fasting subjects by a medical laboratory scientist, with participants sitting on a chair for 15 minutes. Blood samples were stored for one hour at room temperature to allow blood-clotting. The blood sample was centrifuged and expressed serums left at -80°C pending final measurements. BDNF concentrations were measured using Enzyme-linked-immunosorbent assay (ELISA) kit (Eastbiopharm, Hangzhou Co. Ltd, China).

Training Protocol

The Experimental group was exposed to the HIIT protocol. The HIIT protocol involve performing 10-minute warm up session that included jogging, stretching, and running for a 5-minute 50% to 85% of maximum heart rate (training started with 50% of intensity) at commencement of each session. Then, participants performed 20-minute strength training for large muscles of the upper and lower body, which included windmills, burpees, sit-ups, heel raise, side jumps, alternate lateral tilting and alternate leg-arm kicking at 50% to 80% of one repetition maximum (training commenced with 50% of intensity and increased steadily). Three (3) sets of 10 repetitions (with 1-minute rest interval between sets and 2-minute rest interval between exercises) were performed.

Training sessions were concluded using a 10-minute cooling-down session by slow walk. It has been demonstrated that this type of exercise protocol corresponded to acute HIIT (Nazari, et al., 2016). The recommended protocol of High Intensity Interval Training (HIIT) was validated by Machado, et al. (2017). The control group participants were not subjected to the High Intensity Interval Training (HIIT) protocol, rather each of the exercises for the experimental group was also executed by the control group, although without applying the necessary increment or overload. This means that the tempo or intensity with which they started was the same till the end of the training programme.

Statistical Analysis

Statistical Package for Social Sciences (SPSS) – IBM version 20, was employed to analyze the data. Descriptive statistics of mean and standard deviation was employed to describe the anthropometric and BDNF profile of the sample collected. The formulated hypothesis was tested using inferential statistics of independent sample t-test to determine the differences between the intervention and control groups. The alpha level was set at 0.05 level of significance.

Results

Table 1: Physical and Anthropometric Characteristics of the Subjects (n=24)

		Group	
Variable	**Measuring**	**Control (n=12)**	**Experimental (n=12)**
Age (yrs)	Pre-training	26.3 ± 9.4	27.5 ± 4.1
Height (cm)	Pre-training	1.69 ± 0.1	1.74 ± 0.1
	Pre-training	86.4 ± 9.4	92.0 ± 8.2
Weight (kg)	Post-training (Acute)	86.2 ± 9.2	91.5 ± 8.6
	Pre-training	30.6 ± 4.5	30.3 ± 3.0
BMI (kg/m^2)	Post-training (Acute)	30.6 ± 4.2	29.9 ± 3.1
	Pre-training	39.6 ± 10.6	37.5 ± 10.8
Body Fat (%)	Post-training (Acute)	38.8 ±11.4	37.9 ± 10.5

**** BMI – Body Mass Index, Values expressed as Mean ± SD***

Table 1 presents means and standard deviations of physical and anthropometric characteristics (age, height, body mass index, body fat percentage) of participants in the experimental and control groups.

Table 2: Descriptive Statistics Showing the Serum BDNF concentration of the experimental and control participants

Variable	**Experimental**		**Control**	
	Pre	**Post**	**Pre**	**Post**
BDNF (ng/ml)	1.05 ± 1.4	1.42 ± 2.2	2.50 ± 3.1	2.68 ± 3.2

**** BDNF – Brain Derived Neurotrophic Factor.***

Values expressed as Mean ± SD

Table 2 reflects an increase in Serum BDNF with a mean and standard deviation of 1.05 ± 1.4 and 1.42 ± 2.2 were observed at posttest assessment in the experimental group when the pretest and posttest assessments are compared. Similarly, among the control group, a slight increase in Serum BDNF with a mean and standard deviation of 2.50 ± 3.1 and 2.68 ± 3.2 were indicated at posttest assessment when compared with pretest assessment respectively. In order to ascertain if the increased difference is significant or not, the need to test the hypothesis became necessary.

Table 3: Independent Samples t-test of the Experimental and Control Groups

Variables		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Serum BDNF	Equal variances assumed	6.323	.020	1.108	22	.280	1.26667	1.1434	-1.1047	3.6380
	Equal variances not assumed			1.108	19.457	.281	1.26667	1.1434	-1.1228	3.6561

**** No significant difference (p<0.05) between the control and experimental group***

From Table 3, differences in the serum BDNF prior to and following an acute HIIT programme was determined using an Independent Sample t-test. No significant difference in the control and intervention groups with mean scores of serum BDNF indicating [t(22)=1.108, p=0.280]. Thus, the hypothesis which states that there is no significant change in the BDNF levels of the experimental and control obese undergraduates following HIIT programme was accepted. It therefore implies that HIIT had no substantial effect on the BDNF levels of the University of Benin obese undergraduates.

Discussion

This study evaluated changes in BDNF concentration following HIIT protocol among obese undergraduates. The outcome of this study indicated an increase in the serum BDNF concentration following an HIIT intervention among the obese undergraduates. However, the observed increase was not statistically significant. This finding is in agreement with the submissions of Nazari, et al. (2016); Saucedo Marquez, et al. (2015), which reported heightened serum BDNF concentration of the participants. The increase in the BDNF concentration after the acute HIIT programme could be attributed to its stimulated secretion from several tissues (muscles and brain). This could be slightly different from chronic training, which could be attributed to increased gene expression and activation of transcription-pathways. Wrann, et al. (2013) posited that musculo-skeletal contractions during HIIT programme can be a possible initiator of the biochemical processes that cause heightened BDNF concentration in the brain. The extent of physical exertion during an intervention phase may be potent in altering BDNF concentration. Varying exercise types and intensities may also affect BDNF responses.

In contrast to this finding, the study by Mehrjardi (2017) and Kim (2016) reported a significant decline in serum BDNF concentration. This discrepancy in findings are not far-fetched as a different sample involving athletes was studied, and among the same cohort, previous studies have showed that basal BDNF in sport persons was reduced by habitual exercising (Nofuji, et al., 2008; Babaei, et al., 2014). Another reason for this discrepancy in findings could be that about storage of 90% of blood BDNF proteins occurs in the platelets, with platelet-activation facilitating its secretion or released during clotting process (Kim, 2016). Exercise induces mechanical and functional stress, leading to nerve injury and muscle damage (Kuipers, 1994). Athletes participate in series of elevated intensity exercises which may lead to tissue damage tissue, and continuous repair is required. BDNF is active in repair process and injury recovery (Kim, 2016). The findings of Kim (2016) further reflected chances that BDNF release from platelets to injured tissues elevates in order to facilitate repair process, which in turn decreases BDNF stored in platelets. The decrease

in serum BDNF may also be attributed to the type of training protocols involving regular taekwondo exercises. Timing and varying blood sampling methods may have also contributed to the discrepancies.

Interestingly, despite an increased serum BDNF from both the control and experimental group in this study, it is worth noting that the observed increase was higher for participants exposed to the HIIT intervention, suggesting that the HIIT programme may be an effective means of promoting brain health.

The result of an independent sample t-test resulted to acceptance of the null hypothesis of no significant alteration in the serum concentration of the obese undergraduates following a single exercise bout of HIIT programme. The implication is that the HIIT programme administered had no substantial effect on the participants' serum BDNF.

Conclusion

Based on the findings of this study, the following conclusions were made:

- HIIT protocol initiated an increase in the serum BDNF concentration of the obese undergraduates.
- HIIT protocol did not elicit any significant change in the serum BDNF level of the obese undergraduates.
- The advantageous effect of HIIT may be observed almost immediately, as single session of training rapidly improves cognitive function.

Recommendations

Based on the findings, the following recommendations were made:

- Further research with prolonged exercise duration and larger sample size is essential to elicit statistical significance, as well as to confirm the finding that increased serum BDNF levels are associated with HIIT intervention among university obese population.
- Obese students should be sensitized to the various benefits of HIIT programme as they relate to the general health and well-being of individuals.
- Coaches and personal trainers should attend courses or seminars, where they can learn more on how to incorporate HIIT programme into their training regimen in eliciting increase in serum BDNF.

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ORIGINAL RESEARCH ARTICLE

Community engagement and compliance monitoring of COVID-19 safety protocols: innovative approach combining indigenous practice and GIS technology in Oyo State, Nigeria

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Abstract

Background: One of the major challenges that has driven the spread of Coronavirus Disease 2019 (COVID-19) worldwide is the burden of enforcing the preventive measures required to contain the pandemic. Enforcement of COVID-19 precautionary behaviour should not be homogenous; every country needs to be creative to ensure that humane considerations guide all decisions during the extraordinary experience that COVID-19 pandemic portends. The model of self-policing is acceptable and maintained principally because the citizens of any communities operate, recognize, and accept them as preferred alternatives to the official models of policing for enforcement. Hence the approach presented in this paper, which deployed existing indigenous alternative systems in ensuring compliance with COVID-19 precautionary behaviour. This article therefore documents the unique approach deployed for the containment of COVID-19 in Oyo State, Nigeria.

Objective*:* This intervention was designed to explore established indigenous alternative systems and models of control, justice, law, security, and enforcement in Nigeria. Additionally, geographic information system (GIS) technology and investigative journalism was used to monitor and evaluate the effectiveness of the intervention.

Method*:* The method employed was community conversation; a method of increasing inclusive, community-based engagement harnessing the expertise and motivation of key stakeholders. The community conversations were convened after the pattern of a traditional Town-hall meeting. Community conversations were organized as a qualitative framework focusing on deploying the indigenous practice of self-policing associated with Nigeria's trade unions and aims to inform COVID-19 preventive behaviour at the community level. Geographical information system technology was used to develop COVID-19 Containment Compliance Citizens' Reporter App. The App was developed using ESRI ArcGIS online platform to crowd source public feedback on

compliance or contravention of COVID-19 protocols. Social media platforms were also deployed for monitoring and evaluation of the intervention post townhall meeting.

***Results**:* The establishment of a State-wide Containment response network provided the required inroad for advocacy and deployment of state-wide community conversation framework in the different communities comprising diverse ethnic groups, religious leaders, market leaders, National Union of Road Transport Workers (NURTW), and so on. Testimonials from the various communities showed that the people have embraced the self-policing strategy and the network system was effective with good outcomes in terms of response to decontamination, containment, and advocacy. The COVID-19 Containment Compliance Citizens' Reporter App, investigative reporting by mass media were highly effective tools for monitoring and evaluation of the outcome of the intervention as well as possible evidence for melting out incentive and disincentive measures as necessary. This approach is a template, which could be adapted and replicated in other parts of Nigeria and other African societies with similar structures, demographics, and indigenous practices.

Keywords: *Indigenous Practices, COVID-19 Containment, Community Conversations*

Introduction

Nigeria, the most populous country in West Africa made up of 36 States and the Federal Capital Territory. According to the Worldometer elaboration of the latest United Nations data, Nigeria has a population of 212, 725,060 with a Population Growth Rate (%) of 2.6 per annum (World Population Review, 2021). A total of 53.39% and 43.87% were in the age ranges of 15 – 64 years and 1 – 14 years respectively, while those in the age 65 and above accounted for 2.75% (World Population Review, 2021). Though, the index case of COVID-19 was not recorded in Nigeria until February 27, 2020, the novel coronavirus disease 2019 (SARS CoV2) was designated a pandemic on 11 March 2020 (WHO, 2020). According to the World Health Organization (WHO), knowledge related to regular hand washing, application of hand sanitizers, wearing of face masks, respiratory etiquettes, physical distancing, and self-isolation when ill will reduce the widespread infection of the disease (WHO, 2021).

Oyo State is an inland state in South-western Nigeria. According to NIPC, (2021), the state covers a total land area of approximately 26,500 sq.km and has an estimated population of 8,392,588 persons (4,280,220 (male) and 4,112,368 (female). Ibadan is the capital and most populous city with a population of over 3 million; it is the third most populous city in Nigeria after Lagos and Kano and the country's largest city by geographical area. There are eleven (11) Local Government Areas in Ibadan consisting of five (5) urban and six (6) semi-urban Local Government Areas. In containing COVID-19, Oyo State employed a Town-Gown Partnership approach (an approach that brings academics and stakeholders including government and community leaders together) which was reflected in the COVID-19 taskforce composition consisting of individuals from the academia, healthcare, industry, and the government. Some of the immediate containment measures announced by the taskforce were the establishment of six (6) isolation centres which cut across the state (Infectious Disease Centre, Olodo, and Chest Hospital, Agbami (Ibadan); Igbo-Ora (Ibarapa); Saki (Oke-Ogun); Aawe (Oyo), and the LAUTECH Teaching Hospital (Ogbomoso), helplines for rapid response, disease surveillance and notification officers in all the 33 Local Government Areas (LGAs) and 35 Local Council Development Area (Daily Post, March 21, 2020).

The Oyo State COVID-19 Decontamination and Containment Team was inaugurated on 13th April 2020. The goal was to complement the activities of the State Central Task force in the areas of containment, including provision of prophylactic and interventional decontamination support vital to limiting the spread of the SARS CoV2. However, it was observed that the major challenge to

containment of the spread of COVID-19 was in ensuring compliance with the WHO recommended precautionary behaviours. The responses of the Country's Law Enforcement Agents in ensuring people's compliance with precautionary protocols have been less than optimal. The initial inter-State lockdown prescribed by the Federal Government to contain the virus with the index states of Lagos, Ogun and the Federal Capital Territory was quite ineffective because enforcement was futile and, in some cases, fraught with report of citizens' harassment and extortion. To ensure citizen's compliance with COVID-19 precautionary protocol; it was imperative that another approach be devised. The Oyo State COVID-19 Containment Committee therefore came up with the innovative approach of combining Community conversation, intrinsic indigenous practices, and utilize GIS technology, mass and social media for monitoring and evaluation. Geographic Information System (GIS) is defined as "the Science of Where" that combines mapping and analytics to reveal deeper insight into public health data, helping policy makers to make smarter decisions. The GIS is a framework for gathering, managing, and analysing complex data.

Methodology

In response to a Statewide spread of COVID-19, Oyo State COVID-19 Containment Committee inaugurated a Statewide Containment response network team on 4th of August 2020, to enhance the State's COVID-19 response and containment, and ability for compliance with precautionary protocols across the 33 LGAs (Figure 1).

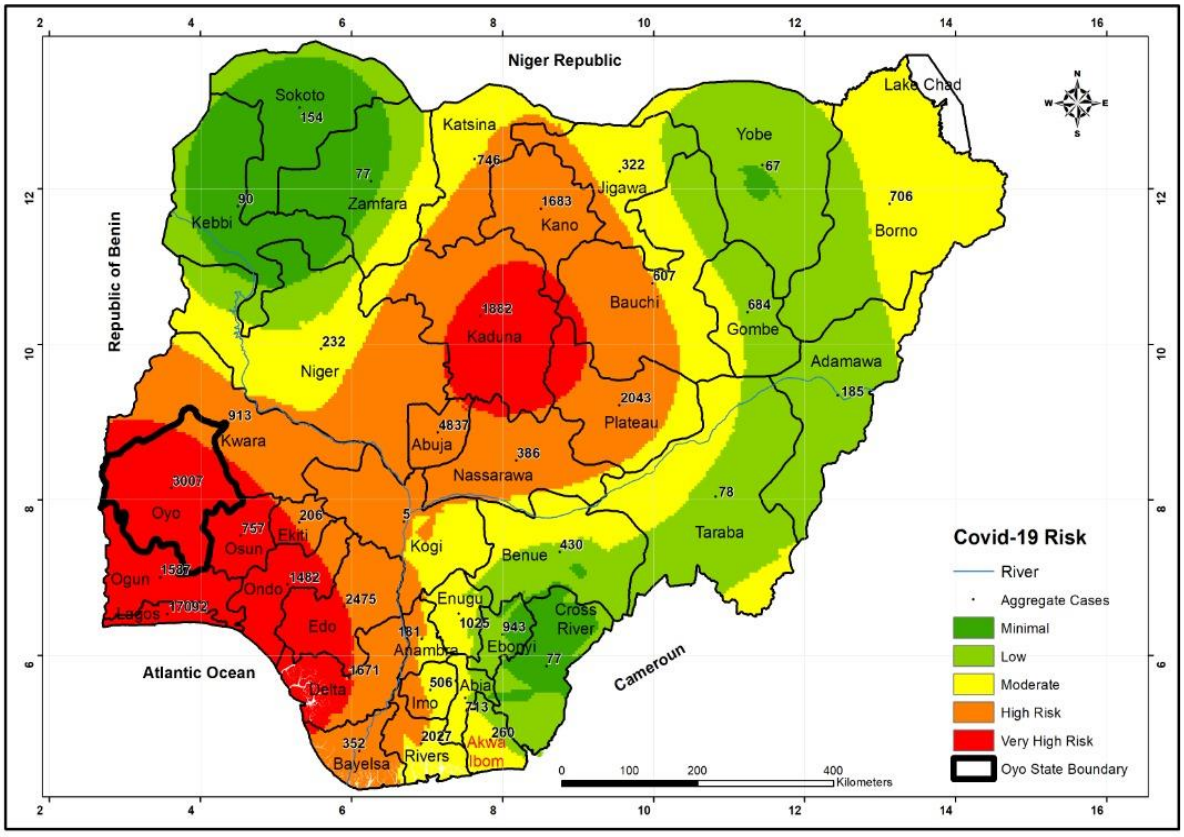

Figure 1: Hotspot Analysis of Confirmed Covid-19 Aggregate Cases as at 21st August 2020. Nigeria

Administrative Boundaries datasets curated from the Humanitarian Data Exchange (HDX) by Oyo State Decontamination and Containment Team

The containment activities of the response network team included advocacy with the people and leaders in their localities, prophylactic, and interventional decontamination support as well as reporting of contraventions with the precautionary COVID-19 protocols. To support the structure,

a Covid-19 Hub was setup with dashboards, maps, models, and information modules to analyse and provide location intelligence from the information inputs, https://oyo-covid-19-control-uigis.hub.arcgis.com/. Part of the data to be fill after opening of the app link included, types of activities engaged in by the team (advocacy or decontamination or both), location, compliance and/or contravention by the people based on observation.

The network team supervisors were then trained to use GIS apps for the following purposes:

1. ***Supervisor's APP***: to report every containment exercise- www.arcg.is/0vnbO8
2. ***Monthly Zonal Report***: for monthly report only by the Team Lead of each Zone- www.arcg.is/15KvLq.

Towards identifying and mapping the communities recalcitrance in complying with COVID-19 precautionary behaviours, a GIS app called **"***COVID-19 Containment Compliance Citizens' Reporter"* (https://arcg.is/19jK4n0) was deployed and publicized across social and mass media. The app enabled citizens to upload pictures/videos of compliance as well as outrageous contraventions such as vehicle overcrowding, non-use of face masks or absence of physical distancing in banks, markets and communities in Oyo State. As an alternative to policing, a community conversation involving stakeholders where contraventions were most severe was convened on 13th August 2020. The community conversation strategy brought the different community leadership together and adopted a participatory approach, including participants as decision-makers and implementers (Kemmis and McTaggart, 2005, Stoecker and Brydon-Miller, 2013). The community conversation strategy was to secure the commitment of the leadership to deploying the indigenous practice of self-policing. Post community conversation effectiveness monitoring and evaluation was anchored on the "*COVID-19 Containment Compliance Citizens' Reporter*" app, while partnership was brokered with mass and social media practitioners to follow-up with investigative reporting to expose contraventions. The containment network in each zone started with stakeholder's awareness campaign and meeting with traditional rulers and the leadership of different groups to secure commitment by assisting with compliance with COVID-19 precautionary measures in their communities and spheres of influence. Both oral and written informed consents were obtained from all the participants in this study. This intervention using the above methodology was as a result of data analysis from the activities of the Oyo State COVID-19 Containment and Decontamination team as shown in Figures 2 and 3.

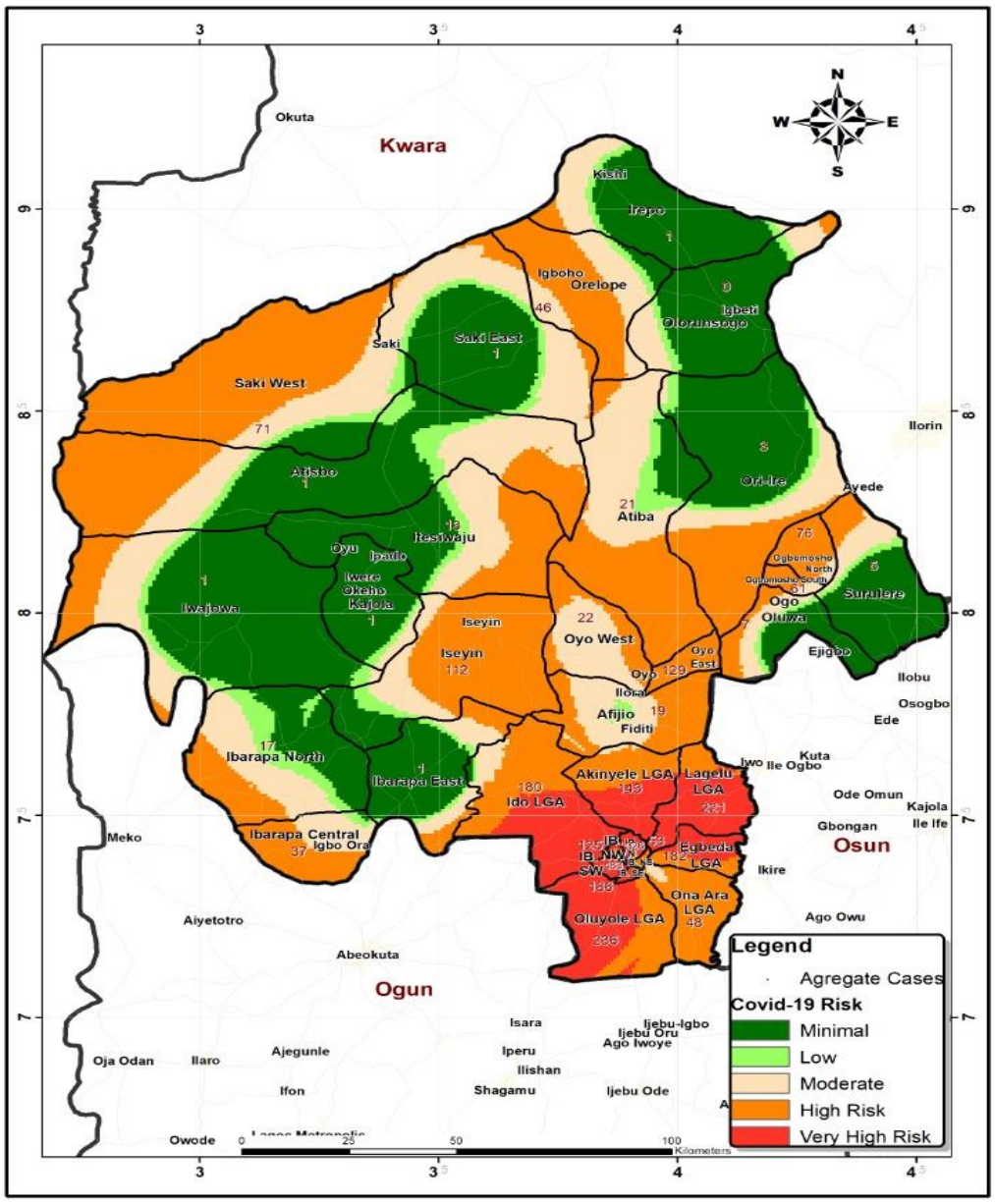

Figure 2: The hotspot analytics for Oyo State as at 18th August 2020. Oyo State administrative boundaries datasets curated from the Humanitarian Data Exchange (HDX) by Oyo State Decontamination and Containment Team

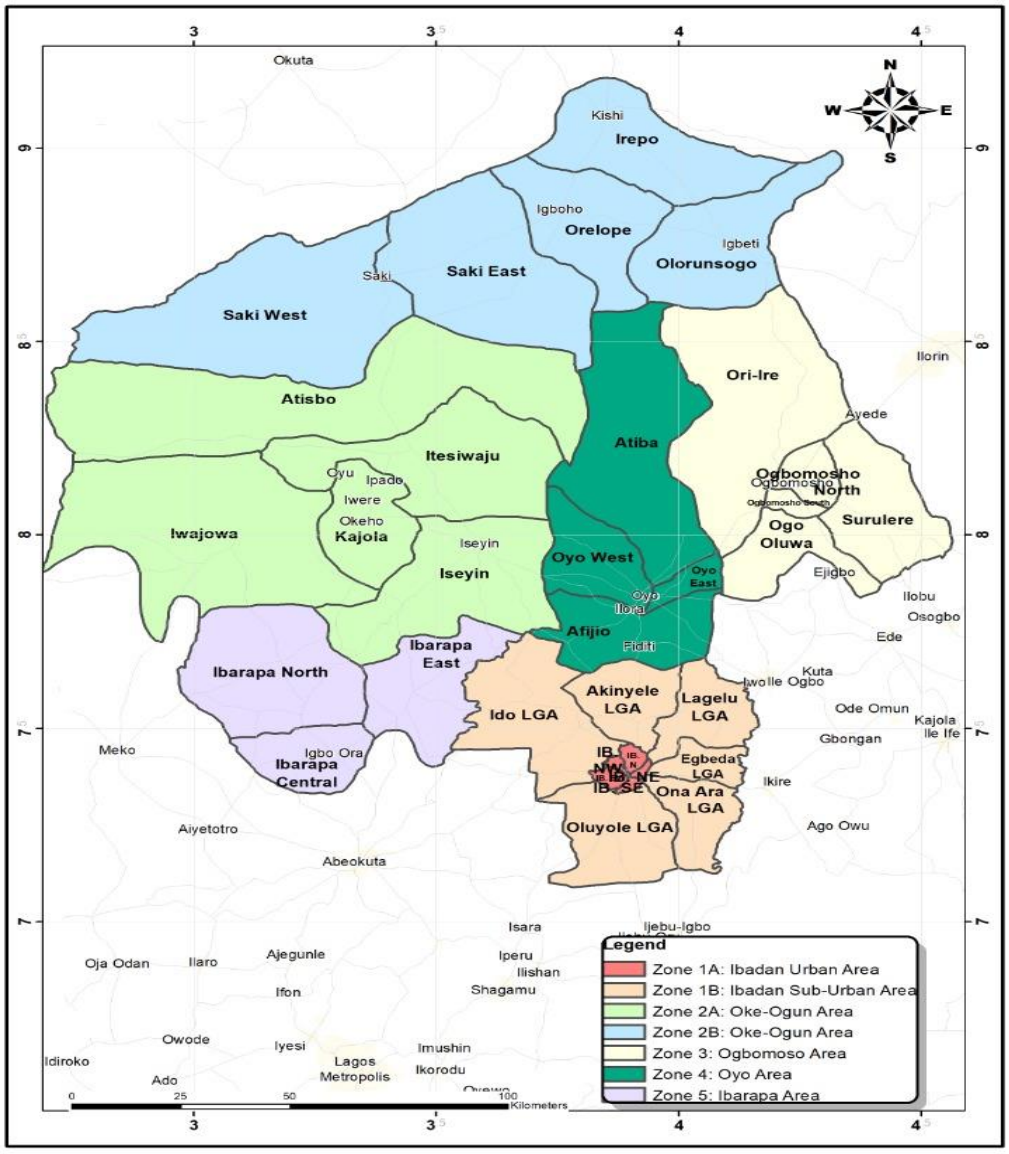

Figure 3: Oyo State, Nigeria, and the geographic delineation of the State-wide COVID-19 Containment Response Network. Oyo State administrative boundaries datasets curated from the Humanitarian Data Exchange (HDX) by Oyo State Decontamination and Containment Team

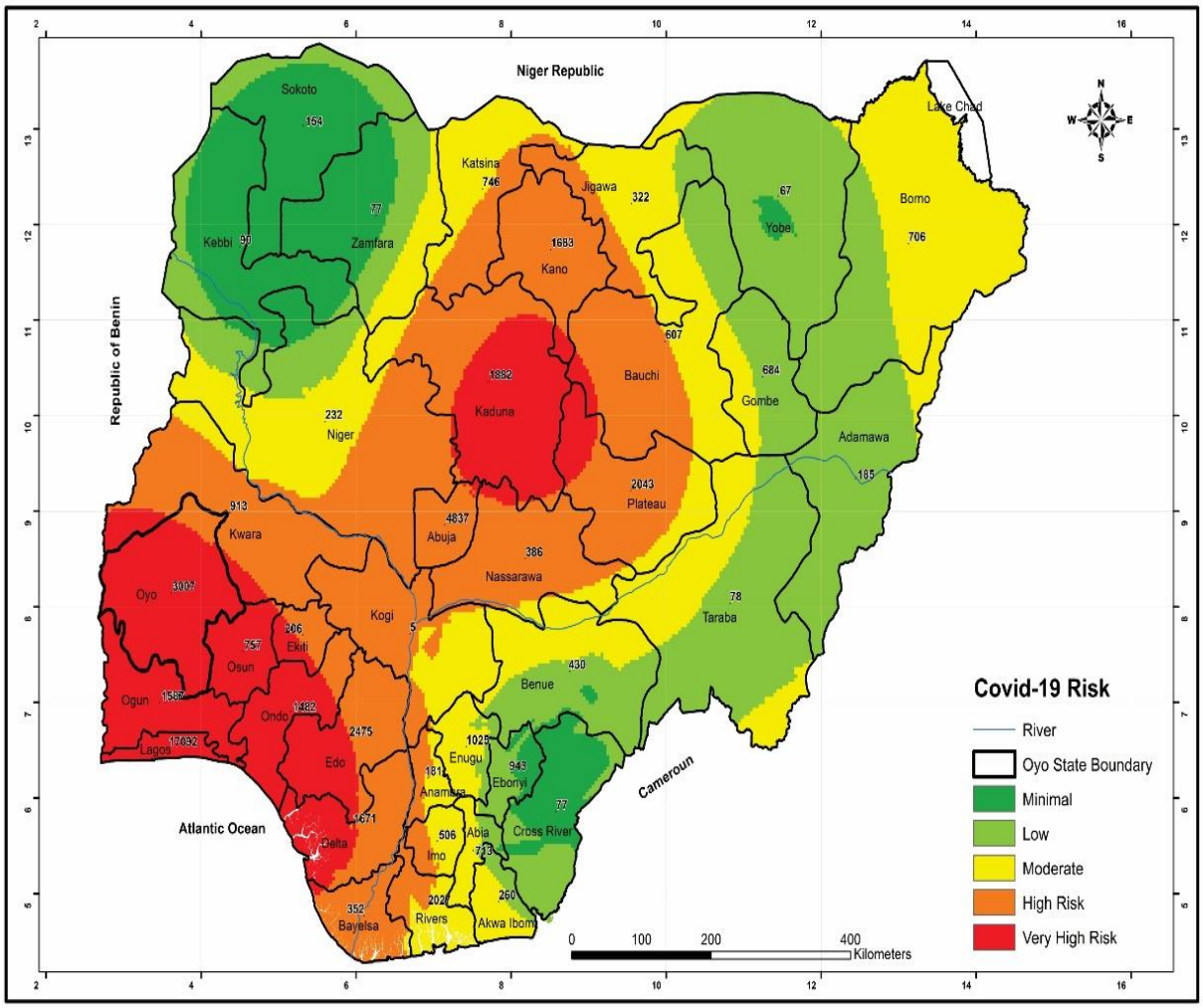

Figure 1: Hotspot Analysis of Confirmed COVID-19 Aggregate Cases as at 21st August 2020

Figure 2: Hotspot Analysis of Confirmed COVID-19 Aggregate Cases as of 21st August 2020

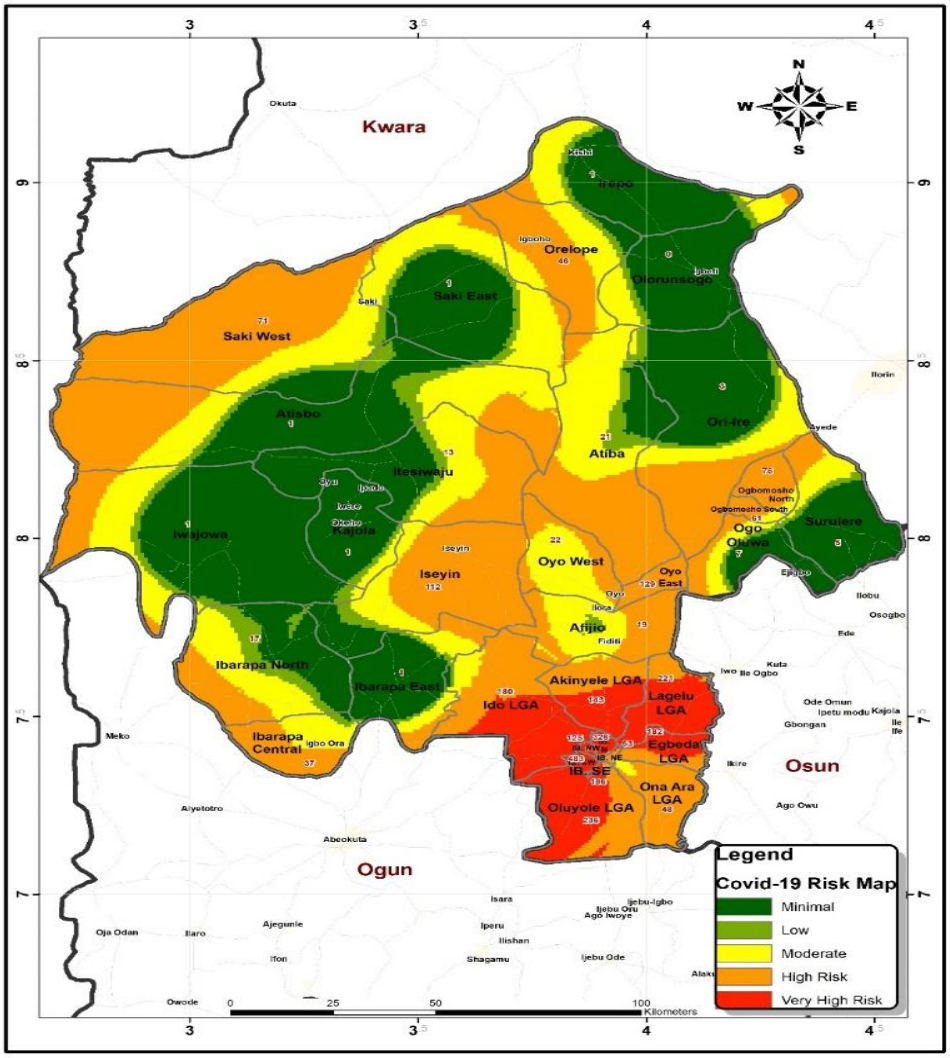

Figure 3: The hotspot analytics for Oyo State as at 18th August 2020
Oyo State Decontamination and Containment Team

Results

To date; the state-wide containment response network team has been quite effective in prevention, containment and decontamination. The stakeholders' awareness campaign and advocacy strategy allowed the team to meet with traditional rulers and the leadership of different groups to secure commitment by assisting with compliance with COVID-19 precautionary measures in their communities and spheres of influence (Figure 4). Based on the data generated from the *COVID-19 Containment Compliance Citizens' Reporter,* it was revealed that the deployed app link provoked self-policing. It also showed that noncompliance was mainly around banking activities, markets, and transportation vehicles (Taxis, buses, "Okada" and tricycles) as seen in Figure 5 below.

Figure 4: Advocacy Visits on COVID-19 Preventive Measures Adherence to Iluju Market Executive Members (A), and Onikoyi palace, lkoyi Ile (B) and a Zonal Launch of the Containment Network at Oriire Local Government Area, Ogbomosho (Zone 3).

Figure 5: Citizen's self-policing Report of Non-compliance with COVID-19 Precautionary Behaviour in Oyo State

The response from the stakeholder's town hall meeting/awareness campaign also resulted in a successful community conversation event which had in attendance the leadership of the different categories of associations and organizations, including, monarchs and chieftains of different ethnic

groups, religious leaders, market leaders, National Union of Road Transport Workers (NURTW), Amalgamated Commercial Motorcycle Owners and Riders Association of Nigeria (ACOMORAN), Operators of Tricycles, School owners, Union of teachers and other relevant organizations with land use facilities in Oyo State (Figure 6).

Figure 6: Cross section of attendees at the stakeholders Town Hall meeting of 13th August 2020

Rapid response is the heart of COVID-19 Containment. The adoption of the state-wide containment response network ensured proactive response through an effective chain of command, actual response to request for decontamination and other containment efforts. Testimonials from the various communities showed that the people have embraced the strategy and the network system employed was effective based on community response to decontamination (Figure 7), containment and advocacy (Table I).

Figure 7: Oke-Ogun Zone 2b team decontaminating a primary school (A), a primary health care facility (B) at Idere in Ibarapa Central Local Government (Zone 5) and Atiba Town Hall (C), Oyo Town, Atiba Local Government (Zone 4)

Table I: Frequency of advocacy and decontamination activities across Oyo State from August 2020-April 2021

Zonal Networks	Aug/Sept 2020		Sept/Oct 2020		Oct/Nov 2020		Nov/Dec 2020		Dec/Jan 2021		Jan/Feb 2021		Feb/Mar 2021		Mar/Apr 2021	
	AD	DC	AD	DC	AD	DC	AD	DC	AD	DC	AD	DC	AD	DC	AD	DC
1A: Ibadan Urban	0	3	0	4	1	0	0	2	0	0	0	1	0	1	0	0
1B: Ibadan Sub-Urban	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0
2A: Oke-Ogun	5	0	0	0	1	0	0	1	1	0	1	0	0	0	0	0
2B: Oke-Ogun	1	32	0	24	0	2	0	0	0	0	1	0	0	0	0	0
3: Ogbomoso	2	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0
4: Oyo	3	1	0	2	1	0	0	1	0	0	0	0	0	0	0	0
5: Ibarapa	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Key: AD – Advocacy; DC - Decontamination

Following school's resumption, it was reported in the News Agency of Nigeria's article of 18th August 2020 that all COVID-19 safety protocols were strictly adhered to in Oyo State during the conduct of West Africa Senior School Certificate Examination (WASSCE). According to Oyo State Chairman of Nigeria Union of Teachers (NUT), *"When you get to the schools, you will see the hall where students were spaced to observe social distancing and all the candidates put on their face masks. At the entrance of those exam halls, you will see washing hand basins and hand sanitisers as well as an infrared thermometer to measure the temperature of the students*". This was also corroborated by The Guardian Newspaper and Punch Newspaper (18th August 2020),

where it was stated that "*in Oyo State, the examination was conducted amid strict adherence to COVID-19 protocols*" (The Guardian Newspaper, 18th August 2020, News Agency of Nigeria, 18th August 2020, Punch Newspaper, 18th August 2020).

The COVID-19 trend in Oyo State to date is presented as Figure 8 below. Before the constitution of the state-wide containment response network, the number of confirmed cases and death (which coincided with the first wave of the pandemic) were on the increase between May 2020 and August 2020 (Figure 8). Between August and December 2020, there was a relative decline in the number of both confirmed cases and death rate. Oyo state observed the second wave of the pandemic between January and March 2021 coupled with reduction in the rate of engagement between the response team and the people. This was due to several factors, including, increase in the number of people that visited the state during December 2020 and January 2021, drastic reduction in the confirmed cases of COVID-19 before the incidence of the second wave, which was responsible for the lackadaisical attitude of the populace.

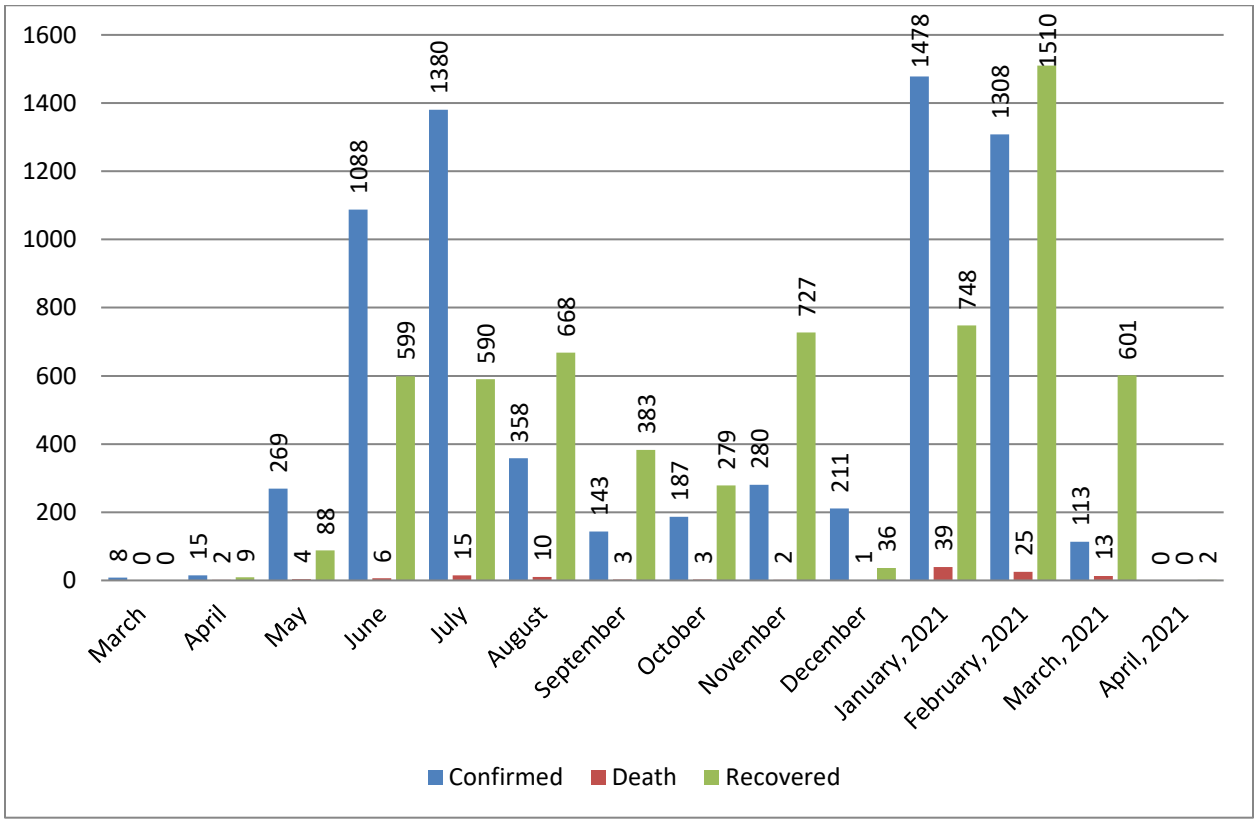

Figure 8: Trend of COVID-19 incidences in Oyo State from March 2020-April 2021 plotted using Monthly Aggregate of Cases

Discussion

Science advice is particularly challenging in the face of the complexity, uncertainty, and public visibility of the COVID-19 pandemic. The unprecedented situation also posed some difficulty as to how best to apply science advice frameworks and practices to secure greater resilience in the aftermath of COVID-19. An effective response to COVID-19 requires critical access to timely and accurate location-specific information to arrest the spread of the virus, save lives and restore the economic fortune of Oyo State and indeed Nigeria. It also requires that every country looks inward to re-imagine the whole fabric and structure of the society, going forward.

COVID-19 is the greatest pandemic affecting our generation and it will be studied at length for the next foreseeable future. It is therefore important to document lessons learnt, identifying resilience strategies and experiences of and from Africa based on the unique tradition, culture, and geography.

The Oyo State COVID-19 Containment strategy was developed to holistically ensure compliance and monitor implementation of the containment strategy. The statewide containment response network deployed in Oyo State fast-tracked responses throughout the length and breath of the State in real time.

In Oyo State, the governor pronounced on April 17th, 2020 that the donning of facemasks in public places had been made compulsory (Vanguard, April 18, 2020). However, the government was reluctant to deploy police officers to enforce compliance. A 102-page report, *"'Everyone's in on the Game': Corruption and Human Rights Abuses by the Nigeria Police Force,"* produced by Human Rights Watch (2010) aptly documents the myriad forms of police corruption hallmarked by institutionalized extortion, which makes deploying the Nigerian Police Force in situations such as that of COVID-19 pandemic unattractive. Additionally, police harassment, extortion and other accompanying disorders in the process of COVID-19 protocol compliance enforcement had been reported in other States in Nigeria (BusinessDay, May 9, 2020, Punch Newspaper, June 24, 2020).

International practice is therefore leaning toward a mix of public and private security to deal with citizen's concerns about public space, specific 'hot spots' and "hot times". Increasingly, it has been accepted that the police no longer possess a monopoly on policing (Shearing, 2001). Before the advent of colonialism in Nigeria, the various indigenous communities, like elsewhere in Africa, had evolved various self-help institutions (vigilante groups in modern sense) for maintaining public order. However, with the emergence of the colonial state and all its coercive paraphernalia, traditional institutions of public order management, that had for centuries served the people, were relegated to the background, as the modern police force, the precursor of the present-day Nigerian Police, under the direction of the colonial authorities, became the *primus inter pares*, in the internal security architecture of the colony (Ahire, 1991).

Each, race, or identity group in the world have all accepted the collective patterns and methods of social control and conflict resolution (Shearing, 2001, Owumi and Ajayi, 2013). Although not an established research methodology, community conversation framework embodies many elements commonly found in qualitative research. This approach interrogates social and cultural phenomena of the type that are central to qualitative studies (Denzin and Lincoln, 2003). Community Conversations fills in data gaps by providing immediate results and deeper insights into what is going on at the local level.

In the present study, community conversation was centred around the remarkable traditional and indigenous social control mechanisms as an inexpensive, more rapid and culturally relevant justice and social order system (Ajayi and Aderinto, 2008). This is because Nigeria has well-coordinated informal trade organizations with rules and regulations guiding the conduct of all members' activities. For example, Market Associations are headed by "***Iyaloja***" and "***Babaloja***" and in the case of road transport workers, their leaders are "***Chairmen***" who are revered. Membership is usually compulsory for anyone engaging in trade or other activities within the vicinity of such association, and members are made to pay dues and are also subject to being fined as disincentive to contravention of existing rules and regulations. Embedding COVID-19 containment in an indigenous and grassroots-driven approach was found to be more appropriate and quite effective in ensuring compliance with COVID-19 preventive measures in a society like Nigeria where

citizens are disenfranchised with contemporary policing and the associated harassment and extortion.

Rooted in the science of geography, geographic information system (GIS) is a technology that stimulates innovation and was particularly crucial to monitoring the containment efforts of the COVID-19 pandemic in Oyo State. The GIS technology was very valuable in real-time tracking, reporting, feedback and archiving of data for future referencing and studies. GIS technology also made it possible to track the activities of the state-wide Containment Network centrally.

Conclusion

This paper introduces and recommends community conversation as a tool for researching, collaborating, and educating, as was deployed to promote compliance with COVID-19 precautionary behaviours in Oyo State, Nigeria. Considering the efficacy of the indigenous systems and practices in the Nigerian society (traditional, religious, neighbourhood associations, and communities); there is an incontrovertible need for each State Government to recognize and promote the relevant indigenous systems of security maintenance, crime prevention, and general law enforcement as complementary body to that of the police in the containment of the spread of COVID-19 by ensuring strict compliance with WHO's well laid out preventive measures. Also proposed is selective enforcement by the Nigerian police force in which contravening associations and land use facilities are sanctioned with the evidence provided through the Compliance Reporter APP**.** This approach is a template, which could be adapted and replicated in other parts of Nigeria and other African societies with similar structures and indigenous practices. The limitation to the study is the fact that COVID-19 is an ongoing Pandemic, and this intervention can therefore not be a once and for all event. An on-going community conversation will go a long way in ensuring that COVID-19 precautionary behaviour is sustained. Additionally, introducing incentive and disincentive measures would improve the enthusiasm for compliance.

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The Executive Governor of Oyo State, His Excellency Oluseyi Makinde's decision to collaborate with and be guided by expert's advice, has positively defined the pace of COVID-19 Containment in Oyo State and is an example of good leadership during public health crises.

***Authors' contributions*:** All authors were involved in the conceptualization and execution of the project. Olanike K. Adeyemo developed the draft manuscript, Analyses and graphs were jointly prepared by David T. Afolayan and Selim A. Alarape. Other authors provided input, corrected, and revised the manuscript before submission.

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ORIGINAL RESEARECH ARTICLE

Computing systems in a pseudo–marine operational environment: design and initial test results

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Abstract

Contemporary research recognizes the need to reduce the cooling costs of data centre systems. This is beneficial and also reduces the operational costs. The operational costs can be reduced by using water for cooling instead of relying on conventional cooling systems comprising air–conditioners, chillers and cooling towers. The cooling effect of water can be leveraged by siting the underwater data centre in a marine or pseudo–marine environment. A pseudo–marine environment is considered here since it overcomes the operational challenges associated with obtaining the regulatory permits required to access the marine environment. In addition, the discussion in the paper presents the design of a desktop computing system that uses water for cooling in a pseudo–marine environment. The performance test of the desktop computing system is conducted in Oyo, Oyo State Nigeria. This is done to examine the viability of designing and using mini–data centres sited in a pseudo–marine environment in Nigeria. The initial results indicate that a personal desktop computer in the role of the mini – data centre is able to support the execution of software installation without the use of conventional cooling i.e fans for a period exceeding 25 minutes. In this case, the cooling is realized using the emulated pseudo – marine environment.

Keywords – *Computing, Underwater locations, Cooling, Data Centres*

1. Introduction

Data centres play an important role in computing and hosting internet content. Cloud computing platforms comprise multiple aggregated and networked data centres. The operation of data centres in cloud computing platforms incurs high operational costs. These high costs arise due to the necessity of powering and cooling data centres. However, operational costs increase with the number of data centres. This has necessitated the design of solutions that can reduce data centre operational costs. Suitable solutions for reducing data centre cooling costs are siting data centres in naturally cold locations. Examples of such locations are countries with naturally cold climate, and non–terrestrial locations such as the ocean and the stratosphere.

The use of the ocean as a feasible location for hosting data centres has received consideration by organizations such as Microsoft (Cutler et al. 2017, Simon, 2018; [1, 2]). In addition, Google has also experimented with the use of an ocean barge as a data centre i.e. ocean data barge (Gough, 2015). The siting of data centres in the ocean or leveraging on the ocean's resources is only suitable for

locations with access to maritime resources. This implies that it challenging to deploy data centres leveraging on massive water cooling in locations without maritime resources.
[1]

Nevertheless, it is important for data centres in such locations to benefit from the cooling capability of water arising from its high specific heat capacity. This is considered in this paper. The discussion in this paper focuses on describing a computing system that is intended for operation in a pseudo–marine environment. The computing system is realized via a single desktop computing system. In addition, the paper discusses the performance of the designed dis–aggregated computing system.

The discussion in this paper makes the following contributions:

1) First, the paper proposes the use of pseudo- marine environment for hosting servers i.e. computers to be used in future data centres. A pseudo–marine environment is one hosting an environment similar to the ocean's sub–surface. In this paper, the proposed pseudo–marine environment is capable of hosting multiple servers in the realization of a given data centre. In addition, the proposed pseudo – marine environment hosts a desktop computing system. In our consideration, the dis–aggregated computer is realized from the design of a personal desktop computer with components that are sourced from the Nigerian market. The research being presented discusses the factors that limit the realization of an ideally functioning dis–aggregated computing architecture in the context under consideration.

2) Second, the research presents the results obtained from performance tests with a focus on the cooling capability of the pseudo–marine environment. In the performance test, the pseudo–marine environment is realized in an emulated physical environment. An emulated physical environment is used due to the challenges posed by cost constraints. The cooling capability of water in the emulated physical environment is determined by the length of time i.e. duration for which the personal computer can function while solely relying on water for cooling. In addition, the success of installing software i.e. Windows Operating System and Microsoft Office on the computer is also considered in the description of the computer operation while being cooled with water in the emulated physical environment.

This research focuses on presenting the design and the performance test results for the proposed dis–aggregated computing architecture. The computer is sited in an emulated physical environment. The novelty of the research consists in it being the first to present the performance test for a dis–aggregated computing system in an emulated (marine) physical environment in cash constrained African (Nigerian) context. The performance test is conducted in Oyo Town, Oyo Nigeria. The choice of the location demonstrates the feasibility of using pseudo–marine environments to realize low-cost cooling computing platforms in Tropical Africa.

1. R. Miller, 'Microsoft CEO Nadella: Underwater Data Centers Are the Future', Nov 2 2018, [Online] https://datacenterfrontier.com/microsoft-ceo-nadella-underwater-data-centers-are-the-future/, Accessed: August 12, 2020.

2. B. Cutler, S. Fowers, J. Kramer and E. Peterson, 'Want an Energy-Efficient Data Center? Build It Underwater: Microsoft wants to submerge data centers to keep them cool and to harvest energy from the sea', 21 Feb 2017, IEEE Spectrum, [Online] https://spectrum.ieee.org/computing/hardware/want-an-energyefficient-data-center-build-it-underwater, Accessed August 12 2020.

The rest of the paper is divided into six parts. Section 2 focuses on background work. Section 3 discusses computing system design. Section 4 describes the emulated marine environment. Section 5 presents details on system set – up and performance procedure. Section 6 is the conclusion.

2. Related Work

Krein (2017) examines the relations between building facilities housing the data centre and the power usage effectiveness (performance measure). Liquid immersion is recognized as a viable technological solution to enhance data centre performance usage effectiveness. In this regard, advanced hydro-fluorocarbon liquids[3] (Kawaguchi et al., 2017) and mineral oils (Shah et al., 2019) are reported to have been used. However, the use of these specialized fluids has high costs due to the high cost of fluid acquisition. Water is a suitable coolant since it has a high specific heat capacity. Moreover, water can be acquired for this purpose at low cost. In addition, water can be easily accessed without significant environmental degradation by siting data centres in the ocean.

Fujitsu has considered an approach where they totally remove fans thereby eliminating the role of fans in servers and computers [3]. The removal of fans in the servers is observed to enable noise–less operation for server farms. In addition, the removal of fans led to a reduction of the required floor space by 50%; with benefits also in the aspect of real estate acquisition for the establishment of server farm facilities. The cooling liquid used in this regard is a fluorocarbon fluid called Fluorinert. The inert liquid driven immersion does not rely on the availability of maritime resources[3]. Therefore, they can be used at locations without access to maritime resources i.e. oceans and rivers. However, this is at the expense of high cost.

Kawaguchi et al. (2017) addressed the challenge of reducing the energy consumption and improving the energy efficiency of data centers. The Fujitsu group is reported in Kawaguchi et al. (2017) to recognize that energy consumption in data centers is increasing with more subscription to cloud computing services. This is accompanied with increased CO_2 emissions. The main approach that has been recognized to be suitable is the conduct of measurements and tests in a building management system. A building management system displays operating conditions for air–conditioning facilities and server room temperature management systems. Deploying air conditioning technology and temperature sensors are suitable techniques for data centre management with the aim of improving energy efficiency. Though, the use of air–conditioning systems and temperature sensors can enhance data acquisition to improve data centre management; their use increases the power consumption in data centre facilities. This invariably exacerbates in the challenge of increasing data centre operational costs.
[2]

In transitioning from air cooled systems to liquid cooling systems or immersion oil-based cooling systems for data centers, the reliability is an important performance parameter that should be considered. The impact of mineral oil data center cooling on data center reliability receives consideration in (Shah *et al.* 2019).

Shah *et al* (2019) recognize the suitability of using mineral oil-based cooling for server farm operation. It is recognized that submerging servers in dielectric mineral oil reduces energy consumption of server farms. The discussion in Shah *et al* (2019) recognizes that proprietary mineral oil cooling solutions have been designed and exist. However, it is recognized that mineral

[3]J. Boyd, 'Fujitsu Liquid Immersion Not All Hot Air When It Comes to Cooling Data Centres', IEEE Spectrum, 18-May-2017, [Online] https://spectrum.ieee.org/tech-talk/computing/hardware/fujitsu-liquid-immersion-not-all-hot-air-when-it-comes-to-cooling-data centers, Accessed August 11, 2020.

oil has the potential of reacting with components of the computing system. Examples of such components are printed circuit boards in the computing payload and associated information technology equipment such as cables with important networking role. It is recognized that mineral oil can erode markings thereby making component identification challenging. This makes the conduct of maintenance and servicing difficult when the need arises. The visual results presented show that immersion in mineral oil results in the fading of component markings in comparisons to component labeling in an air–cooled server. From a mechanical perspective, components from servers immersed in oil results in a significant reduction in the Young's modulus of printed circuit board. The microstructure of capacitors used in oil immersed servers is also observed to experience significant degradation in comparison to those of capacitors in air–cooled servers.

Rispoli[4] acknowledge the increasing proliferation of liquid cooling technologies in data center systems. Two technologies i.e. direct to chip cooling and immersion cooling has been recognized. The study in Shah *et al* (2019) notes that direct to chip cooling has been adopted by a significant number of original equipment manufacturers. The identified challenges of direct to chip cooling are non–uniform heat dissipation, potential occurrence of vendor lock–in and risk of leak on critical components. Immersion cooling is noted to have reduced susceptibility to hardware failures, enhanced life span, reduction in capital and operating expenditures and reduced risk of vendor lock–in. However, it is recognized that direct to chip cooling relies on water as the main coolant[4], the best coolant for the immersion cooling technology has not been identified.

The use of immersion cooling has the benefits of reducing cooling costs, required operational power and data center facility associated real estate costs. Immersion cooling can be realized via inert liquids, mineral oil (Kawaguchi et al, 2017, Shah et al., 2019), and water (Krein, 2017). The use of these fluids for data center cooling poses different contextual challenges. However, the use of inert liquids and mineral oil has a high cost. The use of water overcomes the high costs associated with acquiring either inert liquids or mineral oil. However, the use of water in the considered manner is only feasible for regions with access to significant maritime resources.
3

This makes the use of regions with low access to water and maritime resources as potential data center sites challenging. Examples of regions in this category are Egypt (due to the renaissance dam conflict with Ethiopia), locations that are based in Africa's desert zones. Examples of locations in Africa's desert zones are Mali and Northern Nigeria. These locations do not have access to a marine environment in a manner similar to coastal African cities like Cape Town, Port Elizabeth and Lagos.

Nevertheless, it is important to site data centers in locations within Africa's desert zones to ensure that subscribers at these locations do not experience high content access latency. This challenge can be addressed by installing pseudo–marine environments at these locations. The usefulness and potential of pseudo–marine environments in realizing data center cooling as proposed here is yet to receive sufficient consideration in research. Pseudo–marine environments are marine–like systems that can be found in large aquaria, fish ponds and other controlled marine like artificial control systems. Aquarium systems have been observed to significantly benefit from technologies such as the internet of things (Lin *et al*. 2019). The use of aquarium in hosting computing systems

[4]Danielle Rispoli, 'Immersion Cooling, High Performance Cooling for HPC', EuroHPC Summit Week 2019, 15/05/2019, [Online] https://events.prace-ri.eu/event/850/contributions/751/attachments/913/1580/15.05_15.30_Immersion_Cooling_High_Performance_Cooling_for_HPC_Rispoli_1.pdf, Accessed August 11, 2020.

has received consideration[5]. This discussion is from a hobbyist perspective and does not present performance test results.

The use of water has been recognized to be suitable for data centre cooling applications. In this application, it is implied that water is passed through a chiller that reduces water temperature (Sondur et al., 2018, Oltmanns et al., 2020 and Kohonen et al. 2020). The use of the chiller increases data centre energy consumption. This reduces data centre energy efficiency. A periodic operation of the chiller leads to the reduction of data centre energy consumption and leads to the use of warm water for data centre cooling (Jiang et al. 2019 and Meyer et al., 2013). The warm water arises due to the non – operation of the chiller at all data centre functional epochs. Another approach such as that presented in (Mytton, 2021) considers the use of smaller less power intensive chillers. The use of such chillers has the dual benefits of reducing acquisition and operational (power consumption) costs.

Another approach to realizing data centre cooling is via the use of liquid immersion cooling systems (Liu *et al.* 2021). Liu *et al.* (2021) identify two types of liquid cooling i.e. direct liquid cooling and indirect liquid cooling. The latter method i.e. indirect liquid cooling is described in (Liu *et al.* 2021) where the servers are submerged in a tank containing the dielectric liquid Novec 7100 from 3M. It is recognized by Liu *et al.* that the dielectric Novec 7100 is expensive. In this case, the process of heat transfer occurs from the data centre to the dielectric Novec 7100. The use of Novec 7100 though advantageous due to its high boiling point of $61^{O}C$ has the drawback of high cost.

Types of inert liquids that can be used for data centre cooling are the Fluorinert Electronic liquid and Novec Engineered Fluid[4]. These coolants are costlier than water. Nevertheless, the discussion in (Liu *et al.* 2021) demonstrates that the design of an engineered submerged environment hosting coolants is feasible for future data centre realization. The consideration of the use of coolants in cooling data centres has also received earlier attention in (Parida *et al.*, 2012). However, the procedure in (Parida *et al.*, 2012) describes results obtained for locations in the USA. In addition, it does not consider the context of a cash constrained developing tropical nation. This describes the case of a West African nation such as Nigeria.

[4]https://multimedia.3m.com/mws/media/1798606O/3m-immersion-cooling-brochure.pdf

3. Design of Low-Cost Computing System

The dis–aggregated computing system being proposed is realised using the conventional components of a desktop personal computer. These components are: (i) Motherboard hosting processors, (ii) Hard Disk Drives, (iii) Temperature Sensors, (iv) Aluminium Sub–casing, and (v) Plastic Casting. The motherboard hosts processors and other computing peripherals that enable data storage and algorithm execution. The hard disk executes the conventional function of providing a storage space for data and user defined programs. Temperature sensors are used to monitor the temperature of the environment in which the computer executes its functions.

The aluminium casing is used as an external component holder to support the positioning of computing components. It also ensures enhanced heat transfer from computing components to the surrounding environment due to Aluminum's high thermal conductivity. The plastic casing is used to store the coolant mixture of ice and water with the aim of insulating it from the heat arising in the external environment. This is because of poor thermal conductivity of plastic. These components are used to design an abstraction of a data centre that utilizes ice–water mixture as the main coolant. The use of an ice–water mixture is necessitated to model the sub–zero temperature of the ocean's sub– surface environment. The aim of the design is to realize a minimum function

prototype of the abstraction of a data center while utilizing ice–water mixture as a coolant. This is done with the goal of realizing a type of the environment that can be found in existing work[4].

The realization of the abstraction of the computing entity makes use of two Aluminium casings. The first Aluminium casing hosts an array of hard disk drives. The second aluminium casing hosts the computer motherboard alongside the processors and supporting computing peripherals. Aluminium has a high thermal conductivity and radiates arising from the operation of the computing components to the environment. Nevertheless, it is important to ensure that the heat from the external environment does result in a rapid increase in the temperature of the ice–water mixture serving as the coolant. The setup limits the influence of external heat by placing each Aluminium casing in a plastic casing. The plastic casing is of larger dimensions than the Aluminium casing with sufficient volume to host the ice–water mixture and the Aluminium casing. There are two plastic casings with each casing hosting one Aluminium casing each. The displays on two important parameters are monitored for each plastic casing. The first display provides information on the operational temperature within each plastic casing. This is realized via the deployment of temperature sensors. The second display provides information on the time elapsed for the use of ice –water mixture composition as a coolant.

The implementation of an abstraction of the computing entity also serves as the realization of a minimum function prototype. The minimum function prototype is expected to support functionalities on the deployed hard drives. These functionalities are: (i) Hard Drive Formatting, (ii) Hard Drive Partitioning, (iii) Windows operating system installation, (iv) Linux operating system installation, (v) MATLAB software installation on Windows partition.

In the functioning of the minimum function prototype, it is intended that the ice-water i.e. coolant mixture will be changed seamlessly. This is necessary to ensure that the computer does not experience functional outage during the operation. Furthermore, the prototype is intended to be scalable and its full scale implementation should be able to support online video streaming and e-commerce applications. These are examples of applications requiring the use of data centres.

4. Emulated Physical (Marine) Environment

The marine environment should ideally be a location in the ocean's sub–surface environment. A suitable sub–optimal solution will be the launch of the abstracted computing entities into a large sized marine environment analog. However, these options have high costs that make their use for the realization of the proposed system infeasible in the research being described. The marine environment analog that is used here is designed within the limits of cost constraint and leverages on the easy availability of water and its derivatives i.e. ice. The emulated physical (marine) environment does not incorporate the feature of coolant circulation. This aspect is not incorporated for two reasons. The first is that the inclusion of coolant circulation feature requires the use of large-scale server farms comprising more computers than used in this study. This is cost–prohibitive. The second reason is that existing literature in [3–4] considers that single units of abstracted computing entities are housed in compartments with self-enclosed fluid coolants. In addition, existing work also demonstrates the feasibility of cooling from a hobbyist's perspective[6]. [5]

[4] M. Szczys, 'Aquarium Computer', [Online], https://hackaday.com/tag/aquarium-computer/, June 10, 2019, Accessed August 11, 2020.

[6] M. Szczys, 'Aquarium Computer, [Online] https://hackaday.com/tag/aquarium-computer/,June10 2019, Accessed Aug 11, 2020

5. Description of Set Up and Performance Testing

The discussion in this section presents the experimental set up and the conduct of procedures enabling the performance testing. This section is divided into five parts. The first part presents considerations on the design for performance evaluation. The second part discusses the details associated with prototype design. The third part focuses on the procedural set–up and system design details. The fourth part describes the observed behaviour of the computing system i.e. the post set–up computing system behavior. The fifth aspect describes aspects related to scalability and system realization.

Existing work has significantly considered the use of inert liquids such as fluorinert and Novec. However, an attempt to mimic the ocean hosting an abundant of cold-water coolant in a terrestrial context is yet to be considered. The performance analysis has not considered using inert or dielectric fluids due to the high cost. Water is easier and less costly to obtain than inert or dielectric fluids. In addition, the performance procedure differs from existing work in focusing on a developing nation like Nigeria.

5.1 Considerations on the Design for Performance Evaluation

The performance evaluation aims to determine the ability of a computing system to enable data storage and algorithm execution while relying on maritime resources for cooling. The computing system is intended to be a dis–aggregated system. In a dis – aggregated system, computing components are not collocated within a single chassis. Instead, they are distributed and functionality is realized via local level bus inter–connections. In our consideration, a dis–aggregated system is one where components can be added to increase computing capacity without the need to execute a system shutdown procedure. However, this is challenging to realize.

The experiment aims to determine the functioning duration of the computing system without the use of conventional cooling components. This is done while algorithm execution is ongoing. The cooling environment is realized via a design ocean analog environment. This environment is realized via the use of water in ice state and liquid state. This cooling environment is used while removing the conventional onboard fan system that is initially installed and configured aboard the computing system. The computing system is realized by using components from a standard desktop personal computer.

The goal of the procedure is to determine the functioning duration of the proposed computing system for executing a given algorithm in a given environment state.

5.2 Prototype Design Details

The procedure intended to use a computing system with the capacity of a server, server farms or data centre. However, the realization of computing systems in these categories has a high cost which is beyond the reach of the research team. Hence, a computing system on a lower scale was designed considering the financial resources and the constraints being experienced by the research team. The computing system used in this case is a desktop computer with components enabling data storage and algorithm execution.

The prototype was designed using a lead cost strategy in which realization at the lowest possible cost was actually sought by the research team. This approach was considered without recourse to the use of computing components with a low reliability or known poor functionality level. In addition, this approach was considered due to the economic climate at the time.

Existing work has significantly considered the use of inert liquids such as fluorinert and Novec. However, an attempt to mimic the ocean hosting an abundant of cold-water coolant in a terrestrial context is yet to be considered. The performance analysis has not considered using inert or dielectric fluids due to the high cost. Water is easier and less costly to obtain than inert or dielectric fluids. In addition, the performance procedure differs from existing work in focusing on a developing nation like Nigeria.

The research team that conducted the performance procedure had no funding support and used personal funds. In this regard, improvised components were used to realize expected functionality in the realization of the proposed components. The components that were used in realizing the computing system were all new. These components are: four hard drives, motherboard, cables, and two ATX form factor computer casings.

The conduct of the procedure also requires the use of additional components to prevent contact between the computing components and the cooling mixture. The cooling mixture models the underwater environment and is realized via an ice – water mixture. The ice–water mixture is intended to model the ocean environment and is an ocean analog. The components used in this regard are: Aluminium casing (two units) and polythene water proof material (two units) and two units of ice packs comprising multiple ice blocks. A pictorial view of an empty Aluminium casing, hard drives being placed in the Aluminium casing and Motherboard in the Aluminium casing are in Figure 1, Figure 2 and Figure 3, respectively.

In addition, recording devices such as thermometers and stop watch were also used for recording data. Thermometers are used to record the operating temperature of the computing system environment. The stop watch is used to record the functioning duration of the computing system. Furthermore, the performance evaluation procedure was also recorded using a video camera. The computing system components have been individually identified to enable the realization of low cost minimization without experiencing a vendor–lock in challenge. This also enables the realization of a heterogeneous desktop computing system.

Figure 1 – Aluminium casing used to host computing system components for enhanced heat transfer.

Figure 2 – Insertion and placement of hard disk array in the Aluminium casing.

Figure 3 – Motherboard being placed in Aluminium casing.

The placement of the motherboard showing the passage for the connecting cables is shown in Figure 4.

Figure 4 – Motherboard in Aluminium casing showing opening on casing side. The opening provides pathway and passage for connecting signal cable.

5.3 Procedural Set – Up and System Design

The computing system was initially assembled in a default configuration. The default configuration is one of a normal desktop computing system. This is done to ensure that all components are able to execute data storage and algorithm processing in the expected manner.

The original plan aimed at the design of a dis–aggregated computer system. In this conceptualization, the demonstration of the proof of concept/ prototype required the use of two power packs. In the initial system conceptualization, the first power pack unit was intended to drive the motherboard. The second power pack unit was intended to supply alternating current to the hard disk drive array. The hard disk drive array was enclosed within the aluminium casing in a separate computer casing (the casing is the standard ATX desktop casing form factor). The intended computing system set–up i.e. the disaggregated computing system is presented in Figure 5 and Figure 6. Figure 5 shows the hard disk drive arrays (4 hard drives) placed in the Aluminium

casing within the ATX desktop computing system. The scenario in Figure 6 is one showing the intended design of the dis–aggregated system. The left casing in Figure 6 hosts the motherboard and hard disk drive array, respectively. In Figure 6, the power pack that supplies power each component is in the centre. The scenario in Figure 6 is intended to show the design of the intended computing system.

Figure 5 – Hard Disk Drives in Aluminium casing (with slanted lid) showing connecting cables to the motherboard in the next AT

Figure 6 – Two ATX form factor desktop casing with motherboard (left) and hard disk drive (right) and power pack (middle).

However, a dis–aggregated system configuration though desired is not technically realizable. This is because the power pack is not able to send simultaneous signals for switching between multiple motherboards (two multiple motherboards). This switching is essential for deploying the motherboards to be used in different roles while they are controlled by a single processor. The

capacity here can be realized in a server with sophisticated capacity but challenging in a less sophisticated desktop computing system that is used here due to financial constraints.

The configuration of the computing system showing the placement of the Aluminium casing in the main chassis of the desktop computing system (with ATX desktop casing) is presented in Figure 7. Figure 7 shows ice blocks placed on the lid of the Aluminium casing. The Aluminium casing is housed within the ATX desktop casing. The case in Figure 7 is a scenario showing the layout of the components used in the procedure. The Aluminium casing in this case does not host any computing component.

A case showing the hard drives placed in the Aluminium casing in the within the ATX desktop casing is shown in Figure 8. There are four hard drives within the Aluminium casing that are connected via cables to a separate experimental set up (comprising ATX desktop casing and Aluminium casing hosting different components). The Aluminium casing has inlets on its side enabling the passage of cables to the separate and external experimental set up. An example of a separate experimental set–up to which the set–up in Figure 8 is connected in Figure 9. The set – up shown in Figure 9 hosts the motherboard (with on–board memory and processing capability) and is placed within a polythene water proof material. This is done to protect the motherboard from water which can lead to the occurrence of short–circuit.

The case in Figure 9 shows the placement of the onboard motherboard in the experimental procedure. In this case, the fan aboard the motherboard has been removed. In conducting the performance evaluation, the ice was added at the beginning and placed in the polythene water proof material. This was done before powering the components of the computer entity. Initially, the ice was solid with minimal liquid water dripping from the plastic. The temperature observed at this stage was very low as recorded by the digital thermometer device. This applied to components in both ATX form factor computer casings.

The motherboard in the Aluminium casing prior to being placed within the ATX desktop computing system casing is shown in Figure 10. The set up shown in Figure 10 is covered with main lid of the Aluminium casing and wrapped with the polythene to prevent water entry. Ice packs are placed on the top of the resulting experimental set–up. The resulting set–up is shown in Figure 11.

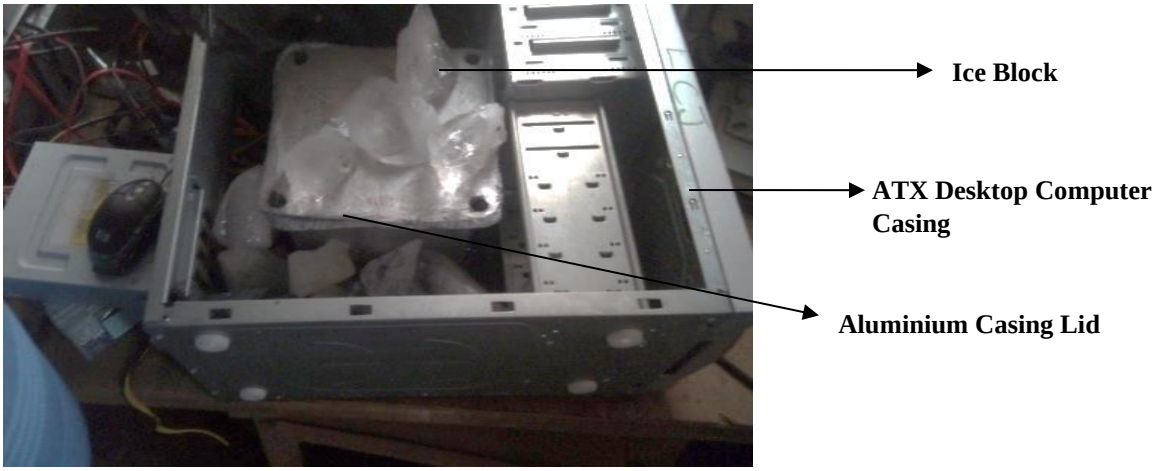

Figure 7 – Layout showing Aluminium Casing with overlaying ice block in ATX desktop computer casing.

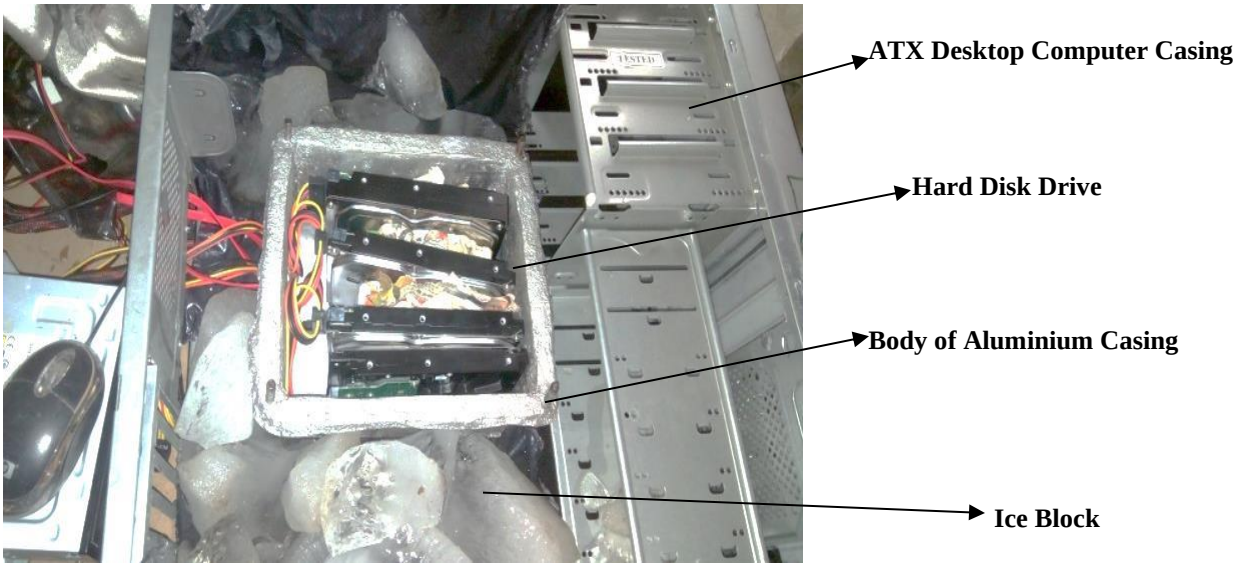

Figure 8 – Hard disk drives in Aluminium casing being cooled by ice blocks with connecting cables for signal transmission.

The effectiveness of the ice – water mixture is improved by increasing the exposed area i.e. the surface area of the ice. This is realized by crushing the ice and putting the crushed ice besides the aluminium casing hosted in the separate ATX computing casing. This is the case for the scenario presented in Figure 5. The ice was pre-loaded in the casing prior to powering all the components. This was done to avoid the occurrence of electric shock since some handling was necessary at this stage. It was observed that the hard disk drive array was non–functional after the provision of electrical power supply.

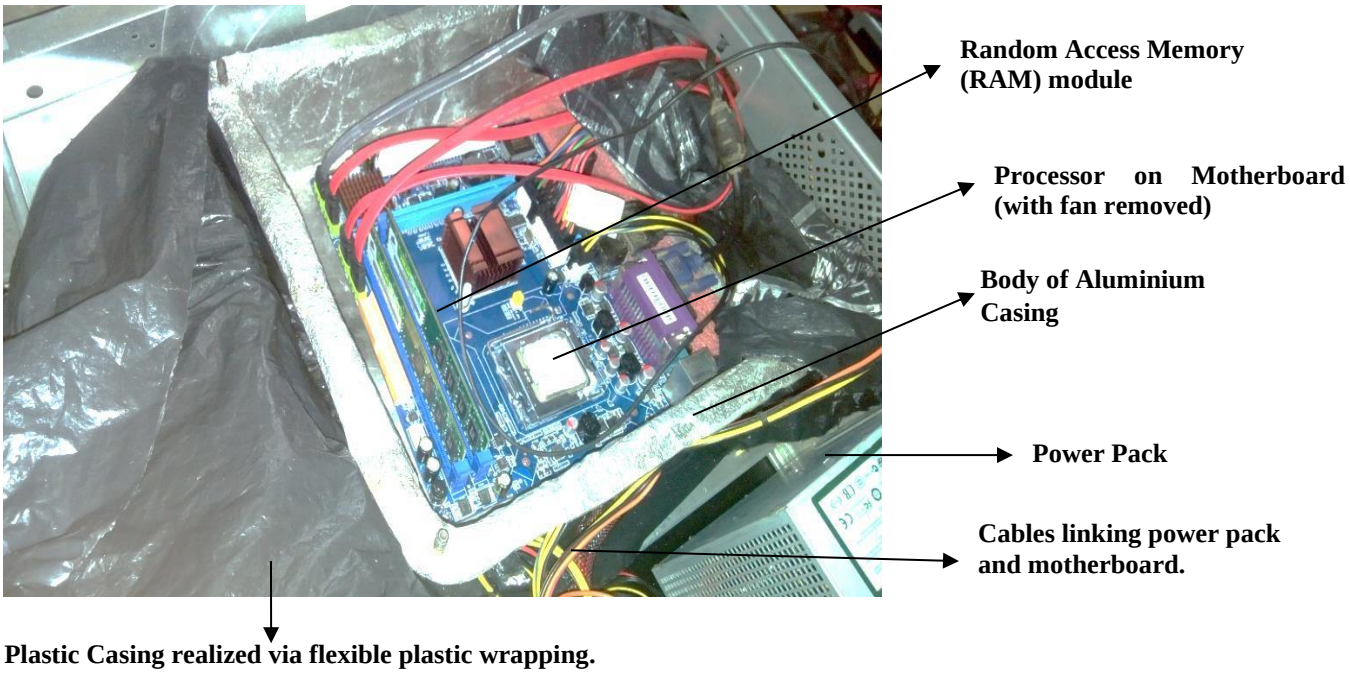

Figure 9 – Motherboard (with fans detached) showing connection to power pack housed in the Aluminium casing.

Figure 10 – Motherboard placed in aluminium casing being placed into the plastic plane and the ATX form factor casing.

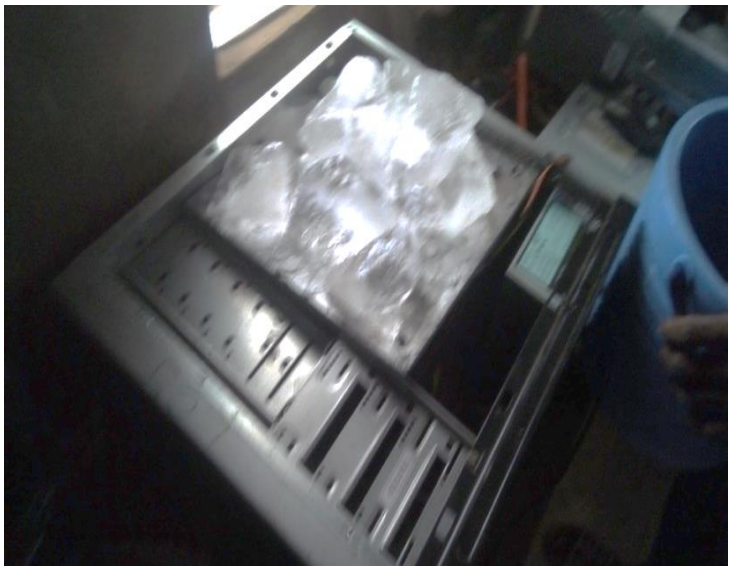

Figure 11 – Placement of additional ice blocks for cooling prior to commencement of performance tests and observations.

The observed challenge was addressed by powering the hard disk drive array using unutilized power connectors from the power pack unit providing the motherboard and processor with alternating current. However, this was a departure from the original design.

5.4 Post Set – Up Computing System Behavior

The completion of the experimental set–up is followed by the evaluation of the system performance. The behaviour of the components of the desktop computer system was also observed. The hard disk drive array was observed to become functional after implementing the change in the prototype design. Hence, it was concluded that the hard drive was designed to function in the presence of a switching mechanism i.e. function initiation trigger which was absent in the case of

the initial conceptualization. In this case, the motherboard had a switching component (the port beside the main powering port). Hence, the hard disk was detected by the operating system.

Initially, four hard disk drives were intended to be used. However, we had to add an additional CD-ROM drive to achieve the installation of the Windows operating system. The CD-ROM drive derived its operational power from the powering unit supplying alternating current to the motherboard and the processor. The inclusion of the CD-ROM was also a change from the original design. This is because the power consumption of the CD-ROM exceeded that of the hard disk drive array.

The CD-ROM and the windows OS installation proceeded as intended. The installation procedure commenced after successful execution of hard disk drive formatting, selection and configuration. These processes were executed with the ice already loaded for the intended cooling of the computer system and with the motherboard onboard fan removed. The installation commenced smoothly until it was observed that the windows (with scrolling blue icon) awaiting final desktop display following installation was non–responsive. The screen later went blank after some time. This was not expected and we proceeded to troubleshoot the system.

Prior to this it was observed that the processor reached a peak temperature of $40.6^{O}C$ despite the presence of solid ice in the ATX casing. In response to the temperature build–up, we added more blocks of ice and the temperature measured was noted to decrease with the temperature sensor indicating a low temperature. It was observed that the installation proceeded smoothly after adding more ice. This drop in processor temperature was followed by another event. It was observed the installation process which was at the final stage was no longer responsive. This was observed due to faulty electronic circuit in the desktop computer's motherboard. The procedure of troubleshooting commenced and this could not be resolved during the procedure. Hence, the continuity in the conduct of the procedure was interrupted.

During the procedure, the total mass of ice used for the overall proof of concept was less than that calculated theoretically. In addition, the casing was exposed to the environment. This was necessary to ensure that environmental effects were considered to the fullest extent possible. A constraint that prevented the loading of significant ice for the cooling was the size of the ATX form factor casing. The casing could barely provide enough room to use 6kg of ice for cooling when we had determined that about 15kg of ice was theoretically required for cooling. Calculations show that 15kg of ice was required to provide cooling for the motherboard.

However, the use of roughly 5 kg of ice provided operations for *44mins 37 seconds*. Hence, it is recommended that a bigger casing with capacity to hold 15 kg of ice be used. However, it was challenging for us to obtain such a casing at this point due to capital and financial constraints. Secondly, it is recommended that the hard disk drive array be powered separately and not like used in the arrangement for the proof of concept. This is necessary to avoid increasing the load on the power pack that supplies the motherboard with electrical power. The experimental procedure that has been described was conducted on August 09, 2017 in Oyo Town, Oyo state between the hours of 08:10 am–09:48am. The minimum temperature and maximum temperature values are measured to be $2^{O}C$ and $37^{O}C$, respectively.

5.5 Aspects on Scalability and Realization of System Design

The proposed system design i.e. the non–disaggregated system whose performance is investigated via the conducted and described procedure is intended for data centre operators. Being intended for final use by data centre operators, additional design consideration is required. In realizing the

achievement of a real-life deployment, the computing entity being used will be placed in an emulated underwater environment. The emulated underwater environment can be achieved via a large aquarium or aquaria system. The aquaria system in this case will have an underlying network enabling communications between data centres in different aquaria. Such a communications network is integral but its performance has not been tested here.

Instead of using a personal desktop computing system, a server or server farms will serve the role of the computing entity. In this case, the server's components are shielded from water by using a chassis that has good heat conduction property but dis–allowing water entry into each server interior. A real implementation will comprise a water ice mixture leading to the emergence of cold water which enters into a pipe and maintains a cold temperature environment. Servers are submerged in this cold temperature environment.

Therefore, the realization of the proposed system requires the provision of an underwater environment. This is realizable via a large aquaria or network of large aquaria systems. In addition, the aquarium or aquaria requires the supply of ice via an inlet of sufficiently high diameter to accommodate the ice packs. Furthermore, a steady supply of water and ice packs is required to ensure that the underwater environment consistently has a low temperature. This design option has been chosen to ensure that servers are maintained at a low temperature.

The duration of the test is less than an hour and falls short of the expected uptime for a server farm in a data centre. However, continuous supply and maintenance of the ice – water mixture environment enables the continuous functioning of a data centre or server farms realized using the proposed design.

6 Conclusion

The paper proposes the use of a pseudo–marine environment for the cooling of computing systems. The computing system is realized via a personal desktop computer system. In addition, the research designs a minimum function prototype of a dis-aggregated data center and presents preliminary performance test results. This is done while identifying design challenges and discussing the performance test results. The results presented in this research constitute an initial proof of concept for a desktop computer system in a Tropical African location. It also demonstrates the functional viability of using pseudo–marine based desktop computing system in Nigeria. Future work aims to investigate the functional viability for more computing systems, re–design the computing system with a new switching technique to support multi–scale dis–aggregated computing systems and explore larger sized pseudo–marine environments.

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ORIGINAL RESEARCH ARTICLE

Environmental contribution to antimicrobial resistance: A largely ignored global health issue

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Abstract

Environmental contribution to the continued occurrence of antibiotic resistance has been largely unexplored. There has been much focus on clinical isolates for their resistant nature but non-clinical bacterial isolates in the environment have been considered as the chief contributing factors that facilitate the spread and dissemination of antibiotic-resistant bacteria (ABR) and antibiotic-resistant genes (ARGs). The natural environment acts as a reservoir for bacteria, providing them with a favourable condition for their emergence and breeding of resistance. One such environmental leverage is inter/intra-specie exchange of genes encoding resistance factors. It was argued that human activities aid immensely in the emergence of antibiotic resistance in the environment. The rationale for this review is to examine extensively the complex interplay of antibiotic resistance from the natural environmental perspective and factors that influence the occurrence and dissemination of such resistance. It also seeks to stress the biological factors that facilitate the emergence of resistance and link it to general biological processes. The review has been structured to capture the general threat posed by the circulation of antibiotic-resistant bacteria and their genes, as well as the influence of the environment in contributing to this global health threat. In addition, the review looked at the effective methods used to tackle the "silent pandemic", by controlling the spread of resistance in the environment. Environmental stakeholders and policymakers are recommended to be included in tackling the development of antibiotic resistance.

Keywords: *Antimicrobial resistance, Natural environment, Non-clinical bacterial isolates, multidrug resistance genes, Wastewater.*

Introduction

Antibiotic resistance poses a devastating threat to the global health sector. Not long after the advent of antibiotics as chemotherapeutic agents, resistance emerged. There is a projection that infections related to antibiotic-resistant organisms may cause about 10 million deaths annually by 2050

worldwide with about 100 Trillion dollars cumulative economic burden if the menace is not halted [1,2]. As a natural phenomenon, antibiotic resistance is a condition where bacteria become less susceptible to the antibiotic to which it was once vulnerable. The development of antibiotic resistance is driven by complex evolutionary processes that influence the selection pressure by the application of antibiotics [3, 4, 5]. The emergence of new infectious diseases and the resurgence of many infections that have been treated necessitates the use of antibiotics, which has substantially contributed to the recent surge of resistant bacterial pathogens of public and clinical importance [6].

Extensive indiscriminate use of antibiotics for treatment purposes, lack of patient's compliance to complete prescription and use of antibiotics for non-medical purposes have been identified as the causes for the development and spread of resistant bacteria [7, 8]. Worldwide usage of antibiotics has significantly increased in recent years. A report of antibiotics consumption in 76 countries covering a span of 15 years (2000-2015) shows an increase of 65 % on daily basis, which account for the increase in the consumption rate of about 39 % globally [9]. The authors generated data on daily consumption of drugs measure known as "defined daily doses" (DDD) in which numbers of antibiotics used over a period of months or quarterly basis were assessed to be representatives of the total drugs consumed. Demographically, the study categorized the assessment based on the economic strength of countries from high, middle and low income to get the difference in the driving force of antibiotic usage. The study subsequently, analysed the contributing factors which may largely depend on individual countries or regions [9]. To come up with the global antibiotic use, the researchers employed the use of a country's yearly antibiotic usage and expressed in DDDs per 1,000 inhabitants per day according to the World Bank DataBank [9]. The results showed a sharp increase in antibiotic consumption worldwide from 21.1 to 34.8 DDDs (65%). However, on the further classification of the consumption; low and middle-income countries (LMIC) had an increase of 114% while high-income countries (HICs) only increase by 6% within the period under study. The main contributing force for antibiotic consumption can be attributed to the population size. Other factors such as antibiotic legislation and policy, accurate data of antibiotic use and increase in incomes are also to be blamed for the increase in antibiotics consumption. However, further analysis of the published data indicated that some important countries among LMICs with significant-high populations were not captured, for instance, the inclusion of Nigeria with over 180 million populations with characteristic antibiotic use and misuse may even change the data on antibiotic consumption in the group [10,11].

It is established that global antibiotics consumption has skyrocketed, which resulted in the rise in antibiotic resistance; however, there is a slow discovery of new antibiotics to tackle the threat thus putting global public health in danger [12,13]. Since the birth of penicillin that marked the golden era of antibiotics in the early 1940s, few antibiotics have been introduced after the roaring period of antibiotic manufacturing in the 1960s and currently, there are limited new antibiotics in the pipeline of development [14]. Only five new classes have been traded in the last 18 years, namely; Oxazolidinones, lipopeptides, pleuromutilins, tiacumicins and diarylquinolines [15].

Realizing the threat of resistance and agreeing with the urgency of development of new agents, the world's health stakeholders, Global Action Plan for Antimicrobial Resistance under WHO in conjunction with the Drugs for Neglected Diseases initiative started a campaign for the development of new classes of antibiotics to tackle fast development of bacterial recalcitrance [16]. It is apparent that pharmaceutical industries lack interest in the development of novel antibiotics due to the cost involved in the discovery, trials and validation of such agents which is expected to have all the ideal qualities of an ideal antimicrobial [14]. Despite this, there is hope for the development of new antibiotics that can work against the major pathogens of public health

importance. Currently, there are about 15 new antibiotics in the US that are under clinical trials which might tackle drug-resistant Gram-negative bacteria [17]. Therefore, there is a need for speeding up the creation of a new class of antibiotics to address the fast emergence of resistance. This review explored the complex nature of Antimicrobial resistance (AMR) from an environmental perspective, and it is evident that there is a gap in tackling the threat of resistance with much focus on the clinical aspect while neglecting its interconnectivity with the environment. Thus, this important area is most often ignored in policymaking and regulation of AMR.

Environment and antibiotics resistance

The development and dissemination of antibiotic resistance is a multifaceted aspect ranging from clinical use and overuse of the drugs, and their use in agriculture to now its role in the ecosystem. It is believed that the environment houses antibiotic-resistant bacteria (ARBs) and antibiotic resistance genes (ARGs). The environment is a geographical platform that harbours the activities of living things, among its constituents include; physical, natural, social and behavioural [18]. Furthermore, in an ecological perspective, the components involve physical and natural parts that allow interaction between living and non-living; hence the role of microorganisms as ubiquitous organisms comes into play in the environment. This interaction between environments is described in Fig (1).

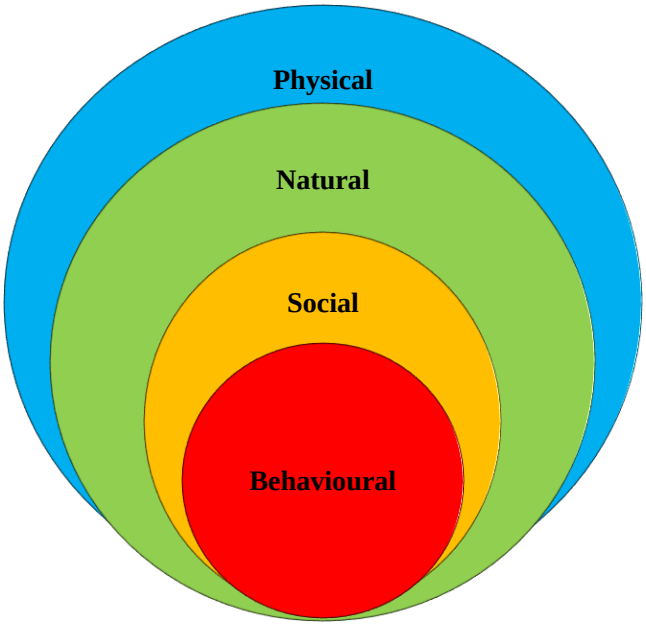

Figure 1: Schematic representation of components of environments. Adapted from Sahoo *et al*., 2012 [18].

The environment has been a centre play that allows interactions of pathogenic organisms from different sources such as, hospitals, industries, agricultural sites, community sewage and as a result it is considered as a pool of interplay of resistance. The end product of antibiotics utilization ends up in the environments, especially the water environment which serves as a hub for antibiotics residues, ARB and ARGs [19, 20]. There have been studies on how community sewage and hospital effluents, wastewater pollutants from agricultural farmland, as well as groundwater, be a hotspot of pathogenic bacteria, antibiotics, ARB and ARGS which can be released to large water bodies and subsequently circulate in the environments [19,21,22,23]. Other studies reported that antibiotics used for medication are either modified or remain unchanged and are excreted and released into environments. Application of biocides in the cleaning of environments can also influence the discharge into the environment, animal faeces and birds droppings that are used as

fertilizers have a direct link with crops in farms which contaminate environment with bacteria. These could enhance the selection of resistance in bacteria because they are at sub-optimal concentration due to the decrease in concentration [24,25]. Recent reports have shown that antibiotics and substances containing antimicrobial actions are getting in contact with the environment through many means; some of these substances are biodegradables and can even serve as sources of living for the microbiotas [25,26]. However, Dolliver and Gupta [27] observed that not all these are easily degraded in the natural environment by factors such as low temperature, moisture and soil structure, hence continue receiving antibiotics from hospitals wastes, farms and households sewages.

In an extensive study, the report by Wassem *et al*., [8] showed the occurrence of antimicrobial resistance (AMR) in environmental aspects and raises the concern of environmental safety. The study in particular further reviewed resistant bacteria and their genes in water environments and pointed that urban wastewater treatment plant (WWTP) is a major source of concern for the dissemination of antibiotics and bacteria regardless of the method employed for the treatment process. This is also supported by other studies [28,29]. Moreover, the study further provided evidence that sewage treatment plants housed pathogens and they contribute to the distribution of resistance and this was also confirmed by another study by Akiba *et al*., [30] in which water samples were investigated and found *E. coli* that are multidrug resistance. In another study, Goulas *et al*., [31] observed that surface runoff and leaching could be another route of circulation of antibiotic resistance in the environment. It is obvious that the distribution, emergence and spread of antibiotics, ARB and ARGs are interconnected factors in the ecosystem, hence, to overcome the daunting challenge, multi-factorial aspects such as the concept of "One Health" need to be employed.

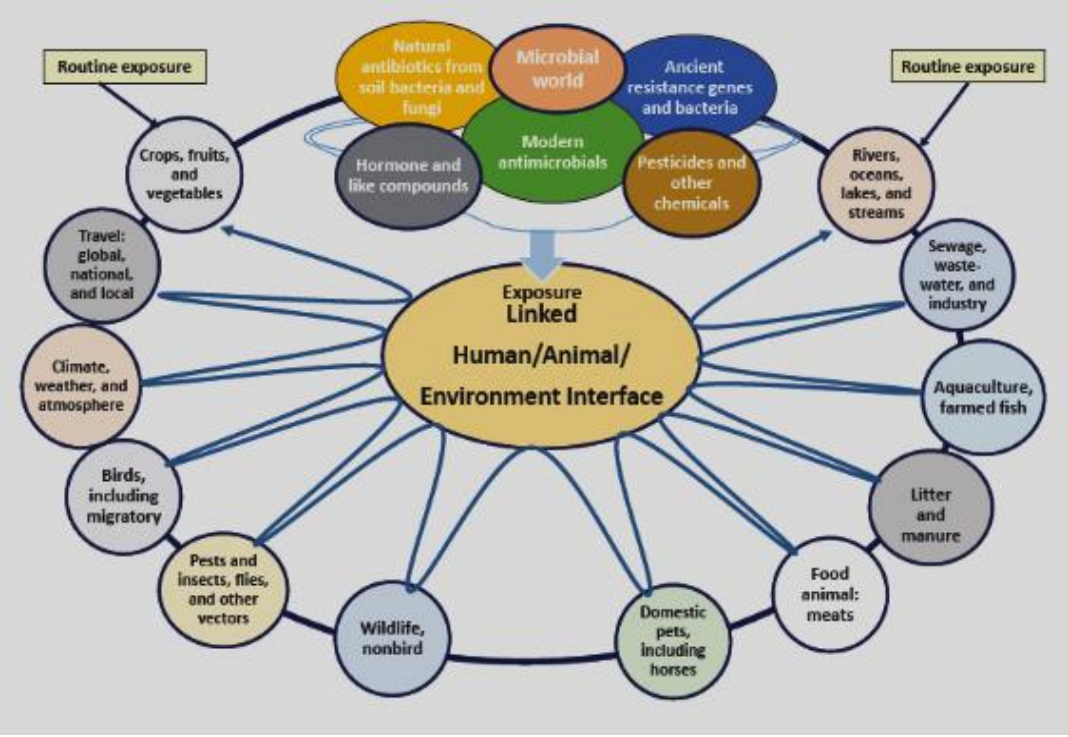

Figure 2: The collective Antimicrobial Resistance Ecosystem (CARE). Adapted from USDA [33].

The concept of the global "One Health" approach is a unique dynamic connection between humans, environments, animals and pathogens and their relationship, and the descriptive interplay

is described in Figure (2) [32]. With this complex interlock, the environment can be considered as the source of antibiotic resistance; because bacteria in these environments (soil, wastewater, sewage, rivers) can develop resistance via exchange with other resistant bacteria, antibiotics and biocides discharged from the community and subsequently, humans and animals are exposed to more antibiotic-resistant bacteria.

In the past years, there have been ample research efforts that focused on resistant bacterial isolates of clinical origin using molecular techniques to identify the mechanisms through which bacteria become resistant to different antibiotics. Said *et al*., [34] profiled resistant pathogens from tertiary care centres in Saudi for one year and the results revealed the presence of multi-drug resistance *Staphylococcus* species, members of Gram-negative bacteria such as *Acinetobacter baumaniii*, and enteric bacteria like *Klebsiella pneumoniae*, *Proteus mirabilis*, *E. coli* and *Pseudomonas aeruginosa.* Of interest to note is the increased rate in multiple drug-resistant A. baumanii and P. aeruginosa and also the increased risk for carbapenem resistance in members of Enterobacteriaceae in the study. A particular study covering south Eastern Europe indicated a high prevalence of A. baumanii from 2010-2015, a significant increase in resistance to major antibiotics were noticed, for example, ampicillin-sulbactam increased from 46.2 to 88.2%, gentamicin 69.3 to 86.4% and meropenem from 82.6 to 94.8% [35]. With this development, treatment of this important pathogen is undermined and affected the control measure for infection. Along similar lines, a study conducted in Spain to analyze the resistance of *P. aeruginosa* towards carbapenems, antibiotic of choice for the treatment of serious infections caused by *P. aeruginosa*, and resistance was observed in varying degrees [36]. The study further analyzed the genes responsible for the resistance and reported the *Oxa40* gene in P. aeruginosa isolates for the first time.

Resistance in clinical isolates has been of interest in many regions, for example in 2017, Paul et al., [37] reported a hospital-based study of resistance patterns in Eastern India. Among the criteria set for the determination was the frequent use of antibiotics among indoor and outdoor patients, and the prevailing isolates include; *Staphyloccocus* species as dominant amongst the Gram-positive whereas *E. coli* dominated Gram-negative. Similarly, significant numbers of the isolates were 100% resistant to penicillin and cotrimoxazole, while up to 75% of the isolates were resistant to carbapenem agents. Worthy to note is the high resistance to aminoglycosides in Pseudomonas (75%) and Klebsiella (85%) [37]. The authors concluded that the outcome of the study was alarming, having a high resistance index to different common antibiotics in different groups of bacteria. Therefore, they suggested that the data generated can be used for antibiotic stewardship and also to formulate antibiotic use protocols [37]. One of the favourite classes of antibiotics, carbapenems that are used to treat patients in intensive (ICU) care units has become less effective against K. pneumoniae, A. baumanni, and P. aeruginosa isolated from patients in both hospital and community [38]. There have been reports indicating series of evolution, emergence and spread of antibiotic resistance of important pathogens like *Streptococcus pneumoniae, E. coli*, multi-resistant *Enterococcus faecium*, carbapenem-resistant *K. pneumoniae* and extensively drug-resistant *P. aeruginosa* and *A. baumanni* [38].

It is not surprising that these isolates have continued to resist the action of antimicrobial agents due to the evolutionary process influenced by the utilization of these agents, but this situation calls for concern when implicated in patients in ICU. Most of the clinical isolates that have become highly resistant are now grouped as priority 1 critical class bacterial pathogens according to WHO hence urgent measure needs to be taken for the development of new antibiotics and reducing the emergence of resistance (Table 1). The classification of these bacterial pathogens was necessitated to develop a worldwide list of antibiotic-resistant bacteria for more focus on their resistant patterns and the discovery of novel agents against them [39].

In the recent past, there was a paradigm shift in antibiotic-resistant organisms from Gram-positive to Gram-negative bacteria. Hospital infection control was a success in reducing infection with methicillin-resistant *Staphyloccocus aureus* and subsequent resistance but clearly, there is an increase among gram-negative [40]. Colistin, an excellent agent for treating patients in critical conditions with carbapenems multidrug resistance Gram-negative infection is been inactivated, this makes the treatment and management of such infection a difficult task [41,42, 43]. Recently, there is an increase in the emerging mobile Colistin resistance gene, *mcr-1;* the gene that is responsible for the spread of pan-resistant Gram-negative bacteria. It is detected in many clinical isolates across the world. In a study in India, Twenty-four Colistin-resistant isolates were detected mainly encoded by *K. pneumoniae* in one and half years [44]. In China, [45] identified 6 variants of mcr-1, 2 of *mcr* 2 and *mcr* 3, interestingly China has been considered as the first reservoir of mobilized colistin gene mcr-1 that was isolated in 2011 in *E. coli* which was resistant to Colistin [46]. Across the world, countries that harbour a high burden of *mcr*-1 genes were China, Vietnam and Germany with *E. coli* dominating the list of mcr-1 positive isolates [47].

With the rising interest in the detection and characterization of bacteria, ABR and ARGs in the environment brought the question of environmental safety and management; and these isolates are regarded as new environmental pollutants of great public health concern and should not be overlooked. The presence of such pollutants would continue to favour the development of resistance as the pathogens can easily donate the genes responsible for the upsurge of resistance in a microbial community. This phenomenon is aided by mobile genetic elements like plasmids and transposons in a horizontal manner [48,49]. Exchange of genetic contents between bacteria is common as a survival strategy; Bridget *et al*. [50] detected recurrent conjugative transfer of resistant genes in the 83% of environment isolates that had exchanged one or more resistant genes. Similarly, horizontal transfer of resistant genes by conjugation from *P. aeruginosa* to *E. coli* was detected by Shakibaie *et al* [21]. Also, the evolution in organisms can be achieved via mutation of already existing genes in a process popularly known as vertical evolution [50]. It is evident that the environment allows the exchange due to proximity; hence the transfer of resistant genes among bacterial isolates can be disseminated further to sensitive bacteria strains.

Table I: WHO Priority Pathogens List For Research and Development of New Antibiotics

Priority Levels	Class of antibiotic-resistant to
Critical	
Acinetobacter baumannii	Carbapenem-resistant
Pseudomonas aeruginosa,	Carbapenem-resistant
Enterobacteriaceae	Carbapenem-resistant, 3rd generation cephalosporin-resistant
High	
Enterococcus faecium	Vancomycin-resistant
Staphylococcus aureus	Methicillin-resistant, vancomycin-intermediate and resistant
Helicobacter pylori	Clarithromycin-resistant
Campylobacter	Fluoroquinolone-resistant
Salmonella spp	Fluoroquinolone-resistant
Neisseria gonorrhoeae	3rd generation cephalosporin-resistant, fluoroquinolone-resistant
Medium	
Streptococcus pneumoniae	Penicillin-non-susceptible
Haemophilus influenza	Ampicillin-resistant
Shigella spp	Fluoroquinolone-resistant

Adapted from WHO global priority pathogens list (global PPL), 2017 [39].

Environment as the breeding ground of resistance

There has been much focus on clinical isolates for their resistant nature but non-clinical isolates in environments have been considered as a chief contributing factor that facilitates the spread of antibiotic-resistant bacteria [51]. The natural environment act as a reservoir for bacteria, providing them favourable factors for the emergence and breeding of resistance; and exchanges of genes encoding resistance has well been documented [51,52,53,54,55,56]. Hall and Barlow [57] reported that molecular analysis to detect the origin of resistance indicated that beta-lactamase genes were available in the environment even before the application of antibiotics in man and animals. Despite the presence of such genes in environments long ago, it is believed that anthropogenic factors increase resistance in the environment; this can be explained by the resultant increase in selection pressure, and an extension to evolution, prevalence and dissemination of resistance in the ecosystem [55]. This complex interplay between the natural environment and human activity greatly increases the threat of resistance to global health as shown below (Fig. 3)

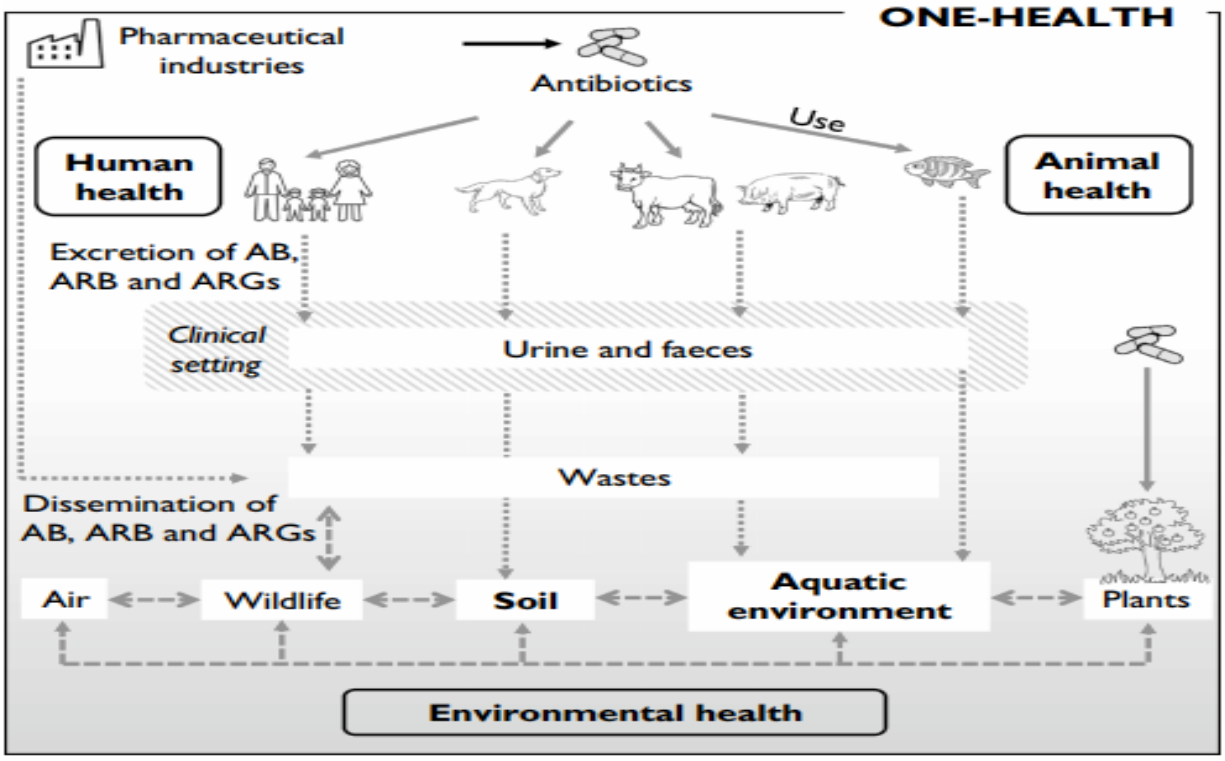

Figure 3: Dissemination pathways of antibiotic residues (AB), ARB, ARGS Adapted from Pal *et al*., (2016) [55]

Resistance occurs in an accelerated manner due to the sub-lethal concentrations of antibiotics in environments which could be a result of discharge from hospitals, pharmaceutical companies, agricultural sources such as applications of fertilizers or use of antibiotics in animal husbandry, and biocides from households which are all believed to allow cross-resistance [58]. In addition, horizontal gene transfer is possible since the resistant genes are abundant in the environment [59,60]. Regardless of the source, it is evident that the environment play important role in bacterial resistance since it was previously reported that cross-resistance from one species to another, also from one environment to another is possible. This phenomenon could be possible via mobile genetic elements such as plasmids and transposons horizontally [48,50,61,62].

How water environment contributes to spread of resistance

It is a fact that water constitutes the largest part of the earth (70%) and provides favourable conditions for biological systems to thrive. Hence, it has an impact on the evolution, spread and transmission of bacteria, ARBs and ARGs are well established [63,64, 65]. Water environments contain huge nutritional constituents that enhance the growth of antibiotic-resistant bacteria, the water serves a dual role in storing and transmission of antibiotic-resistant bacteria [66]. Several water sources exist such as wastewater from hospitals or industrial environments, sewage from the community, agricultural runoff, and wastewater from treatment plants, dams, rivers and streams, and these sources can provide excellent conditions for the evolution and exchange of resistant genes. Several studies reported antibiotic resistance in water bodies, and they harbour multidrug-resistant bacteria of public and clinical importance [21, 22, 24,67, 68]. In the work of Kummerer [58], traces of different antibiotics residues were found in surface water due to the discharge from hospitals or runoff. Another explanation for the presence of antibiotics in the water environment is discharge from industrial sites such as pharmaceutical companies or abattoirs. A study was conducted in Germany and the authors identified the occurrence of antibiotics such as sulfadiazine, sulfamethoxazole, trimethoprim in water that is implicated with pollutants from the

pharmaceutical industry, and such drugs at low concentration can select for resistant bacteria and further spread [69]. A trace of antibiotics in the environment is now considered the emerging pollutant that poses a serious threat to global health, as it will ease the transmission of bacterial resistance and resistant genes. This system brought much concern because not all treatment of wastewater eliminates such bacterial strains.

Another study conducted by Nguyen *et al*., [70] in Vietnam on different water sources for the detection of antibiotics residues, revealed the presence of sulfamethoxazole, sulfadiazine, trimethoprim, and enrofloxacin. In a similar assessment of antibiotic residues in the water environment, high residues of sulfamethoxazole, norfloxacin and Oxolinic acid which are important agents in the treatment of human and animal infections were found [71]. The discharge of antibiotics from human or human activity is not the end process to the antibiotics because reports have it that not all antibiotics in the environment are being degraded, for instance, fluoroquinolones are known to persist long in the environment as reported by previous studies [72,73]. Sukul and Spiteller [74] also reported the occurrence of a significant amount of fluoroquinolones in groundwater, which is believed to have reached such environments as waste from urine, faeces, fertilizer or discharge from hospitals. The agent has a strong attachment to the surfaces of soil which in turn delays their biodegradation. Thus, it will be in the soil for a long period and can be washed to the larger water body such as a river, and more worrisome is that water treatment could only remove 79-87%. Another example is the detection of genes responsible for tetracycline resistance in the ocean [75].

The occurrence of antibiotic residues is well documented which is one of the drivers of the spread of resistance in environments. The occurrence of resistant bacteria is also reported in several studies [76,77,78]. The assessment of bacterial resistance made in Italy found a high burden of *E. coli* that was resistant to ampicillin, chloramphenicol and tetracyclines. Basri and co-workers [77] also isolated over 400 bacterial isolates which were identified as *Salmonella* spp, *Shigella* spp, *E. coli* and *Pseudomonas* spp from samples of water. The susceptibility pattern of such isolates was tested and found that they were resistant to erythromycin, amoxicillin, cephalexin, penicillin G, cloxacillin, ampicillin, ciprofloxacin, gentamicin, chloramphenicol, and trimethoprim-sulfamethoxazole antibiotics [77]. The research concluded that the occurrence of multidrug-resistant bacteria in wastewater is a threat to humans and recommended a proper water treatment process. In an extensive search for the occurrence of antibiotic-resistant bacteria and their genetic determinants, Thai-Hoang *et al*., [76] assessed resistant bacteria from hospital wastewater in a tropical country in which ten commonly used antibiotics were tested against *E. coli* and *K. pneumonia.* These appeared to have a high frequency in 236 colonies, and the study further detected antibiotic resistance genes responsible for resistance to beta-lactam and co-trimoxazole [76].

Barancheshme and Munir [79] to suggest ways to limit the antibiotic bacteria and resistant genes in the environment, particularly water environment, reviewed the current ways of treatment of wastewater in environments, and the authors suggested that low-energy anaerobic-aerobic treatment reactors, constructed wetlands, and disinfection processes as effective procedures of eliminating environmental contaminants such as ABR and ARGs. Interestingly, the study opined that newer strategies such as nanomaterials and biochar have excellent removal of ARB and ARGs, however, these methods are not readily available, especially in developing countries. Therefore, the isolation and characterization of ARB and ARGs are significant in monitoring and evaluating the treatment processes in use, because some of the isolates found in such wastewater are life-threatening in nature. These bacteria in a way that is poorly understood can get their way into the environment and likely infect humans. Many studies raised concern over the increase in ARB and

their genes in the water environment, which has now turn to be global health issue [53,80,81]. Municipal wastewater plants are also known to contain resistant bacteria, for example, Kwak *et al*., [82] reported a high prevalence of *E. coli* in wastewater treatment of a hospital, this has also been confirmed in another study conducted by Odjadjare and Olaniran [83] in South Africa in a wastewater treatment site close to a hospital, where the isolates showed high resistance to many antibiotics.

Another water environment of interest to the present study is hospital effluent and sewage, for the fact that the sewage is a complex constituent with many toxic chemicals, traces of antibiotics and other biological systems. Hence, such an environment can be a pool of bacteria and resistant genes [84]. Here, hospital sewage that is discharged from an area can allow exchange between different bacterial populations [85]. The study reported high multidrug-resistant Gram-negative bacteria with high multiple antibiotic-resistant indexes (MARI) in hospital wastewater in Nigeria [85]. Furthermore, discharge from health institutions into larger water receiving bodies may lead to the further spread of antibiotic resistance [67]. Regardless of the source of the water, an aquatic environment can offer an excellent environment for the growth of pathogens, allow evolution and transmission. Therefore, proper wastewater treatments need to be employed to reduce the spread of resistant bacteria and genes and possibly reaching humans.

Resistance from other environmental sources

Apart from the water environment which contributes largely to the emergence and spread of resistance, other environments contribute substantially to this threat of antibiotic resistance. As is established above, hospital effluents, municipal wastewater and wastewater from industrial sites that allow discharge of chemicals, traces of antibiotics and a high burden of antibiotic-resistant bacteria are channelled into the environment [85,86,87,88]. Wastes from agricultural sources have been another focal point of the emergence of antibiotic resistance to the environment. Sadly, multidrug-resistant bacteria have been found in soil samples from agricultural lands known to house livestock and other agricultural activities [89]. The explanation for this scenario has been established previously, as the concentration of the antibiotics in such environments are at sub-therapeutic levels, hence facilitate the evolution of bacterial strains to select antibiotic resistance [58]. Significant ARBs and ARGs are isolated in such environments, the main genes are reported to be *blaTEM* gene, which causes beta-lactams resistance, *tet(B)* resulting in tetracycline resistance, *str(A)* for streptomycin resistance, *cmlA* for chloramphenicol resistance, *sul1* gene for sulphonamide resistance and *mecA* gene which causes methicillin resistance [90].

A large number of the world's antibiotics are used for non-human and non-therapeutic purposes but used as growth promoters, feed additives and for prophylaxis in animal care. It is estimated that the global consumption of antibiotics is approximated to be around 70 to 80 % and a projected increase of 67% by the year 2030 [91,92]. This could be explained by the quest for large livestock products for profit-making in many countries. Although, the application of antibiotics in farming and agriculture is banned in most European countries for prophylaxis, however, the practice of applications of antibiotics in animal husbandry is still common in many countries across the world [93]. The use of antibiotics in animal husbandry results in the presence of antibiotic residues in animals and food of animal origins [94, 95]. These sources have largely played role in environmental dimensions to the complex nature of resistance and are extensively discussed.

Role of soil environment in the spread of resistance

There are currently collaborative efforts on 'one-health' approach which recognises the interconnection between humans, animals, plants, and their shared environment, including their health and well-being. The thought of global health recognizes the associations among all living

beings occupying the biosphere of their health and well-being. The soil environment being the base of the biosphere plays a role in the interrelation that do exist between the microbiota, inhabiting the soil humans and other living organisms. The soil can be described also as the podium for the most biological process between living organisms, synthesis and degradation of compound and metabolites such as antibiotics [96, 97]. Of recent, the soil environment is also becoming a natural source for antibiotic resistance, this is caused by the increased used and released of antibiotics into the soil environment [97]. Human health is now in a complete dilemma considering the use of antibiotics as a cure for infection and its reoccurring resistance consistently. This phenomenon is of global concern to the health care system of human and animal health [98]. The soil environment is an essential passageway over which humans are exposed to antibiotic resistance. Environmental conditions can also be used to determine the effect of antibiotic resistance as temperate soil has shown high cases of résistance to polar soils. [98].

Soil environment: A primary reservoir for biological compounds

A large population of soil microorganisms inhabiting the soil environment produce a large group of secondary metabolites, specifically antibiotics. The microbe in the soil primarily produces these compounds to help in signalling communication or to antagonise other organisms in search of food, and if there is any change in the environmental condition the organism can now adapt to it [99]. Microorganisms produce secondary metabolites but non-ribosomal peptides and polyketides are the two major metabolites produced from cultured microorganisms. [100,101]. In the early time of antibiotic production, the American microbiologist and a novel price winner were the first to discover streptomycin from a bacterium *Streptomycetes* from soil [102]. Supplementary, with the use of molecular technique more search for these antibiotics in the soil, is practised [102,103].

Soil environment: The main pool for environmental resistome

Considering the trending abuses in the use of antibiotics, there is the possible emergence of genes conferring resistance to the antibiotics in the soil environment. Hence, antibiotic resistance genes are now considered a major part of environmental pollutants found in the soil. It is clear to note that many of these genes are deposited in the environment which is now becoming a threat to human and animal health [80, 104,105]. Like antibiotics, ARGs occur naturally [106]. Soil harbours many microorganisms that produce antibiotics and consequently ARGs. These AGRs naturally produced in the soil are termed intrinsic resistome.

The intrinsic resistome can either be structural or functional depending on the natural integral characteristics [107]. Furthermore, like ARGs, this systematic diversity ascended autonomously of human activity – for example, multiple drug resistance was discovered from a meta-analysis of DNA from olden permafrost [108]. Even though similar ARGs with diverse resistance mechanisms were identified from pristine environments such as Antarctic soil. [109].

Effect of human activity on soil resistome

The advent of antibiotics has immensely contributed to human and animal health, consequently, the misuse and misappropriation of antibiotics have led to the emergence of resistance against most of the first and second-generation antibiotics. According to the Centre for Disease Control in the US [110], most antibiotics taken by humans are neither prescribed by physician nor taken appropriately. Developed and developing countries used a great number of antibiotics in livestock productions, or as growth promoters in animal breeding. The consistent use of antibiotics has led to the prevalence of ARGs to many clinical pathogens. Bacteria may be resistant to the antibiotic through; ARGs via gene transfer, or by mutation, these led to the emergence of antibiotic-resistant bacteria (ARB) [111].

Avertedly, the soil environment will now be dominated by the (ARB) released from humans and animals, which is now of great concern [105,112]. In particular, there has been a development of a specific subset of clinically relevant ARGs in the environment [111]. Human activities have immensely contributed to the development of resistance by soil microorganisms, which represent the larger portion of resistance to antibiotics. Anthropogenic activities from rural soils (farming, manure, livestock breading) and urban soils (hospitals waste, sewage treatments etc.) have caused the resistance to antimicrobials (Fig. 4). The concentration of antibiotics has eventually given rise to the rate of resistance through mutation by microorganisms and lateral gene transfer by resistance bacteria to others [111]. The resistant bacteria in the environment will now continue to propagate and transfer resistance genes through transformation, conjugation and transduction [113].

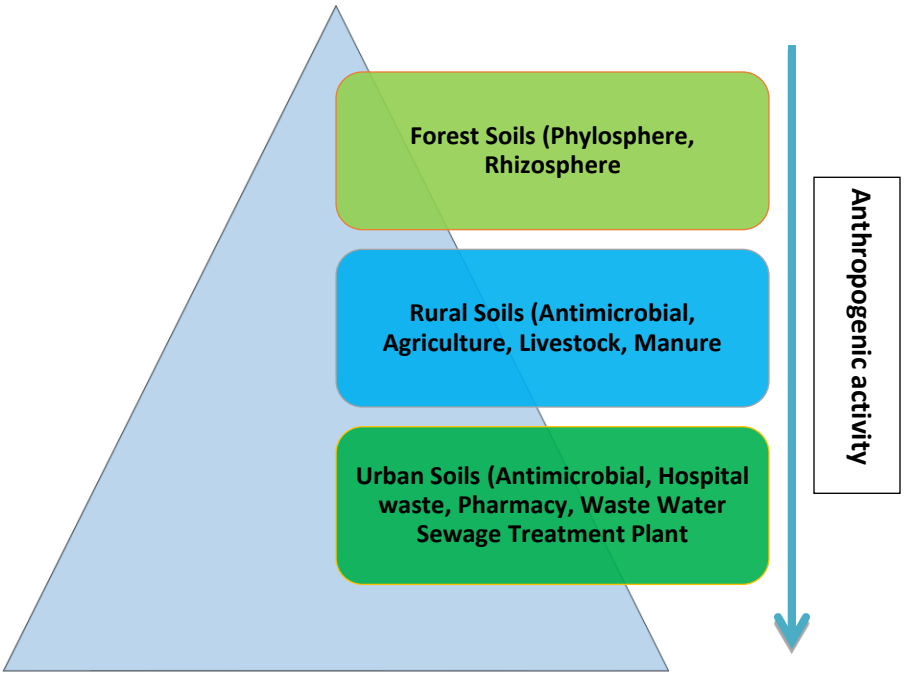

Figure 4: The effects of human activities and the environment on antimicrobial resistance. Adapted from Peterson *et al*., (2018) [111].

A greater quantity of ARGs in the environment with fast expansions and diversity is recognized [114]. It is also reported that no ARGs was present in independent plasmid [111]. As stated, human activities and urbanisation also contribute to the disposal of resistance genes into the soil [96]. Other environmental dimensions that contribute to resistance are hospitals effluent, pharmaceutical industries, domestic sewages which are released into the soil environment before or after treatment. For example, a study from China reported over 200 resistant genes from wastewater treatment plants, with a considerable proportion of these genes persisting during treatment to then become enriched in sewage sludge and effluents [96]. These resistance elements can contaminate urban soils and agricultural land via irrigation with reclaimed water or application of sewage sludge [115]. Resistance genes in urban park soils can be enriched by more than 8000-fold after irrigation with reclaimed water [116]. A study reported a large quantity of ARGs in pristine soil with effluent discharged from domestic households [116]. ARGs can be disposed off through animal defecates which is used as manure for farming activities [117]. Likewise, in animal production and livestock management, antibiotics are used to promote growth which subsequently enriches ARGs in animal guts and associated environments [113, 114]. And directly the soil environment will be the recipient of these ARGs as the animals defecate [114]. It is clear evidence

that the practice of using manure to improved soil fertility in agriculture increases the dissemination of ARGs in soil [114]. In another environmental dimension, ARGs can be easily disseminated through air pollutions by depositions [118]. Apart from the effluent after treatment of wastewater the sludge also contributes to the dissemination of ARGs in soil [119]. Human activities have greatly contributed to the disposal of antibiotic-resistant bacteria which enters the soil from urban wastewater and industrial effluents [116].

Antimicrobial resistance in agriculture

The use of antimicrobial agents in agriculture is estimated to reach above 60,000 tons per annum [12,120]. Although the estimate may be inaccurate due to poor data collection and lack of stringent regulations, it is anticipated that it would rise by over 60% especially in developing countries in the next two decades [91,121]. As outlined in the Centre for Disease Control and Prevention (CDC) report, antimicrobials are used in agriculture not only for the treatment of infections but also for prophylaxis, better health and growth promotion for increased productivity [122,123,124]. In the recent past, it was estimated that there was twice the consumption of medically important antimicrobials in agriculture as it was in humans in many countries [91] including the United States – one of the world's leading users of antibiotics for food production [12]. More interestingly, there are very few differences between antimicrobials used in humans and those used in agriculture.

Livestock production is the major contributor to antibiotic use in agriculture [125]. Agricultural environments may provide a potential reservoir of antimicrobial-resistant microbes and their genes [126]. Alarmingly, the abundance of antibiotic-resistant bacteria is enhanced through the use of antibiotics in animal feeds which are subsequently transmitted to humans along with food processing and consumption routes [127]. After drug administration, the bulk of the antimicrobials may remain un-changed and get excreted in urine and faeces with subsequent spread into the environment [120,125]. As much as 90% of some antimicrobials (especially polar antibiotics) may be excreted un-metabolized [122,128]. Inadvertently, this may increase the development of resistant microorganisms through exposure to antimicrobial drugs and also transfer resistance genes to other microbes in the vicinity [129].

Available evidence suggests that the application of antimicrobials in animal production induces resistance in both the pathogens and also the non-pathogenic commensals [130] and may likely support more global spread and persistence of antimicrobial resistance [131] even if there is declining or zero antimicrobial use [132]. Besides hospitals, animal husbandry represents the largest reservoir of antimicrobial resistance genes [132]. More so, the conditions under which antimicrobial agents are used create a public health challenge especially with regards to the emergence, persistence and spread of antimicrobial resistance [120]. In addition to specific conditions that are predominant in animal farms such as overcrowding; sub-therapy; long treatment period; incorporation of multiple antimicrobials in feeds and lack of proper regulations [133], conditions responsible for antimicrobial resistance in healthcare are also prevalent [131].

Aquaculture is one of the major agricultural activities all over the World. In both intensive and extensive aquaculture, different species grown in ponds or cages develop diseases that require prophylaxis and treatment [125]. Due to the perpetual increase in global food demand, the use of antimicrobial agents in aquaculture becomes indispensable since very few alternatives are readily accessible. The majority of aquaculture activities are in the developing nations with China as the leading country; where the use of 13 different antimicrobial agents is allowed [125,134]. The environmental impact of antibiotics application in aquaculture is a growing concern because of its quantum and environmental fate [135]. Aquaculture has been described as one of the major pathways through which antimicrobial resistance is transmitted to the environment [66].

Various aquatic habitats may contain persistent antimicrobial agents which could lead to the emergence and spread of resistance among both its biotic and abiotic components. Consequently, traces of antibiotics are frequently detected in aquaculture products, most especially oxytetracycline and its derivatives [136]. Reports have shown that applying tetracyclines in aquaculture promote the diversity of resistance genes in river water. Zhang and Zhang [137] examined the incidence, magnitude, and diversity of tetracycline resistance genes in different sewage treatment plants across China and other locations around the World which may represent a general trend Worldwide. Apart from tetracyclines, other antimicrobials like erythromycin and Ofloxacin were also detected in wastewater treatment plants in the United Kingdom [138].

In farming, the use of manure, sludge and municipal water for irrigation of plants significantly contribute to the transfer of resistant microbes and various resistance genetic materials [129]. Research has shown that manure is a minefield of bacteria containing antimicrobial resistance genes accommodated on plasmids and transposons [139]. Its repeated application not only poses risk to the spread of drug-resistant pathogens but also reduces the abundance and diversity of microbial species that contribute to soil quality [140]. When in soil, resistance genes are transferred horizontally to indigenous microbial species which may facilitate the acquisition of genes by commensal bacteria and human pathogens [130]. Several studies have shown the degree and mechanisms of antimicrobial uptake by different plants species [141,142,143].

A quantitative study on the distribution of antibiotic resistance genes conducted by Cerqueira *et al*., 2019 [129] in soil, plant root zones, roots and other aerial parts of some crop species showed the occurrence of the resistance genes in all samples analysed with a gradient decrease from soil to fruits. Resistance genes including *sul1*, *tetM*, *qnrS1*, *blaCTX-M-32*, *blaOXA-58*, *mecA*, and *blaTEM* were detected with the predominance of *blaTEM*. This is a pointer to the magnitude of antibiotic usage in the area especially the beta-lactams. Studies have shown that there is a strong correlation between the extents of specific antimicrobial consumption and resistance to antimicrobials [125,144]. A study conducted by Shi *et al*., [145] reported the presence of 38 resistant genes in agricultural soil including *mexF*, *blaTEM*, *vanD*, *sulI*, *sulII*, and *oprJ* as the most prevalent. The study also established a correlation between the presence of *Int*1 resistome and most of the resistance genes - an indication of horizontal gene transfer. Despite the key role played by manure in the transmission of antimicrobial resistance, recent investigations have shown no disparity between organic and inorganic farming practices with regards to the diversity of microbial species and corresponding resistomes [146]. Although impacted environments are more likely to contain resistance genes, there is a report of a substantial quantity of the genes in pristine environments [127].

Human pathogens acquire antimicrobial resistance genes from agricultural activities as a result of horizontal gene transfer [147]. There are concerns that the long-term presence of antimicrobial may expand resistomes in hosts and the environment leading to the establishment of multidrug resistance [132,148]. Sequel to exposure of humans to resistant microbes of agricultural origin, transmission within the human population is possible [149]. Ultimately, resistant pathogens infect humans through direct contact with livestock, or ingestion of contaminated livestock products. These may lead to devastating health conditions which often requires prolonged treatment and thus, higher healthcare cost and sometimes death [150]. The subsequent resistant progenies are then selected by antibiotic use in humans [147]. Epidemiological studies revealed a strong similarity between human *E. faecium* strains and their resistance elements and the ones isolated from livestock [150]. This elucidated the fact that resistant microbes and resistomes are continually transferred between the environment, humans and livestock [120,147,148]. Strong commitments

by stakeholders, antimicrobial stewardship and antimicrobial conservation have been identified as the major need of the present alarming situation [151].

Conclusion

The role of different environments and human activities, fuel the surge in the spread of antibiotic resistance, and in return facilitate the threat of a silent pandemic in coming years. The emergence of resistance is not only contributed by the application of antibiotics in hospital settings, but also by different environments that serve as hotspots of antibiotic resistance. The release of antibiotic residues at the sub-optimal level into soil and water environment and to large water bodies increase the selection of resistant determinants, and provide a medium for the exchange of resistant bacteria and their genes, thus contributing to an increase in the resistance crisis. It is obvious that human activities in the soil environment and farming such as the application of fertilizers and biocides also aid the dissemination of antibiotics, which in turn contribute to the proliferation of resistant bacteria and resistant genes. With this complex interplay of environmental factors and human activities, coupled with the fact that measures taken in reducing the burden of resistant bacteria in the environment are generally not enough, antibiotic resistance is now considered emerging environmental pollution and therefore, environmental regulators and policy makers must include this aspect in their policies and intervention programmes, in the hope of drastically reducing its continued spread.

Conflict of Interests Statement

No conflict of interest is associated with this work.

Contributions of authors

We declare that this work was done by the authors named in this article and all liabilities pertaining to claims relating to the content of this article will be borne by the authors. AM, IAA, and HYI contributed to the conception, design and manuscript preparation. AM, UAE, MMI, RYB and AUF contributed to the critical revision of the manuscript. All the authors contributed significantly and have all agree with the content of the manuscript.

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ORIGINAL RESEARCH ARTICLE

Readability, stability, and internal consistency of a new psychometric inventory on evidence-based practice in physiotherapy

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Abstract

Evidence-based practice (EBP) has, in the last decade, gained global prominence in health care professions because it provides the framework for lifelong and self-directed learning. These traits are crucial for the continued provision of quality health care. This study sets out to develop a culturally appropriate instrument to measure physiotherapists' knowledge, beliefs, attitudes, and behaviors relative to the use of EBP and establish the instruments' psychometric properties. A 53-item EBP inventory that consisted of seven parts – sociodemographic, EBP competence and behaviors, perceived knowledge of EBP, perceived skills and resources, attitudes about EBP, and barriers related to the use of EBP – was created. The instrument was administered to 25 physiotherapists within a two-week interval on two occasions. The Flesch-Kincaid Reading Ease and Flesch-Kincaid scores for the instrument were 49.5 and 8.3, respectively. Its Cronbach alpha range from "fair" (0.333, $p<.001$) to "almost perfect" (0.837, $p<.001$). The test-retest (stability) scores for the instrument parts were significantly ($\chi 2 = 4.738$, $p<.038$) different for only one (competence on EBP) of the seven factors. The overall findings revealed the instrument is relatively easy to comprehend, highly stable, and internally consistent. The availability of this instrument will promote further studies of EBP in physiotherapy.

Keywords: *Evidence-Based Practice, Psychometric Instrument, Readability, Stability, and Internal Consistency*

Introduction

The roots of evidence-based practice (EBP) started over 3,000 years ago in Egypt with crude experiments to test the effectiveness of bloodletting (Zimerman, 2013). In 1972, Archie Cochrane advocated testing the effectiveness of health care strategies with randomized controlled studies. Sackett and associates (1966) defined EBP as integrating best research evidence with clinical expertise and patient values to improve patient outcomes. In 2009, Satterfield et al. developed a

trans-disciplinary model that included organizational context as the fourth EBP component (Sackett et al., 1996).

Evidence-based practice is not a static state of knowledge but represents a continually evolving state of information (Sackett et al., 2000). Its inclusion in the healthcare process requires modification in practice, self-directed learning, and a favourable work environment that provides a framework for lifelong and self-directed learning, which is crucial for the continued provision of quality care in physical therapy (Ramírez-Vélez et al., 2015; Jody, 2002). EBP is one of the five core competencies recommended by the USA Institute of Medicine to be included in the curriculum of medical and allied health professions to adequately prepare clinicians to practice in the twenty-first-century healthcare system (Institute of Medicine of the National Academies, 2001; 2003).

Several studies around the world have developed inventories to evaluate the knowledge, attitudes, behaviour's, skills, and resources, and barriers that mitigate against the implementation of EBP in physical therapy (Jette et al. 2003; Iles and Davison, 2006; Akinbo et al., 2008; Da Silva et al., 2014; Yahui 2017; Alshehri et al., 2017). Unfortunately, only one of the previous studies (Alshehri et al., 2017) presented limited information on their inventory's psychometric properties. Thus, the findings from the earlier studies may not be reliable and externally valid. There is an urgent need for an EBP inventory that is easy to understand, accurate, and compelling.

Our primary study objectives were to develop a culturally appropriate instrument to measure the knowledge, beliefs, attitudes, and behaviours of Nigerian physiotherapists relative to EBP and establish the new tool's psychometric properties.

Methods

Sample and Experimental Design

Twenty-five physiotherapists participated in this test-retest quasi-experimental design study (Cook and Campbell, 1979). We purposively recruited all grade levels of licensed physiotherapists on full-time employment in the clinical and academic settings at the tertiary hospitals in Borno state. Recent graduates and those with less than three years of clinical experience and employed part-time were excluded from the study.

Sample size estimation

Before data collection, we determined the sample size needed for the study under the following conditions. A hypothetical correlation coefficient of 0.60 (substantial correlation), at an alpha (two-tailed) level of 0.05 (threshold probability to reject the null hypothesis - Type I error rate) and β (the likelihood of failing to reject the null hypothesis under the alternative hypothesis - Type II error rate) set at 0.20. Using the UCSF online calculators for these specified conditions, the study will require a minimum sample size of 19 subjects (Kohn and Senyak, 2020). The sample size of 25 physiotherapists in this study exceeded the estimated minimum sample size of 19 required.

Instrument development

The investigators developed the EBP instrument evaluated in this study (Appendix). Several items were adopted from previous instruments and modified to improve structure and comprehension. The investigators constructed the items in Parts 1 and 2 of the instruments. Part 1 sought socio-demographic information such as age, years of clinical experience, gender, marital status, highest education, employment, clinical specialty, and employment setting. Part 2 consists of eleven multiple-choice questions designed to assess respondents' actual knowledge (i.e., competence) of

EBP. Each item has a "Yes," "No," or "Don't Know" response option. The minimum competence score is 0, and the maximum possible score is 11. For each subject, we computed the aggregate EBP competence score by adding up the number of correct responses out of eleven questions and expressed as a percentage. The minimum and maximum possible scores are 0 and 100% for the actual knowledge component part. A high aggregate score indicates that the respondent is knowledgeable (competent) about EBP.

The items in Part 3 were adapted from a previous study from Brazil by Da Silva et al. (2014). Part 3 of the instrument is on EBP-related behaviors. It consists of four multiple-choice questions about strategies used for updating self professionally, the database used by respondents for literature search, the frequency of database used in the last six months, and where respondents undertake database search. Part 4 of the instrument is on perceived (self-report) knowledge of EBP. It consists of seven items on which respondents were instructed to indicate their opinion on a five-point Likert scale (1=strongly disagree, 2=partially disagree, 3=neutral, 4=partially agree, and 5=strongly agree). The seven items are:

1. I was not taught EBP during my university training.
2. Since I graduated, I have attended workshops on EBP
3. I currently have an excellent knowledge of EBP.
4. I now implement the core elements of EBP in my clinical practice
5. I have excellent knowledge of research designs.
6. I have an excellent knowledge of statistical data analysis.
7. I do have an interest in gaining additional knowledge of EBP.

We derived for each respondent an aggregate perceived (self-report) knowledge of EBP score by adding up the seven questions. The minimum and the maximum possible score are 7 and 35, respectively. A high aggregate score indicates the individual considers him/herself to be knowledgeable about EBP.

Part 5 is on perceived (self-report) skills and resources and consists of eight items. Respondents indicate their opinion on a 5-point Likert scale (1=strongly disagree, 2=partially disagree, 3=neutral, 4=partially agree, and 5=strongly agree). The eight items are:

1. I have the skills to perform searches through databases.
2. I have the skills to evaluate published scientific articles critically.
3. We are rewarded for implementing EBP in my workplace.
4. I have computer/internet access in the workplace that I use for EBP.
5. I regularly discuss EBP at work with my colleagues.
6. I regularly inform my patients of the effective treatment options.
7. I consider the patient's treatment preferences in my clinical decision
8. I try to use the best scientific evidence in my clinical practice.

We computed each respondent’s aggregate perceived (self-rport) skills and resources for EBP by adding up the eight questions. The minimum and the maximum possible score are 8 and 40, respectively. A high aggregate score indicates that individual considers themselves to have the skills and infrastructures needed to engage in EBP.

Part 6 is on attitudes about EBP. It consists of five items on which respondents indicate their opinion on a five-point Likert scale (1=strongly disagree, 2=partially disagree, 3=neutral, 4=partially agree, and 5=strongly agree). The eight items were:

1. EBP is essential to my clinical practice.

2. I routinely access online databases to obtain current scientific evidence
3. My clinical decision regarding treatment of patient incorporates EBP
4. Evidence obtained from the literature rather than the opinion of the expert in my hospital is the most crucial factor in my clinical decision.
5. The use of the best current scientific evidence improves the quality of health services and patient care.
6. I have difficulty understanding the technical language and statistics used in published articles

We obtained the aggregate attitude score about the EBP by adding up the six questions. The minimum and the maximum possible score are 6 and 30, respectively. A high aggregate score indicates that the individual considers themselves knowledgeable about EBP.

Part 7 is on barriers related to the use of EBP, and it consists of nine items on which respondents indicate "Yes" or "No." The nine items are:

1. I have difficulty understanding the technical language and statistics used in published articles
2. I have difficulty in obtaining the relevant full journal article
3. I experience lack of time on the job to implement EBP
4. I have difficulty interpreting the results presented in published articles
5. I have difficulty explaining treatment options to my patient
6. My lack of training in EBP is an obstacle to my effectiveness on the job
7. I am not interested in scientific inquiry and EBP
8. Using EBP may lead to higher healthcare cost
9. The unfamiliarity with the databases is an obstacle to my use of current scientific evidence for my patients
10. EBP disregards the patient's treatment preferences

We obtained an aggregate barrier-related score using the EBP by adding the nine questions. The minimum and the maximum possible score are 1 and 10, respectively. A high aggregate score indicates the individual has high barriers to using EBP.

We revised the initial draft of the instrument several times to improve the clarity of the questions. Subsequently, three physiotherapists with an average of 15 years of clinical experience reviewed the final draft produced. Several of the items were rewritten to enhance the instrument's comprehension and face validity based on their feedback. The final version of the tool has 53 questions categorized into seven parts. After the peer review process, we determined the readability of the psychometric instrument with the Readable® (2019) web-based software.

Procedures

Following the recruitment of the participating subjects, we briefed them of the study's objectives and obtained their informed consent. Participation was voluntary, and subjects were instructed to answer the questions as honestly and accurately as possible. Subsequently, the instrument was administered to the study participants on two occasions, within a two-week testing interval. We did not impose any time limit for the completion of the survey. Most subjects completed it within 20-25 minutes.

On the second occasion, we provided similar testing conditions and instructions. The same research staff members identified in each of the tertiary hospitals conducted the testing, and we offered no stipends or incentives for participating in this study. Anonymity was guaranteed for the respondents.

We printed the survey questionnaire on two colors (white and green) of paper to distinguish the testing done on days one and two. Questionnaire on white paper signify day one testing and green for day two. The respondents were asked to indicate their date of birth for test-retest matching purposes on both surveys.

Statistical analysis

We analyzed the data collected with the Statistical Package for Social Scientists (SPSS) computer-based software, version 16. We cross-checked our data by running frequency distribution for accuracy before statistical analysis. We computed the Chi-square (χ^2) measure between data collected on test one and test two to judge how stable the respondent's answers were over the two weeks. We also calculated the Cronbach's alpha (α) coefficient and the 95% confidence intervals (CI) to evaluate the instrument's internal consistency. We used the guidelines proposed by Landis and Koch (1977) to interpret the Cronbach's α data. An agreement level between 0–0.2 was described by Landis and Koch (1977) as "poor", 0.2–0.4 "fair", 0.4–0.6 "moderate", 0.6–0.8 "substantial", and 0.8-0.9 "almost perfect.

Ethical approval

The Institutional Review Board at the University of Maiduguri, Nigeria, approved the protocol for the investigation.

Results

Demographic profile of the study participants

A total of 25 physiotherapists participated in the study. Their mean age and years of professional work experience were 37 ±11 and 9 ± 9 years, respectively. The majority of the physical therapists were males (72%), married (64%), bachelor's degree holders (64%), and individuals employed in state/federal government establishments (88%). Similarly, the majority of the study participants were clinicians (84%), those with greater than 20 years of professional work experience (12%), and those employed in orthopedic/sports and neurology practice settings (28%%).

Readability of the psychometric instrument

The readability measures for the EBP instrument are presented in Table 1. The instrument Flesch-Kincaid Reading Ease and Flesch-Kincaid scores were 49.5 and 8.3. The Flesch-Kincaid and the Flesch Reading Ease scores reflect the literacy difficulty level. A Flesch-Kincaid score of 8.3 indicates that a minimum of 8th-grade reading level is required to comprehend the contents of the survey entirely. A Flesch Reading Ease score of 49.5 indicates that the test is relatively easy to understand. The instrument's average grade reading level was 11.8, and it is attainable by age 16, which is equivalent to year 12 of education in the British system on which Nigerian schools are modeled (America International School, 2016).

Table 1: The readability indices, text quality, reading time and text statistics for the EBI

S/N	Readability indices	Score
1	Flesch-Kincaid grade level	8.3
2	Gunning-Fog score	10.6
3	Coleman-Liau index	11.0
4	SMOG index	10.9
5	Automated readability index	7.0
6	Average grade level	11.8
7	Flesch-Kincaid Reading Ease	49.5
8	Spache score	5.4
9	New Dale-Chall score	6.9
10	Lix Readability	42.4
11	Lensear Write	87
	Text quality	
10	Sentences > 30 syllables	5
11	Sentences > 20 syllables	10
12	Words > 4 syllables	12
13	Words > 12 letters	3
14	Passive voice count	2
15	Adverb count	37
16	Cliché count	0
	Reading time	
17	Reading time	5.07
18	Speaking time	9.13
	Text statistics	
19	Character count	6,008
20	Syllable count	2,038
21	Word count	1,154
22	Unique word count	402
23	Sentence count	148
24	Paragraph count	120
25	Characters per word	5.2
26	Syllables per word	21.8
27	Words per sentence	7.8
28	Words per paragraph	9.6
29	Sentences per paragraph	1.2
30	Spache Score	5.4

The text quality was 5 and 10 for sentences greater than 30 and 20 syllables, respectively. The reading time was 5.07 minutes, and the speaking time was 9.13 minutes. The EBI text character and syllable counts are 6,006 and 2,038, respectively. The average word per sentence was 7.8. We

evaluated its psychometric properties based on the satisfactory readability indices that indicate the instrument is relatively easy to comprehend.

Test-retest reliability (stability) of the instrument

The Chi-square test results comparing the data collected on test day one with test two revealed no significant difference in six of the tool's seven parts (Table 2). Six of the seven parts of the instrument are stable. Only the test-retest (stability) score for the EBP competence was significantly (χ^2 = 4.738, p<.038) different, i.e., unreliable. The other six items showed no statistically significant difference (p>.05) between testing day one and day two assessments. The latter findings signify the stability of the items.

Table 2: Median score test retest (stability) data on day one and day 2 (N=25)

Instrument component parts	Test day 1	Test day 2	χ^2	p-value
Actual knowledge (competence) on evidence-based practice (*/10)	8.0	7.0	4.738	0.030
Strategies to upgrade level of professionalism (*/5)	3.0	4.0	0.065	0.799
Search engine use in evidence-based practice (*/5)	1.0	1.0	0.000	1.000
Perceived (self-report) knowledge of EBP (*/35)	26.0	25.0	1.384	0.239
Perceived (self-report) skills and resources in evidence-based practice (*/40)	28.0	30.0	0.164	0.685
Attitudes about evidence-based practice (*/35)	23.0	22.5	0.159	0.690
Barriers-related to evidence-based practice (*/10)	3.0	2.0	0.015	0.901

Internal consistency of the instrument

The Cronbach alpha for the different components of the instrument is presented in Table 3. Three of the seven component parts of the instrument showed “almost perfect” (ICC = 0.4 – 0.6; p<0.001) correlation and another three parts showed “substantial” (ICC = 0.6 – 0.8; p<0.001) correlations. Only one of the parts (search engine used in EBP) showed poor correlation.

Table 3: Cronbach's alpha for the component parts of the evidence-based practice instrument

Instrument component parts	Cronbach's alpha value*	95% CI** Lower and upper bands	Interpretation***
Actual knowledge (competence) on evidence-based practice (*/10)	0.837	0.631-0.928	Almost perfect
Strategies to upgrade level of professionalism (*/5)	0.703	0.327-0.869	Substantial
Search engine use in evidence-based practice (*/5)	0.333	0.514-0.706	Poor
Perceived (self-report) knowledge of EBP (*/35)	0.619	0.135-0.832	Substantial
Perceived (self-report) skills and resources in evidence-based practice (*/40)	0.761	0.458-0.895	Substantial
Attitudes about evidence-based practice (*/30)	0.803	0.544-0.915	Almost perfect
Barriers-related to evidence-based practice (*/10)	0.814	0.569-0.919	Almost perfect

***ICC =Intra-class correlation coefficient; p<0.001; **CI = Confidence interval; ***Landis and Koch (1977)**

The Cronbach's alpha for actual knowledge (competence) on EBP was 0.837 for actual knowledge (competence) on evidence-based practice, 0.703 for strategies to upgrade level of professionalism, 0.333 for search engine use in EBP, 0.619 for perceived (self-report) of EBP, 0.761 for perceived (self-report) skills and resources in EBP, 0.803 for attitudes about EBP and 0.814 for barriers-related to EBP.

Discussion

We set out to develop a paper and pencil instrument to measure Nigerian physiotherapists' actual knowledge (competence), perceived (self-report) knowledge (competence), perceived (self-report) skills and resources, attitudes, and behaviours toward EBP and to establish the new tool's psychometric properties. Of all the previous studies (Jette et al. 2003; Iles and Davison, 2006; Akinbo et al., 2008; Da Silva et al., 2014; Yahui 2017) that assessed physiotherapists knowledge of EBP, only one study conducted in Saudi Arabia presented limited information on their instrument's psychometric properties (Alshehri, 2017). Their tool's internal consistency (Cronbach's alpha) was 0.780, and the reliability coefficients were 0.805 for knowledge, 0.601 for behaviour, 0.954 for attitudes, 0.934 for awareness, 0.584 for EBP training, and 0.800 for knowledge barriers. The internal consistency property of their instrument aligned with the findings in our study. However, our study investigated the new instrument's psychometric properties and evaluated its readability properties. None of the previous EBP studies assessed the readability of their tools.

In 2007, Nelson and Steele conducted a national online survey of mental health practitioners in the USA to identify correlates of self-reported EBP use in clinical practice. Two hundred fourteen

mental health practitioners from 15 states and diverse clinical settings participated in the study. The results found the viable predictors of self-reported EBP use were taking a class in EBP, the perceived support of the clinical facility toward EBP, and the clinician attitudes toward intervention research. Attitudes toward intervention research partially mediated the relationship between the clinical facility and EBP use. Negative attitudes toward intervention research partially mediated the relationship between clinician training and self-reported EBP use.

In a systematic review in 2014, Da Silva and associates contextualized the current evidence on physiotherapists' EBP knowledge, skills, behaviour, opinions, and barriers. They found that of the 12,392 potentially eligible studies, only 12 studies met the review criteria (pooled sample = 6411 participants). Of the 12 relevant studies, three analysed knowledge, and 21-82% of respondents claimed to have received formal education on EBP. In two studies that examined skills and behaviour, about 50% of the sample had used databases to support clinical decision-making. Most of the physiotherapists considered EBP necessary in six of the 12 studies investigating opinions. The primary barriers most frequently cited by the physiotherapists were time constraints, inability to understand statistics, lack of support from the employer, lack of resources, limited interest, and lack of generalization of results. The majority of physiotherapists had a favourable opinion about EBP and believed that they needed to improve their knowledge, skills, and behaviour towards EBP.

Our study is the second investigation to assess both actual (competence) and perceived (self-reported) EBP knowledge of physiotherapists. The findings in previous studies on physiotherapists' perceived knowledge of EBP (Jette et al. 2003; Iles and Davison, 2006; Akinbo et al., 2008; Da Silva et al., 2014; Yahui 2017) should be applied with caution. This admonition is warranted because existing literature in education and marketing has firmly established that perceived (self-report) knowledge and actual knowledge (competence) are distinctly different constructs (Bacon, 2016). Sitzmann, Ely, Brown, and Bauer (2010) provided compelling evidence supporting the difference between actual learning and perceived (self-reported) learning constructs. Their meta-analysis study found a correlation of .34 between perceived (self-reported) knowledge and actual knowledge (competence). However, the association was zero between self-reported knowledge gain (perceived learning) and actual knowledge. Thus, physiotherapists who think they are competent about EBP may be unaware of their limited knowledge and unlikely to seek educational training to improve their understanding and skills about EBP (Drass et al., 1989). The potential misperception of EBP knowledge raises fundamental questions regarding applying the findings in previous studies (Jette et al., 2003; Iles and Davison, 2006; Akinbo et al., 2008; Da Silva et al., 2014; Yahui 2017) to provide consistent EBP. Our tool will find a useful application in future studies...

Conclusion

This investigation is a correlational study and no "cause and effect" conclusion should be inferred from any of the findings. The instrument Flesch-Kincaid score of 8.3 indicates that a minimum of 8th-grade reading level is required to comprehend the contents of the survey entirely. Six of the seven parts of the instrument are stable. Only the EBP competence component is unreliable. The Cronbach alpha for three of the seven component parts of the instrument showed “almost perfect” correlation and another three parts showed “substantial” correlations. Only one of the parts (search engine used in EBP) showed “poor” correlation. The Cronbach's alpha for actual knowledge (competence) on EBP ranges from 0.333 for search engine use in EBP to 0.837 for actual knowledge (competence) on evidence-based practice. The overall findings from our study revealed that the psychometric instrument developed is relatively easy to comprehend, highly stable, and

internally consistent. The availability of this instrument will promote further evaluative studies of EBP in physiotherapy.

Conflict of Interest
The authors declare no conflict of interest

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ORIGINAL RESEARCH ARTICLE

Modelling and prediction of hydrolysis index of gluten-free cookies from cardaba banana starch vis-à-vis response surface methodology and support vector machine.

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Abstract

The increase in the onset of celiac disease among the world populace had increased the demand for gluten-free products. Therefore, this study aimed at modelling and predicting the hydrolysis index of gluten-free cookies using response surface methodology (RSM) and support vector machine (SVM). The baking temperature (150 -180 ℃) and baking time (15-25 min) were varied using a central composite design. The obtained result revealed that both modelling approaches (RSM and SVM) accurately predict the hydrolysis index of the gluten-free cookies owing to their higher coefficient of determinant ($R^2 > 0.9$). The predictive capability assessment of response surface methodology and support vector machine revealed the superiority of support vector machine (0.9658, 0.9329, 0.059) in predicting the hydrolysis index of the gluten-free cookies over response surface model (0.9613, 0.9241, 0.063) owing to its high correlation coefficient (R), Coefficient of determinant (R^2) and lower mean square of error as well as root mean square of error (RMSE).

Keywords: *Gluten-free cookies; Hydrolysis index; Starch digestibility; Mathematical modelling; Machine learning*

1. Introduction

Recently, there had been an increase in people with celiac diseases, an immune-mediated enteropathy disease arising for the ingestion of food products containing gluten in people genetically susceptible to it. The increase in celiac disease had led to an increasing demand for gluten-free diets or products. This disease is common among westerners and had been reported low in Africa due to improper health facilities to diagnose the disease. Although, many approaches had been used in the treatment of the disease, the only proven treatment is the removal of gluten and prolamins or its precursors such as hordeins in barley, secalin in rye, and avenins in oats from

genetically susceptible person's diets. This had led to the development of gluten-free products by several researchers from diverse crops such as Vicia faba bean (Schmelter *et al*., 2021), rice flour (Rocchetti *et al*., 2019), pseudo-cereal (Martínez-Villaluenga *et al*., 2020) and plantain flour (Gutiérrez, 2018). These crops however, have both commercial and other industrial values, thereby contributing to the high cost of production of gluten-free products (Olawoye et al., 2017). Hence the need to search for a local alternative amongst the under-utilized crop from which the product can be produced, hence, *cardaba* banana.

Cardaba banana also known as cooking banana is a breed of Musa spp usually cultivated in sub-Sahara Africa. It is widely known for its high starch content (81.84%) in which amylose is made up of 31-35% of the starch composition thereby making it suitable as a diet in the management of diabetes Mellitus; a disease that arises from glucose absorption malfunction. The application of the cooking banana is limited due to its high perishability when ripe and unlike dessert banana, it found no usage after ripening. Due to this, it had found application in the production of complementary food (Ayo-Omogie & Ogunsakin, 2013) as well as functional starch (Olawoye *et al*., 2020a; Olawoye *et al*., 2020c). However, because the cooking banana contains no gluten, it serves as good raw material in the production of gluten-free products.

In the production of gluten-free cookies, the choice of raw materials and their composition are important as they affect the physical, chemical and nutritional characteristics of the final product. One important component of the raw material that affect these is the carbohydrate (starch) composition. Starch is a polymeric aldehyde join together by an alpha 1-4 glycosidic bond in an unbranched chain and a beta 1-6 glycosidic bond in branched chain. During food digestion, starch is broken down in the human gastrointestinal tract by alpha-amylase into glucose which is the main source of biofuel in humans. However, high glucose in human blood resulted in complications arises from type 2 diabetes. To solve this problem, it is necessary to control the amount of glucose in food to produce gluten-free cookies with a low glycemic or hydrolysis index; which is the response of the body to blood glucose after two hours of the consumption of carbohydrate food. Hence, the need for statistical modelling and optimization of the process variables for the production of the low glycemic or hydrolysis index gluten-free cookies.

Statistical modelling and optimization had been widely used for the prediction and analysis of chemical reactions or processes. Of the approaches used in mathematical modelling, data-driven modelling focuses on input-output functionality findings from experimental data set obtained in the chemical process. This approach helps in predicting outcomes and finding the optimum condition of process variables that will bring about the targeted goal. Olawoye and Kadiri (2016) use the response surface methodology approach in modelling the antioxidant properties of grain amaranth flour. Using this approach, they were able to optimize the process parameters for optimal antioxidant activities. Support vector machine is a machine learning algorithm that provides good prediction accuracy, owing to its tolerance to erroneous and noisy data. Its application in food process operation is limited (Saha & Manickavasagan, 2021) and hence its usage in this study. This study aims at statistical modelling of the hydrolysis index of gluten-free cookies using response surface methodology and support vector machine.

2. Material and Methods

2.1. Materials

The main raw materials used for the production of gluten-free cookies are *Cardaba* banana flour and starch flour. Other ingredients in the production of the cookie were obtained from a local supermarket in Ile-Ife, Osun State, Nigeria. Chemicals used for the analysis were of analytical grade and were obtained from Sigma-Aldrich, USA.

2.2. Starch extraction from *cardaba* banana

The starch extraction was carried using the procedure described by Olawoye *et al*. (2020c). Briefly, the banana was washed and peeled underwater to avoid enzymatic browning of the peeled banana. The peeled banana was cut into smaller sizes and was milled mechanically using a Stephan milling machine (Germany). Following milling, the starch mash was diluted with water (1:10) and was passed through a sieve (200 um mesh size). The subsequent starch slurry obtained was washed with water three times and was left for 8 hours for the starch to settle down. This was followed by decanting the water and the starch obtained therein was dried at 40 ℃ for 8 hours and kept inside an airtight container under refrigeration before use.

2.3. Modification of *cardaba* banana starch using citric acid.

Cardaba banana starch produced was modified using citric acid modification following the methodology of Klaushofer *et al*. (1978) as modified by Olawoye and Gbadamosi (2020).

2.4. Gluten-free cookie production

The cookie production was carried out using the method described by Giuberti *et al*. (2015). Briefly, citric acid modified *cardaba* banana starch was blended with cardaba banana flour (80:20 w/w). Buttercream (8.5 w/w of flour blend) and whole egg (12 w/w of flour blend) were mixed and was added to the already pre-mix flour blend in an electric mixer (Kenwood KMM021, UK). The ingredients were thoroughly mixed for 7 minutes to form a homogenous dough. After mixing, the dough was flattened using a roller and was stored in refrigeration (4 ℃) for 30 mins. The dough cutter was used to cut the flattened dough into small sizes and were baked at various baking temperature and time following the central composite design shown in Table 1.

Table 1: Experimental design for process variables

Independent variables	Codes	Range and level				
		-α	-1	0	+1	+α
Baking Temperature (℃)	A	135	150	165	180	195
Baking Time (min)	B	5	10	15	20	25

2.5. In vitro starch digestibility of the gluten-free cookie

The in vitro starch digestibility, as well as the digestion kinetics, was done using the method described by Olawoye *et al*. (2020b). The glucose released was evaluated using the colourimetric method described by Olawoye and Gbadamosi (2020) while the starch released was quantified as the percentage starch release at a different time. The Hydrolysis index was calculated from the relationship between the area under curve (AUC) (0 – 180 min) for the cookie and AUC for white bread as described by Goni 1997. The equation for the hydrolysis index (HI) of the cookie is presented below.

$$\mathbf{AUC} = \mathbf{C}_{\infty}(\mathbf{t_x} - \mathbf{t_0}) + \frac{\mathbf{C}\infty}{\boldsymbol{k}}\left(\boldsymbol{e}^{-\boldsymbol{ktx}} - \boldsymbol{e}^{-\boldsymbol{kt0}}\right) \quad \text{Eq. (1)}$$

$$\mathbf{AUC} = \mathbf{180\ C}_{\infty} + \frac{\mathbf{C}\infty}{\boldsymbol{k}}\left(\boldsymbol{e}^{-\mathbf{180}\boldsymbol{k}} - \mathbf{1}\right) \quad \text{Eq. (2)}$$

Hydrolysis index (HI) was calculated as the relationship between the Area under Curve (AUC) for a test food and AUC for a reference food (White bread), expressed as a percentage (Granfeldt et al., 1992).

$$\mathbf{HI} = \frac{\boldsymbol{Total\ Glucose\ \ from\ \ 100g\ cooked\ sample\ (on\ a\ dry\ basis)\ at\ 120\ min}}{\boldsymbol{total\ Glucose\ from\ 100\ g\ white\ bread\ (on\ a\ dry\ basis)\ at\ 120\ min}} \quad \text{Eq. (3)}$$

2.6. Modelling using support vector machine

Support vector machine is a machine learning algorithm based on Vapnik-Chervonenkis dimension theory (Bisgin et al., 2018). It is a learning algorithm that utilizes a structural risk minimization (SRM) induction principle to profound a unique solution to the experimental data set. SVM exhibits high prediction efficiency over other statistical modelling tools by recognizing a non-linear relationship between the dependent and independent variables. Also, support vector machine - regression poses an advantage over other machine learning tools in that a small number of parameters are required; the kernel type as well as cost parameter C which indicates the balance in the tolerance for training errors and generalization capability. In this study, SVM was applied purposely to correlate the hydrolysis index of the gluten-free cookie with the independent variables (baking temperature and baking time). The data set from the Central composite design were used for the support vector machine (regression). The experimental data were randomly divided into two; 80% of the data was used as training data set while the remaining (20%) was used as the testing data set to predict the hydrolysis index. For the modelling operation, the radial basis function kernel was selected and was characterized by the equation below.

$$Y(x) = \sum_{n=1}^{N} w_n K(x, x_n) + w_0 \quad (4)$$

Where w_n is the model weight and $K(x.x_n)$ is the kernel function

2.7. Performance analysis of the RSM and SVM model

The performance of the model (RSM and SVM) in predicting the hydrolysis index of the gluten-free cookies was evaluated using some fit statistics cateria such as correlation coefficient (R), coefficient of determinant (R^2), adjusted R^2, mean square of error, root mean square of error, average absolute deviation (AAD) and standard error of prediction (SEP).

3. Result and discussion

3.1 Analysis of the RSM model of hydrolysis index

The result of the hydrolysis index of the cookies obtained from a central composite design of response surface methodology is shown in Table 2. The result revealed that the hydrolysis index ranged from 56.04 to 56.79 for actual value and between 56.04 - 56.82 for predicted value. The values obtained in this study were, however, lower than the values obtained by Giuberti *et al*. (2016) for cookies made from waxy rice starch. The lower HI values could be attributed to the citric acid modification of the *cardaba* banana starch before use. Citric acid modification of starch had been reported to slow down enzymatic digestion of starch thereby, yielding a low hydrolysis index (Remya et al., 2018). To ascertain the relationship between the independent variables (baking temperature and baking time) and dependent variable (hydrolysis index), a second-order polynomial model was used and the relationship is presented using equation 5 below. The second-order polynomial model was subjected to analysis of variance and the result is presented in Table 3.

HI = 56.4997 + -0.177778 * A + -0.0565693 * B + -0.0658922 * AB + -0.0264931 * A^2 + 0.0514742 * B^2 (5)

Table 2. Experimental and predicted values of hydrolysis index of GF cookies

Run	Independent variables		Hydrolysis index		
	Temperature (℃)	Time (min)	Actual	RSM predicted	SVM predicted
1	165	25	56.60	56.59	56.56
2	165	15	56.46	56.50	56.43
3	135	15	56.73	56.75	56.76
4	165	5	56.79	56.82	56.76
5	150	10	56.74	56.69	56.75
6	165	15	56.65	56.50	56.63
7	180	20	56.21	56.22	56.28
8	165	15	56.39	56.50	56.53
9	180	10	56.49	56.47	56.43
10	195	15	56.04	56.04	56.08
11	165	15	56.50	56.50	56.53
12	165	15	56.46	56.50	56.53
13	150	20	56.73	56.71	56.69

Table 3: Analysis of variance of hydrolysis index of the GF cookies

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.5379	5	0.1076	17.22	0.0008	significant
A-Baking Temperature	0.3793	1	0.3793	60.71	0.0001	
B-Baking Time	0.0384	1	0.0384	6.15	0.0423	
AB	0.0174	1	0.0174	2.78	0.1394	
A^2	0.0161	1	0.0161	2.57	0.1527	
B^2	0.0607	1	0.0607	9.72	0.0169	
Residual	0.0437	7	0.0062			
Lack of Fit	0.0046	3	0.0015	0.1553	0.9210	not significant
R^2	0.9248					
Adjusted R^2	0.8711					
Predicted R^2	0.8332					
Adeq precision	14.53					
CV (%)	0.14					

The ANOVA result revealed that the model for the experimental design is significant owing to the p-values less than 0.05. Aside from the experimental design model, it could also be seen that among the model terms, only the interaction term of the independent variables, as well as the quadratic term of the baking temperature, were not significant ($p > 0.05$). The linear term of the baking temperature of the gluten-free cookie was the most significant among the model terms,

evident of its very low p-value (0.0001) and high Fisher's test value (60.71). The Pareto chart (Figure 1) shows the relationship between the process parameters as well as the response (hydrolysis index). As could be seen in the chart, the bar chart that crosses the reference indicates significant terms while those below the reference line are not significant in the determination of the hydrolysis index of the gluten-free cookies. The regression coefficient revealed that only the quadratic term of the baking time had a positive value and hence, a positive relationship with the hydrolysis index while others had a negative relationship with the hydrolysis index.

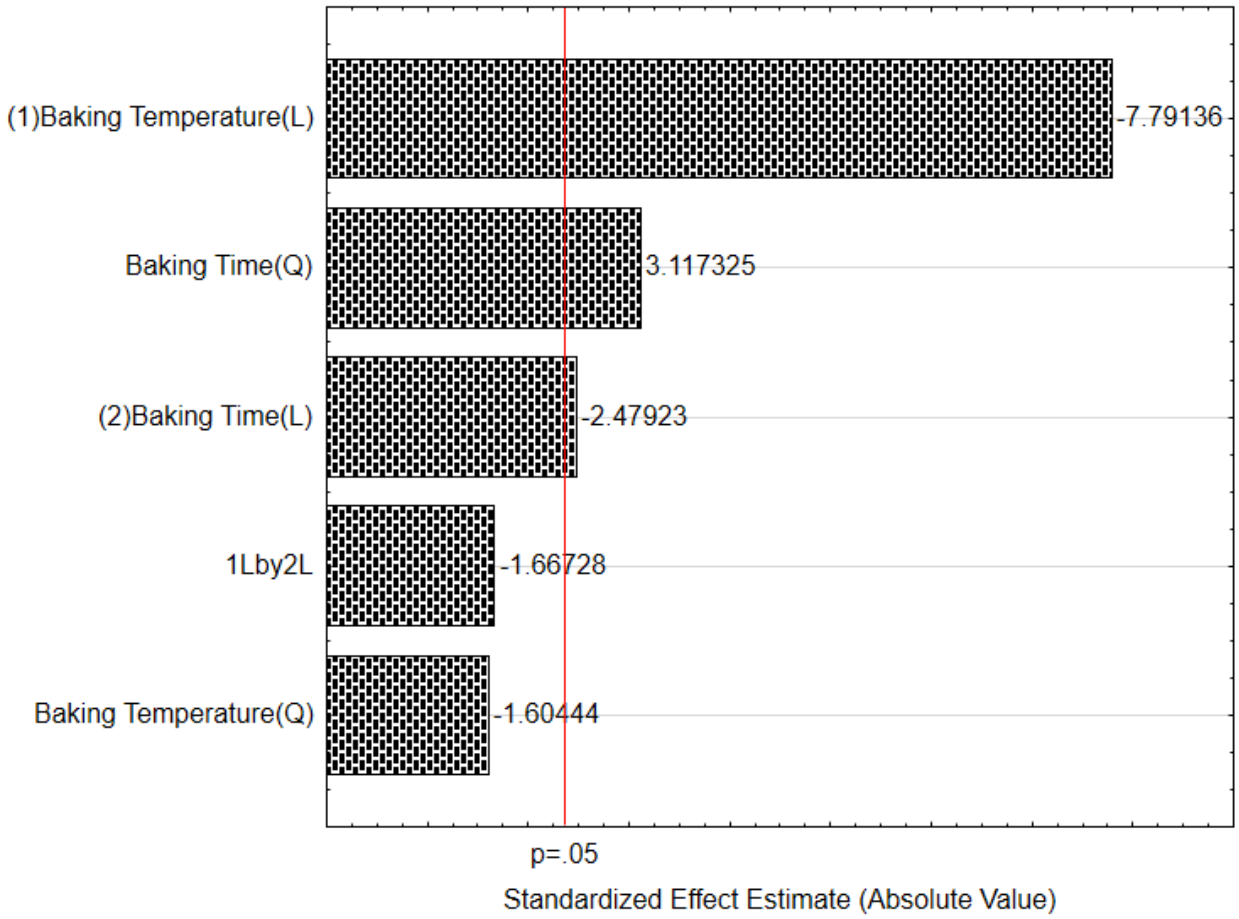


Figure 1: Pareto chart for hydrolysis index of the GF cookies

The goodness of fit of the model was evaluated using analysis of variance and presented in Table 3. The lack-of-fit obtained for the experimental model is 0.9210 which implies that it is not significant ($p > 0.05$) in relation to the pure error. The high lack-of-fit indicate there is a 92.10% chance that the lack-of-fit was due to noise. A non-significant lack-of-fit affirm the goodness of fit of the experimental model. Also, the coefficient of determinant (R^2) of 0.9248 is an indication that 92.48 of the variation in the experimental data could be accounted for by the independent variable while only 7.52% of the variation can't be accounted for. According to Morakinyo *et al.* (2021), an R-square value above 0.80 is a reflection of the significance of the model. The R-square alone, however, does not reflect the goodness of fit of the model because when a new model term is added to the experimental design, its effect is not being accounted for (Odejobi *et al.*, 2018). Hence, the adjusted R-square which take into consideration the effect exhibited when a new independent variable is added was 0.8711. Unlike the coefficient of determinant, the adjusted r-square only increase when a new model term is added to the experimental design. Finally, the adequate precision which also measures the goodness of fit of the model is 14.53. This is a

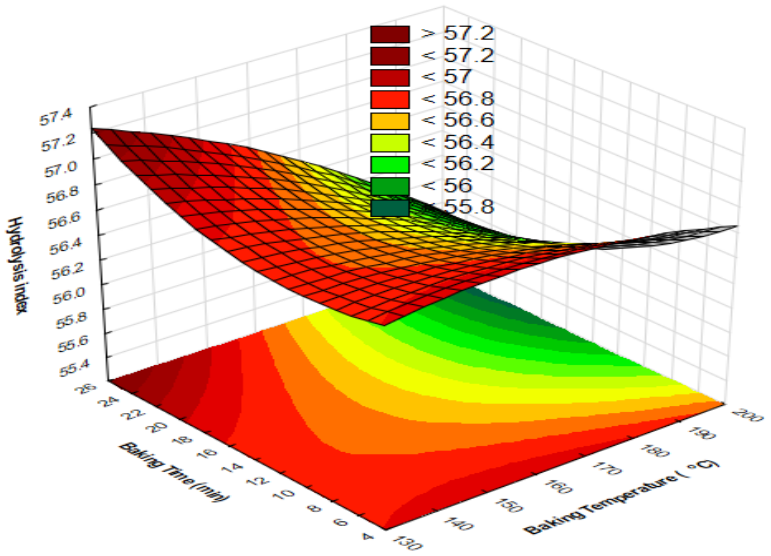
measurement of the signal to noise ratio. A value of above 4 is desirable and the ratio of 14.53 indicates an adequate signal.

3.2. Effects of baking temperature and time on hydrolysis index

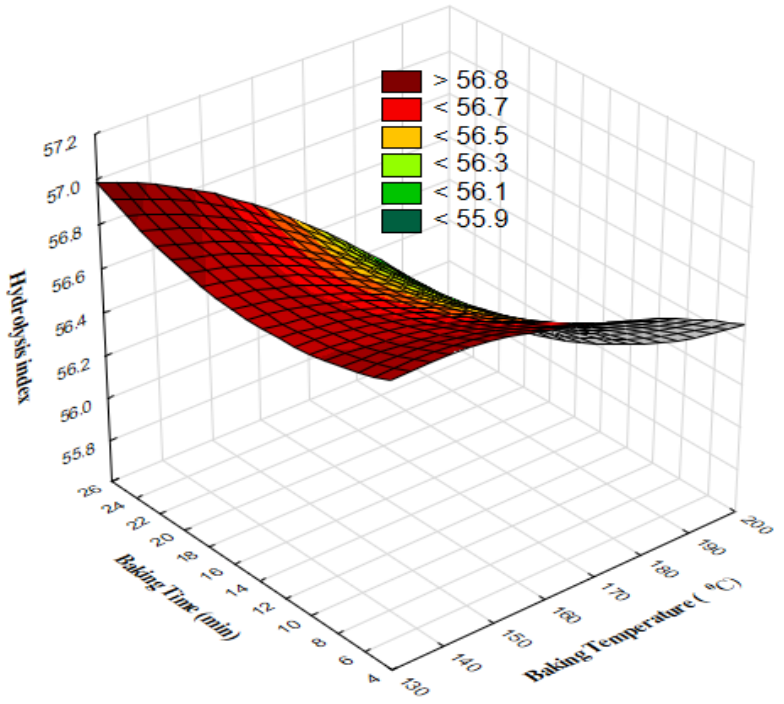
The effect of the processing variables (baking temperature and time) on the hydrolysis index of the gluten-free cookies is shown in Figure 2. The 3-D surface plot shows that both the baking temperature and baking time had a linear effect on the hydrolysis index. At constant, an increase in the baking temperature resulted in a decrease in the hydrolysis index of the gluten-free cookies. An increase in the baking time up 16 mins at a low baking temperature on the other hand resulted in an initial decrease in the hydrolysis index of the cookies. This, however, increases as the baking time progresses above 16 mins. Baking for a long period increases the rate of gelatinization of starch as a result of an increase in the cookies core temperature. This, however, upon cooling of the cookie enhance retrogradation of the starch and hence, limit the hydrolysis index of the cookie. An increase in the baking temperature at an elevated temperature resulted in a significant decrease in the hydrolysis index. This could be due to the formation of complexes between lipids and starch (amylose) at a high temperature which in turn result in low digestibility of the cookie and hence, low hydrolysis index. For health benefits, the hydrolysis index must be at the barest minimum possible (Olawoye et al., 2020). To achieve this, the baking temperature, as well as the baking time, must be at their highest value.

3.3. Modelling hydrolysis index using support vector machine

Support vector machine, a pattern classification technique which unlike the traditional method of modelling minimizes experimental data training error by maximizing boundary separation between the training data set and hyperplane. To model the hydrolysis index of the cookie using SVM, the experimental data obtained from the central composite design were used. The data were divided into two in which 75% of the data set was used as training data while the remaining data set were used as testing data which was used in data prediction. The kernel function selected for the modelling operation was the RBF kernel in which parameters C (error penalty) and Ɛ (epsilon) were carefully chosen as they influence the final model prediction performance.



(a)



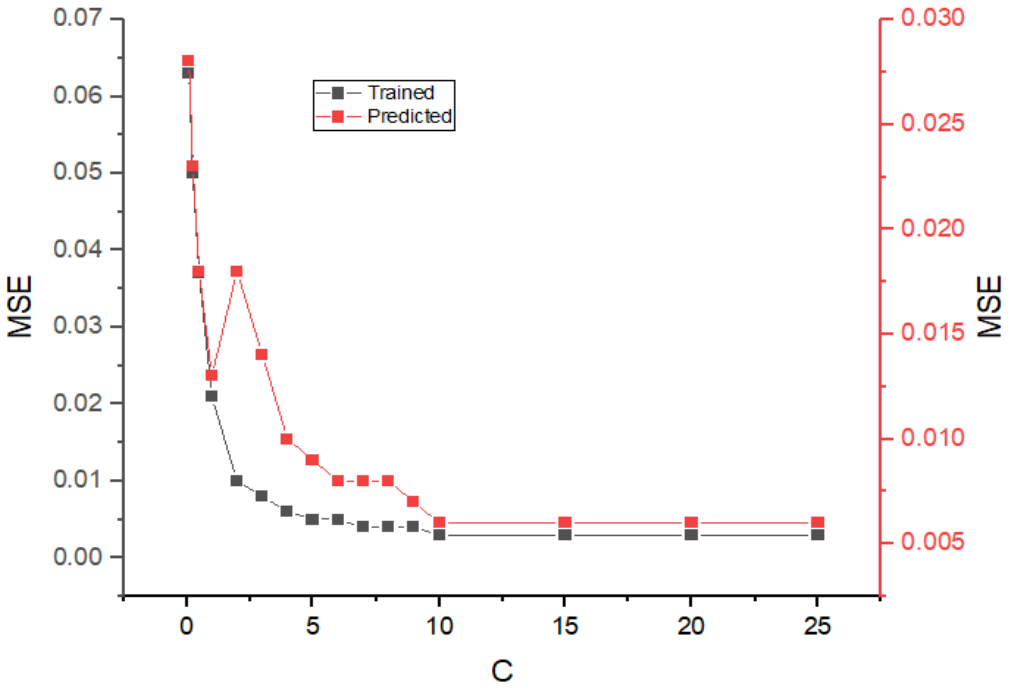
(b)

Figure 2: Effect of processing parameters on hydrolysis index of the GF cookies: (a) RSM; (b) SVM

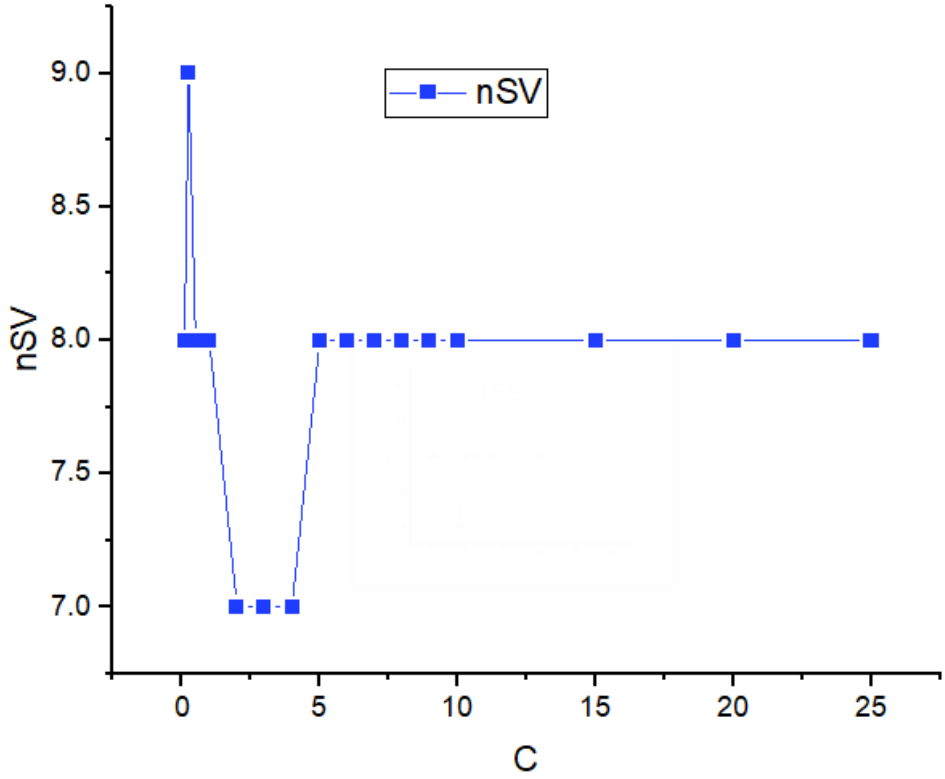
3.4 Selection of the SVM parameters (C and ε)

Selection of C

The parameter C also known as error penalty functions in adjusting the ratio of the learning machine interval and the empirical risk. When the value of C is small, then the empirical error penalty is small which also result in the complexity of the learning machine being small (Shao et al., 2020) and hence the over-learning of the SVM model and vice-visa. Also, when C is too large or too small, it affects the performance of the SVM model. Therefore, in this study, the SVM parameter ε was fixed at 0.1while the error penalty (C) was varied between 0.1 to 25 for the training of the SVM model using central composite design datasets. The result obtained was the mean square of error as well as the number of support vectors, it was recorded as is shown in Figure 3. As it could be seen from Fig. 3, the MSE of the trained and predicted dataset firstly decrease largely as the value of C increases and remain constant when the value of C is 10 and above. The number of support vectors falls sharply and remain constant as C equals 5, it then increases when C was increased to 6 and remain constant throughout the value of C. From this result, 10 was chosen for the value of C.



(a)



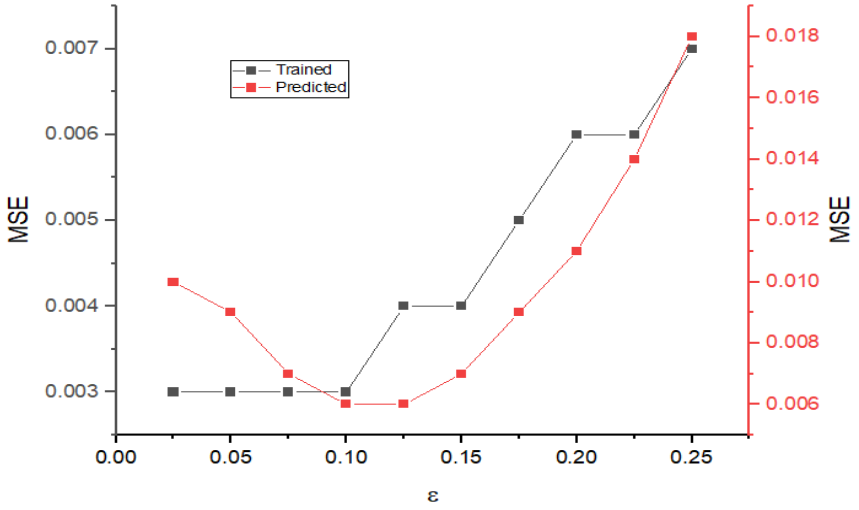
(b)

Figure 3: The result of various C, where Ɛ = 0.01: (a) MSE (b) nSV

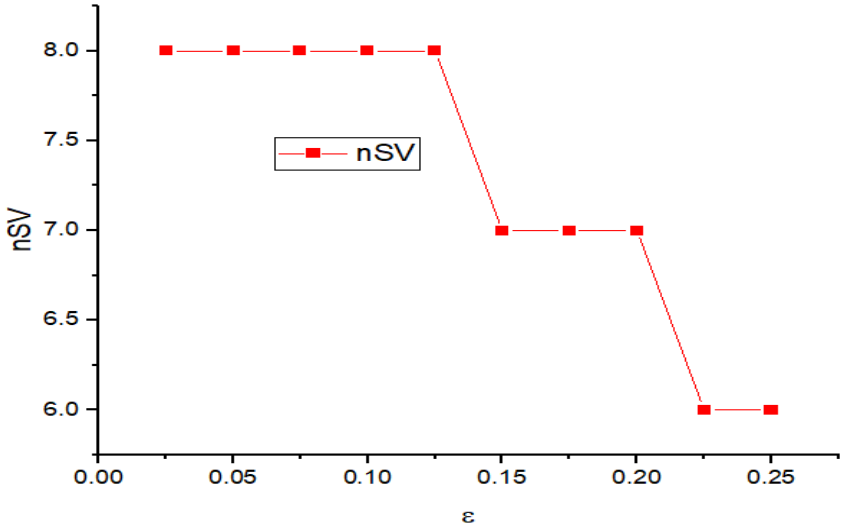
Selection of ε

The selection of ε is important as it influences the performance of the SVM model. When ε increases continuously, the ability of the model to learn the datasets decreases, the empirical risk

increases, while the ability of the model to predict the dataset decreases owing to insufficient learning by the model (Shao et al., 2020). For an optimal selection of ε, the C parameter was fixed at a constant value of 10 while ε was set at various values ranging between 0.025 and 0.25. The result while including the MSE of the trained and predicted data as well as the number of support vectors is shown in Figure 4. From Figure 4, it could be seen that the MSE value of the trained dataset remains constant at first followed by a steady and gently increase as the value increases above 0.1. The MSE value of the predicted dataset decreases slightly and reached a minimum at ε equals 0.1, it then increases slightly as e increases above 0.1. However, the number of vectors remain constant as E increased to 0.125, it was preceded by a sharp decrease in nSV when E increase from 0.125 to 0.15. Based on the value of prediction error as well as the number of vectors obtained in Fig 4., ε was chosen to be 0.1.



(a)



(b)

Figure 4: The result of various Ɛ, where C = 10: (a) MSE (b) nSV

3.5 Prediction of hydrolysis index using SVM

To predict the hydrolysis index of the gluten-free cookies, the dataset was divided into two in which 75% of the datasets were used to train the model while 25% was used in predicting the hydrolysis index of the cookie. Since the performance of the SVM model in predicting the hydrolysis index is dependent on the SVM parameter C and E, the parameters were set at their optimal value of 10 and 0.1 for C and E, respectively based on their MSE value. The predicted hydrolysis index was obtained using cross-validation and it is as presented in Table 4 while the coefficient of determinant, as well as the mean square of error of the SVM model, were 0.9658 and 0.004, respectively. These values confirm the feasibility and accuracy of the SVM model in predicting the hydrolysis index of the cookie.

Table 4: Predictive capability evaluation of RSM and SVM in predicting hydrolysis index

Parameters	**RSM**	**SVM**
R	0.9613	0.9658
R^2	0.9241	0.9329
Adjusted R^2	0.9172	0.9268
MSE	0.004	0.003
RMSE	0.063	0.059
AAD	0.067	0.083
SEP	0.112	0.105

3.6 Performance analysis of RSM and SVM model

The performance analysis of the RSM and SVM model in predicting the hydrolysis index of the gluten-free cookies was evaluated using correlation coefficient, R^2, adjusted R^2, MSE, RMSE, AAD and SEP. The result of the analysis observed showed that the R, $R^{2,}$ and adjusted R^2 were found to be sparingly higher in the SVM model compared to the RSM model (Table 4). The MSE, RSME, AAD and SEP were however found to be low for both models, however, the MSE, RMSE and SEP were low for the SVM model in comparison to the RSM model. This finding is an indication of the superiority of the support vector model in predicting the hydrolysis index of the gluten-free cookies over the response surface model. The superiority of the SVM model over RSM was further affirmed by plotting the actual experimental value, RSM and SVM predicted value against the experimental runs and it's shown in Figure 5. From the plot, it could be seen that the actual hydrolysis index values were superimposed on the predicted values obtained using the SVM model while RSM predicted values swerve away from the observed values.

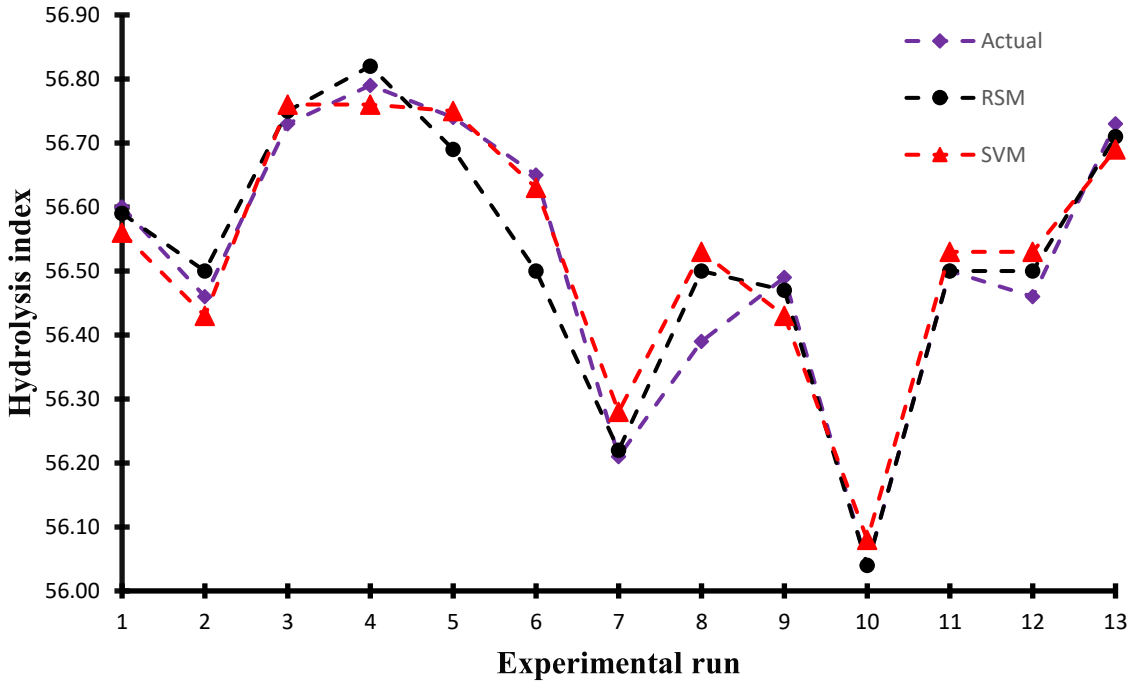


Fig. 5. Comparison between predicted HI (RSM and ANN) against experimental HI

4 Conclusion

In this study, the hydrolysis index of gluten-free cookies made from *cardaba* banana was statistically modelled using response surface methodology and support vector machine. The experimental design was based on a central composite design. The mathematical modelling revealed that both modelling approaches (response surface methodology and support vector machine) accurately predicted the hydrolysis index of the gluten-free cookies owing to their higher coefficient of determinant ($R^2 > 0.9$). The predictive capability assessment of response surface methodology and support vector machine revealed the superiority of the support vector machine in predicting the hydrolysis index of the gluten-free cookies over the response surface model. The result obtained is an indication that the flour and starch of under-utlized *cardaba* banana could served as an important raw material in the production of gluten-free cookies with low hydrolysis index for coeliac and diabetes patients.

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ORIGINAL RESEARCH ARTICLE

Modifying cooking banana starch using octenyl succinic anhydride improves the amylose-amylopectin ratio of starch. A chemometrics approach.

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Abstract

The disadvantage posed by native starch during food application had led to starch modification using physical or chemical techniques. This research therefore, aimed at modelling and optimizing the amylose-amylopectin ratio of modified cooking banana starch using chemometrics approach (response surface methodology). This was done by varying different concentration of octenyl succinate anhydride concentration (3-5%), reaction time (30-60 mins) and pH (8-10) using Box-Behnken design. The result obtained revealed the significance and accuracy of the model in predicting the amylose-amylopectin ratio of the modified starch owing to its low p-value ($p < 0.001$) and high coefficient of determinant ($R^2 > 0.97$). The adequate precision value greater than 4 was an indication that the model can navigate within the design space. Finally, an optimal value of 3.32% octenyl succinate anhydride concentration, reaction time of 32.04 mins and substrate pH of 8 was obtained which resulted in predicted amylose-amylopectin ratio of 0.806.

Keywords*: Amylose-amylopectin ratio; modified starch; chemometrics; cooking banana*

1. Introduction

The increasing world population has compelled the need for food processors and manufacturers to explore underutilized plants that serve as a rich starch sources. Native starch has existing disadvantages in its functionality such as its disposition to retrogradation and less stability to thermal and mechanical treatment (Cahyana et al., 2019) which deters its use for varieties of applications in food. This, however, calls for an absolute requirement for the exploration of specific technologies to modify starch properties.

Starch functions as an important food reserve in plants and it is a principal component of the majority of storage organs in tubers, legumes, cereal grains. It is commonly utilized for various applications such as in food additives typically as thickeners together with stabilizers, in pharmaceutical industries as a source of energy in addition to its use in the production of ethanol as well as gel (Khawas & Deka, 2017). It forms a major dietary constituent in all human populace contributing to the structure (viscosity or texture) of a great range of foods produced on a large scale and for home use. Starch, a carbohydrate, comprises a considerable extensive number of units of glucose which are connected by glycosidic bond (Sonthalia & Sikdar, 2015). The functionality of starch is related to two (2) significant-high molecular weight constituents of carbohydrates; amylose (a soluble linear polymer) and amylopectin (an insoluble extremely branched polymer), in addition to the organization of these two large molecules.

Modification of starch functionality attributes using octenyl succinic anhydride (OSA) enhances characteristics such as solubility, its nutritional, stabilizing, swelling power, thermal, rheology, encapsulating, interfacial and pasting characteristics (subject to the ratio of amylose to amylopectin) (Sweedman et al., 2013). The amylose-amylopectin ratio plays a major role in the interaction of starch and water. Reddy et al. (2015) reported that peak viscosity among different banana cultivars was a function of leaching of amylose, granules swelling and amylose-amylopectin ratio. They also concluded that the thermal properties of banana starch may be subject to starch granule distribution, extraction procedure and the complexes of amylose-amylopectin.

The amylose-amylopectin ratio of starch has a significant outcome on the modification of starch physical and chemical properties such as solubility, syneresis, texture, retrogradation, gelatinization, viscosity, texture and water retention which are important standards of choice selection of suitable food products from starch (Karakelle et al., 2020). This limitations in solubility of native starches in water result in restrictions in their industrial usage, hence the need for their modifications to change their structure by hydrolyzing them into smaller molecules. OSA starch (the resulting starch after esterification with octenyl succinic anhydride) has had wide usage industrially especially as an additive in food and also as a replacement for diverse food substances such as emulsifiers, proteins, fats and gum arabic (Sweedman et al., 2013). Biopolymers, which can be employed as emulsion stabilizers in varieties of products are usually produced from this chemical modification.

Different modifications on banana, which is an efficacious starch source have been studied by several researchers. Industrially, banana starch in its native form has various setbacks such as reduced heat stability as well as the tendency towards retrogradation (Cahyana et al., 2019), hence, the need for physical, chemical or enzymatic modification. Banana starch modification can be achieved by modifying conditions of the environment such as atmosphere and temperature for shelf-life extension. Adiyanti and Subroto (2020) reported that OSA banana starch can serve as a stabilizing agent in emulsions increasing hydrophobic properties. Asides from its usefulness as a stabilizing agent in emulsions, banana starch that has been modified also possesses increased elastic characteristics in comparison to its native starch. These researchers compared the properties of native banana starch and modified starch and reported changes in the structure of amylose content, digestibility, starch granules and crystal structure as well as emulsifying properties of modified banana starch. Quintero-Castaño et al. (2020) also characterized the physical, chemical, structural, morphological and functional properties of starch modification from Gros Michel banana. They concluded an alteration in the ratio of amylose-amylopectin after modification.

However, for optimal response during the modification process, there is a need for an application of chemometrics tools such as response surface methodology, artificial neural network or other machine learning algorithms. Chemometrics is the application of statistic and mathematical modeling to chemical data. This approach especially optimization techniques had gain wide application in food processes. Akande et al. (2017) use the approach in optimizing extrusion process during the production of amaranth-based porridge. Fasuan et al. (2018) in their own research uses the approach in the modification of amaranth starch for its suitability as functional ingredient in mayonnaise production. Although, this approach had been widely used, it's application in production of starch from cooking banana with high amylose-amylopectin ratio is scanty hence the aim of this research.

2. Materials and methods

The cardaba banana used for this research was obtained from the teaching and research farm of Obafemi Awolowo University Ile-Ife, Nigeria. Chemicals used for the analysis were obtained from Sigma-Aldrich, U.S.A.

2.1. Starch extraction

The extraction of the cardaba banana starch was carried out using the method of Olawoye et al. (2020a). Briefly, the cardaba banana was de-bunched, washed and subsequently peeled underwater to avoid enzymatic browning of the banana. After peeling, the banana was cut into small sizes and wet-milled using a Stephan milling machine (Germany). Following milling, water was added to the banana mash obtained in the ratio of 1:10 (w/v) (is it weight : volume or volume: volume?) and was subsequently passed through 200 μm sieves to obtained a whitish starch slurry. The starch slurry was left to stay for 6 hours to allow the starch to settle down. This was followed by washing the starch three times with water and allowing it to settle down. After, the final washing, the starch slurry was made to stay overnight, after which the water was decanted and the starch obtained was dried at 45 ℃ for 8 hours. the dried starch was pulverized and packaged in an airtight container before modification and analysis.

2.2. Starch modification

The modification of cardaba banana starch using octenyl succinate anhydride was carried out following experimental design using the method described by Olawoye and Gbadamosi (2020).

2.3. Experimental design

The experimental design for the modification process was carried out using a three-factor Box-Behnken design. The three factors and levels considered for the modification process are succinate anhydride (2-5%), time of modification (30-60 mins) and pH of the substrate (8-10). The response measure after the modification process was the amylose-amylopectin ratio. In the experimental design, a 12-factorial design and 5 centre points were generated. After the experimental design, a second-order polynomial model (Eq. 1) was fitted to determine the relationship between the independent variables and experimental response. The goodness of fit of the experimental model was evaluated using analysis of variance (ANOVA) while the effects of the various model terms coupled with their interaction were evaluated using the Pareto chart. The Box-Behnken design of the response surface methodology was performed using Design Expert 13.0.1 (State-Ease Inc., Minneapolis, U.S.A.).

$$Y = b_0 + \sum_{i=1}^{k} b_i X_i + \sum_{i=1}^{k} b_{ii} X^2{}_i + \sum_{i<j}^{k} b_{ij} X_i X_j + e \quad (1)$$

Where Y is the response variable (amylose-amylopectin ratio), b_0 is the intercept value, b_i (I = 1, 2, ….k) is the first-order model coefficient, b_{ij} is the interaction effect, and b_{ii} represents the quadratic coefficient of X_i. X_i and X_j are the independent variables that affect the dependent (response) variables and e represents the random error.

2.4. Amylose content determination

The amylose content of the modified starches was determined following the method described by Nwokocha et al. (2011). Briefly, 1ml of 95% ethanol was dispersed into a test tube already containing 0.1 g (dry basis) of modified cardaba banana starch followed by the addition of 9ml of 1M NaOH solution. The mixture was vortexed and heated in a hot water bath at 45 ℃ for 10 mins for the solubilization and gelatinization of the starch. After heating, the gelatinized starch was transferred into a 100 ml volumetric flask and was filled to mark using distilled water. From the starch solution, 5 ml was taken and dispensed into a 100 ml conical flask and 1 ml of 1 M acetic

acid as well as 2 ml of iodine solution (0.2 g I_2/2 g KI). The solution made up to 100 ml using distilled water and was allowed to stay for 20 mins for colour development. The absorbance of the solution in a 1 cm cuvette was read using a UV-Vis spectrophotometer at 620 nm. Iodine solution devoid of starch was used in the reference cell. Potato amylose with the concentration range of 10 - 50 mg was used for the preparation of the calibration curve from whence the amylose content of the modified cardaba banana starch was obtained through extrapolation.

The blue value of the modified starch was calculated using the equation below.

$$\boldsymbol{Blue\ value\ (BV)} = \frac{\boldsymbol{maximum\ absorbance \times 4}}{\boldsymbol{starch\ concentration\ (\frac{mg}{dl})}} \quad (2)$$

$$\%\boldsymbol{Amylose} = \boldsymbol{110.78 \times BV - 24.481} \quad (3)$$

$$\%\boldsymbol{Amylopectin} = \boldsymbol{100 - \%Amylose} \quad (4)$$

$$\boldsymbol{Amylose : Amylopectin} = \frac{\%\ \boldsymbol{Amylose}}{\%\ \boldsymbol{Amylopectin}} \quad (5)$$

3. Result and discussion

The result of the experimental design using Box-Behnken design (BBD) for the amylose-amylopectin ratio of the modified starch is shown in Table 1. As shown in the table, the amylose to amylopectin ratio of the starch varied between 0.26 and 0.80 for observed value while the predicted value range between 0.23 - 0.79.

Table 1. Experimental and predicted values of slowly digestible starch

	Independent variable			Amylose-amylopectin ratio	
EXP. Run	Succinate Concentration (%)	Time (min)	pH	Actual	Predicted
1	3	45	10	0.68	0.70
2	4	45	9	0.60	0.64
3	3	60	9	0.26	0.23
4	4	60	10	0.56	0.58
5	4	60	8	0.47	0.49
6	4	45	9	0.66	0.64
7	4	45	9	0.68	0.64
8	4	30	10	0.80	0.79
9	4	45	9	0.63	0.64
10	5	30	9	0.43	0.46
11	5	45	8	0.64	0.63
12	4	45	9	0.64	0.64
13	5	45	10	0.74	0.72
14	3	30	9	0.67	0.67
15	5	60	9	0.42	0.42
16	4	30	8	0.78	0.76
17	3	45	8	0.66	0.67

To describe the relationship between the experimental factors (succinate concentration, substrate pH and time) as well as the response (amylose-amylopectin ratio), the ratio of the amylose to

amylopectin was fitted using a quadratic regression model as shown in equation 6 below. As shown in equation 2, A, B, and C represent the moisture content, temperature and time, respectively.

$$\boldsymbol{AM: AMY = 0.64 + 0.006A - 0.12B + 0.03C + 0.10AB + 0.02AC + 0.002BC - 0.09A^2 - 0.11B^2 + 0.12C^2} \quad (6)$$

The ANOVA result of the model revealed that the statistical model for the resistant starch is significant owing to its low p-value (<0.0001) and its high Fisher test value (33.19). The result also revealed that among all the terms, the linear term of succinate concentration, the interaction term of succinate concentration and pH as well as interaction term of time and pH were not significant. Among the terms, it could be observed that the linear term of the reaction time was the most significant, evidence of its high F-value (112.01). The lack of fit which is the measure of the accuracy of the polynomial model is 0.3810. The non-significance of the lack of fit is an affirmation of the accuracy of the model. The quality of the model was examined and Table 2. shows the model quality parameter. As it could be seen from the result, the adequate precision which measures and compares the difference between experimental and predicted values was 30.17. According to Olawoye et al. (2020b), an adequate precision ratio greater than 4 is desirable and hence affirmed the accuracy of the model and it also indicates that the experimental model could be used to navigate the design space. The ability of the model to accurately fit the experimental data was determined by evaluating the coefficient of determinant (R^2) (Olawoye and Kadiri, 2016). According to the result presented in Table 2, the R^2 is 0.9771 which is an indication that 97.71% of the variation in the experimental data for the amylose-amylopectin ratio is acclaimed to the independent variables while 2.29% of the variation can't be explained by the experimental model.

The relationship between the experimental response (amylose-amylopectin ratio), as well as the model terms, is shown in the Pareto chart (Fig. 1) below. From the Pareto chart, it could be seen that among the model terms, the linear terms of succinate concentration and time as well as the quadratic term of pH had a negative value and hence, a negative synergistic effect of the model terms on the experimental response. Also, it could be seen that the Interaction terms AC and BC, as well as the linear term of succinate concentration, are below the reference red line which indicates their insignificance in predicting the experimental response.

Table 2: Regression analysis of Amylose-amylopectin ratio

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.3119	9	0.0347	33.19	< 0.0001	significant
A-Succinate Concentration	0.0003	1	0.0003	0.2850	0.6100	
B-Time	0.1169	1	0.1169	112.01	< 0.0001	
C-Ph	0.0071	1	0.0071	6.80	0.0350	
AB	0.0412	1	0.0412	39.46	0.0004	
AC	0.0014	1	0.0014	1.29	0.2927	
BC	0.0011	1	0.0011	1.08	0.3330	
A^2	0.0320	1	0.0320	30.68	0.0009	
B^2	0.0525	1	0.0525	50.24	0.0002	
C^2	0.0656	1	0.0656	62.81	< 0.0001	
Residual	0.0073	7	0.0010			
Lack of Fit	0.0037	3	0.0012	1.33	0.3810	not significant
Adeq Precision	22.68					
C.V. %	5.33					
R^2	0.9771					
Adjusted R^2	0.9477					
Predicted R^2	0.7989					

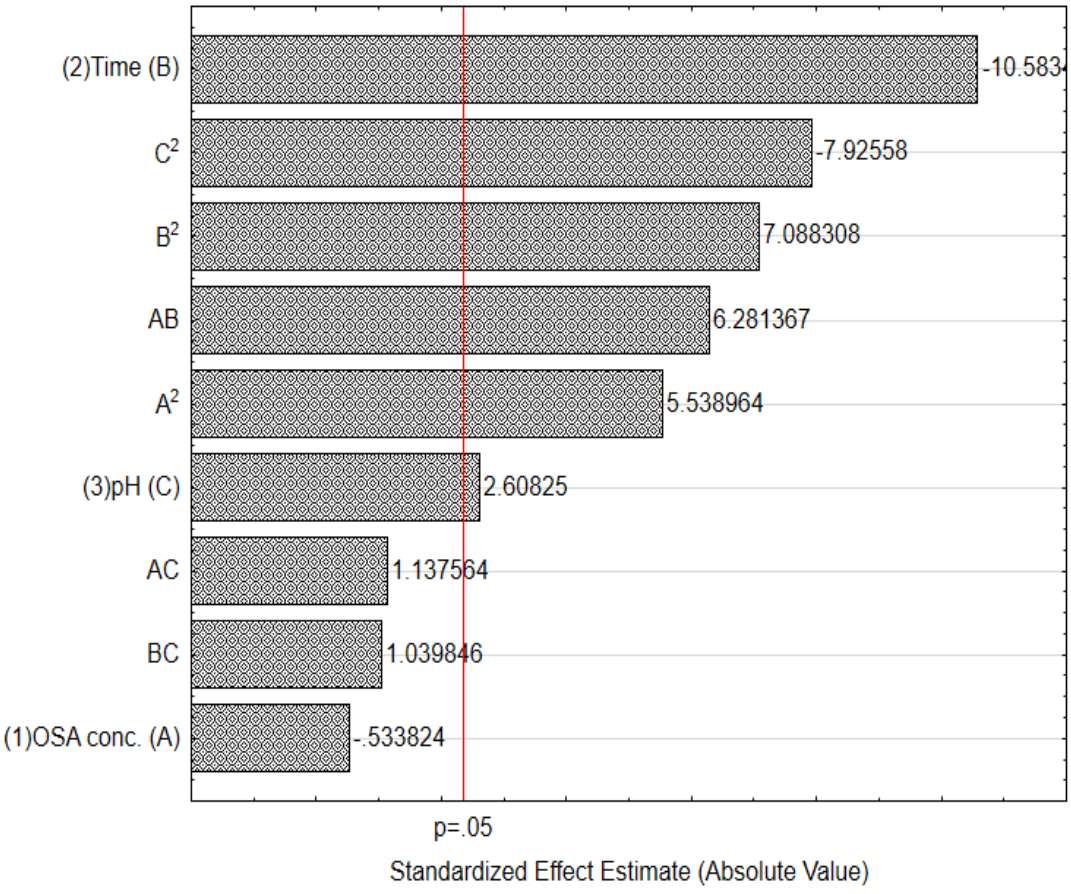

Figure 1: Pareto chart showing the effects of model terms on Amylose-amylopectin ratio

3.1. Diagnostic effect of the experimental model

A diagnostic plot which determines the quality of the developed model on the residuals is presented in Figure 2 (a-d). Figure 2 (a) depicts the plot of a normal probability distribution of the residuals. According to Olawoye et al. (2020c), a studentized residual followed a normal distribution if a straight line is being formed, which commensurate with the findings of the research. In the case an S-shape is formed, the studentized residuals do not follow a normal distribution and hence there is a need for the transformation of the experimental data. Figure 2(b) denote the plot of the studentized residuals against the amylose-amylopectin ratio. As shown in the plot, there is random scattering of the data which is an indication that the response does not contribute to the variation of the experimental data and hence, the accuracy of the model in predicting the experimental process. The outlier t plot which is used to check if there is an outlier in the experimental process as a result of a large residual is shown in Figure 2(c). The plot ranged between a standard deviation of 3, any plot that falls above or below this limit is an indication of experimental error or an outlier in the experimental data. The findings in this study indicate that the plot is within the limit and hence, no studentized residuals variation due to outlier. Finally, the plot of the actual amylose-amylopectin ratio against the predicted value is shown in Figure 2(d). The alignment of the points (values) along the straight line is an indication of the goodness of fit of the model. Where the points are far away from the line or are scattered along the plot, then there exists an experimental error in the model used.

3.2. Effect of processing variables on the amylose-amylopectin ratio

The relationship between the processing parameters and the amylose-amylopectin was examined by plotting the 3-D response surface plot while keeping one independent factor at its centre point. Figure 3(a) shows the interactive effects of reaction time and succinate anhydride concentration while the pH is constant. The plot revealed that the maximum amylose-amylopectin ratio could be obtained within the space of the experimental design. As it could be seen from the surface plot, the succinate anhydride concentration had a linear effect on the response. An increase in the succinate concentration initially had an increasing effect on the amylose-amylopectin ratio, however, an increase in the Succinate anhydride concentration above 4.25% led to an insignificant decrease in the amylose-amylopectin ratio of the modified starch. The reaction time on the other hand had a quadratic effect on the response. Its increase from 25 - 40 mins resulted in a slight increase in the amylose-amylopectin ratio, an increase above 40 mins caused a significant decrease in the amylose-amylopectin ratio of the modified starch. The decrease in the amylose-pectin ratio observed as a result of an increase in the reaction time could be due to the leaching of amylose due to lengthening minutes. For maximum response, the reaction time was 37 mins at a succinate anhydride concentration of 4.1%. The effect of the pH of the substrate coupled with succinate anhydride concentration on the amylose-amylopectin ratio of the modified starch while keeping the reaction time constant is shown in Figure 3b. The result revealed that increasing the pH of the substrate up to 9.2 resulted in a decrease in the response. There exists a significant increase as the pH of the substrate progresses above 9.2. Increasing the succinate anhydride to a concentration of 4.2 caused an increase in the amylose-amylopectin reaction of the starch. Above 4.2 however, led to a significant decrease in the response. A combined effect of both modification parameters revealed that a succinate anhydride concentration of 4.1 coupled with maximum modification pH results in maximum amylose-amylopectin ratio. The simultaneous effect of the modification pH and time of modification on the amylose-amylopectin ratio is shown in Figure 3. (c). There exists a slight decrease in the response as the pH increases to 9.2 which further reduces as the pH increases above 9.2. The time of modification causes a slight but non-significant increase in the response when it increases from 25-41 mins, above this time, it was observed that the amylose-amylopectin ratio decreased significantly. As seen in the plot, the maximum amylose-amylopectin ratio was obtained when the time of modification was 40 min at a maximum pH.

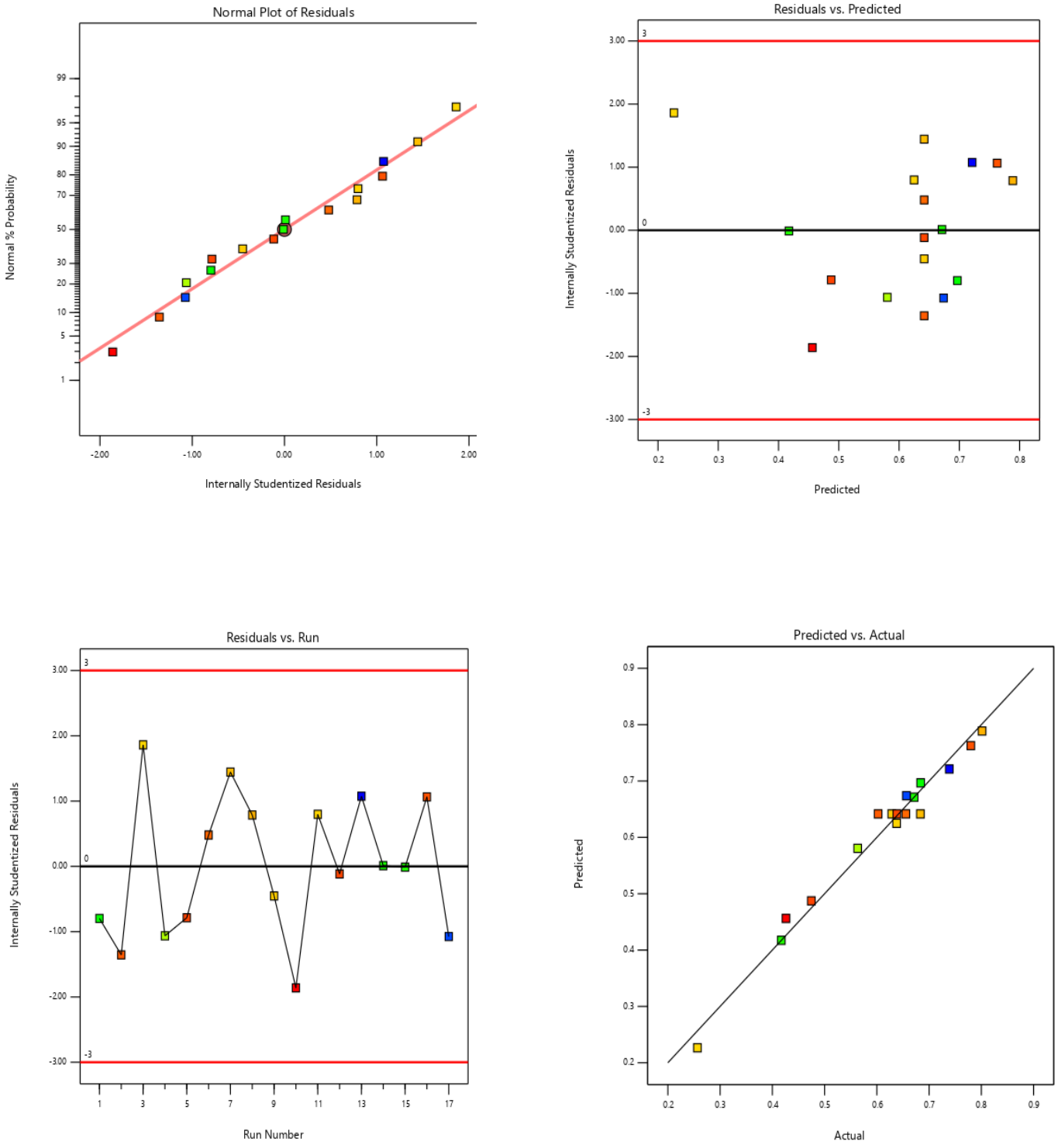

Figure 2: Diagnosis analysis of the model: (a) Normal Distribution Plot; (b) Studentized Residual and Predicted Amylose-amylopectin ratio Plot; (c) The Outlier t Plot; (d) Predicted vs actual value plot.

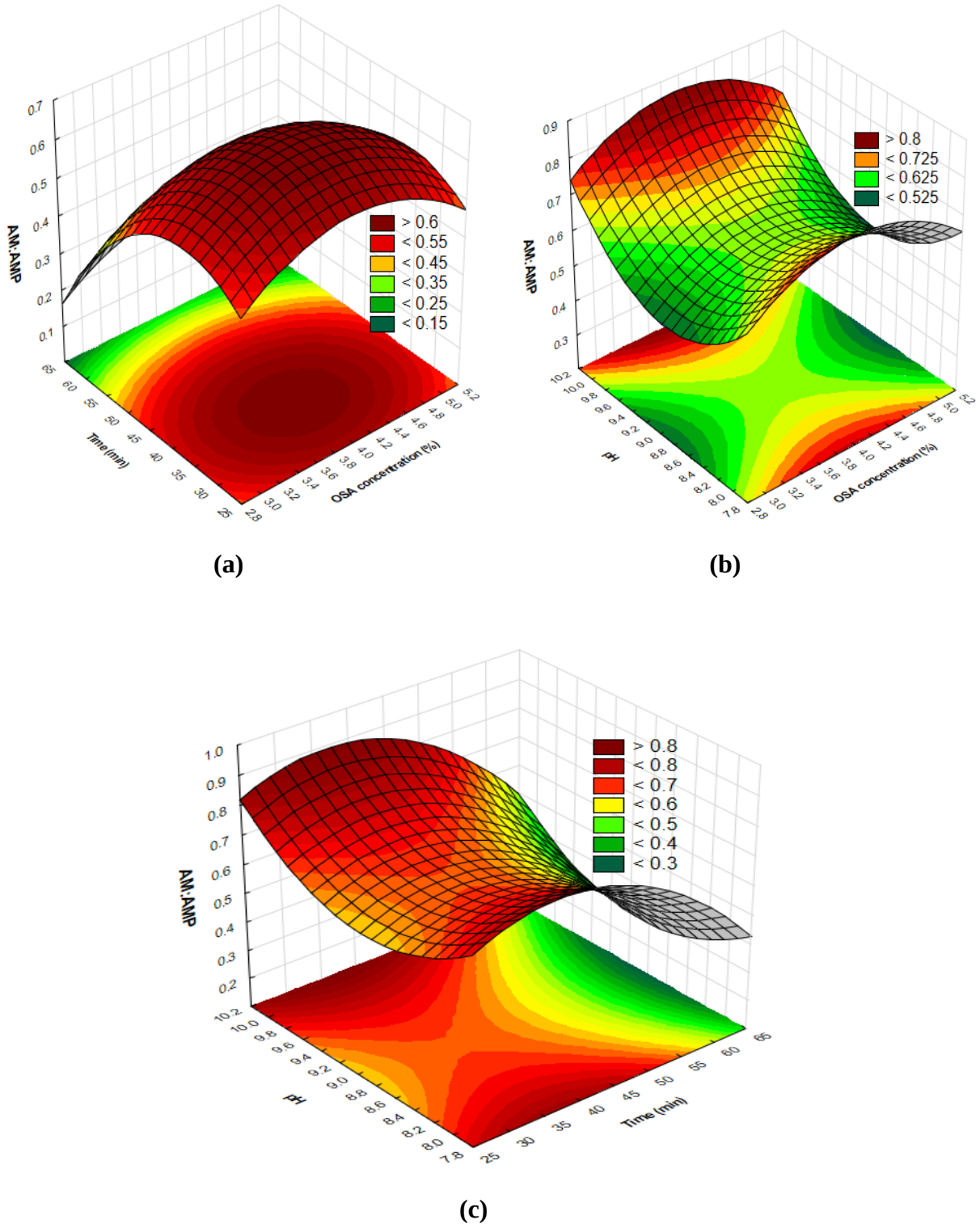

Figure 3: Effects of succinate anhydride concentration, modification time and pH on amylose-amylopectin ratio

3.3. Optimization of the process parameters

The processing variables which were succinate anhydride concentration, reaction time and pH of modification were optimized to obtain modified starch with maximum amylose-amylopectin ratio using response surface methodology. The processing parameter's goal was set in range while the amylose-amylopectin ratio was set at maximum. The optimal conditions obtained were succinate

anhydride concentration of 3.32%, the reaction time of 32.04 mins and substrate pH of 8. The predicted amylose-amylopectin ratio at the optimal conditions was 0.806. The predicted response by the modelling techniques was further validated by carrying out an experiment in triplicate based on the optimal condition. The result of the amylose-amylopectin ratio obtained from the experimentation was 0.812 which affirmed the accuracy of the optimization process.

4. Conclusion

In this study, octenyl succinate anhydride was used in the modification of cooking banana starch. For the maximization of the amylose-amylopectin ratio of the starch, the process variables such as the succinate anhydride concentration, modification time as well as the pH were optimized using RSM (a chemometric approach). The experimental model used (second-order polynomial model) accurately predict the amylose-amylopectin ratio owing to its high coefficient of determinant (R^2) as well as high adequate precision. For amylose-amylopectin maximization, the optimal process variables conditions were succinate anhydride concentration of 3.32%, reaction time of 32.04 mins and substrate pH of 8. The predicted amylose-amylopectin ratio at the optimal conditions was 0.806. The revealed the suitability of the chemometric approach in predicting and optimizing the amylose-amylopectin ratio.

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ORIGINAL RESEARCH ARTICLE

Potentials of microcrystalline cellulose prepared from wood dusts wastes of *Ficus Platyphyla, Planatus Occidentalis* and *Gmelina Aborea*

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Abstract

This research aims to prepare microcrystalline cellulose (MCCs) from native cellulosic wastes in order to find potential applications for each of the tree species. The physico-chemical characteristics of the MCCs were studied using physical and spectroscopic techniques. Acid hydrolysis in 2M HCl was used for the preparation of microcrystalline cellulose (MCC) obtained from agricultural waste sample, *Gmelina aborea (GA) Ficus platyphyla* (FP) and *Planatus occidentalis* (PO) wood dust. The MCCs obtained were off-white and powdery in appearance. The yield of MCCs were 67.55% for *Ficus platyphyla*, 77.00% *Planatus occidentalis* and 80% for *Gmelina Aborea* (GA). The functional groups in the MCC samples were confirmed by the Fourier transform infrared (FTIR) spectroscopic method with characteristic absorption bands of ;–OH stretching at 3416 cm^{-1}; C-H stretching at 2918 cm^{-1}; -OH bending at1377 cm^{-1};, 1159 cm^{-1}; and C-O-C pyranose ring skeletal vibrations at 1026-1033 cm^{-1}, with crystallinity absorption bands showing up at 1432 and 850 cm^{-1} respectively. The thermal stabilities were determined from Thermogravimetric Analysis (TGA) and showed that the MCC samples are thermally stable (50% weight loss at **450^{O}C** or PO, 50% weight loss **470^{O}C** for FP and 50% weight loss at **590^{O}C** for GA). The characteristic morphological features were established by scanning electron micrograph (SEM) and the crystallinity of the microcrystalline cellulose were further confirmed using the X-Ray Diffraction (X-RD) technique which showed three main reflections at 2θ=14.70°, 22.09° and 34.24°, this therefore indicates microcrystalline cellulose were cellulose I type and that acid pretreatment did not affect the structure of the MCC. The crystallinity index values were 69.4, 68.7 and 79.6 for FP, PO and GM MCCs and respectively. The Samples were tested for pH, Moisture content, Hydration and swelling capacities as well. These results showed that the wood dusts form the tree species are good potential sources of high-grade cellulose which can serve as useful starting materials for further processing and applications.

Keywords: *Cellulose, Microcrystalline cellulose, Physico-Chemical and Spectroscopic Characterizations*

Introduction

One of the major sources of pollution in the environment especially in the developing countries is the agricultural wastes. In order to minimize or control the negative impact of these wastes on human and animals, turning them into finished product that would serve as a source of income to man which in turn would reduce the rate at which the wastes liters the environment, is very crucial.(1). Several attempts such as their usage as sources of activated carbon for high

performance capacitors(2), composting for multiple agricultural sources(3), Enzymes (4), applications in bio medicals(5), Pharmaceuticals(6), Cosmetics and food industries (7) have been made into their conversion to useful materials. Most of these agricultural wastes are either by-product of forestry, agricultural crops, animals, microorganisms, as well as domestic and industrial practices such as food processing, wood and rice milling.(8). Examples of these agricultural wastes include, rice husk, corncobs, wood dusts, cow and chicken dungs, kitchen wastes(9), the numbers are numerous. It is worthy of note, that most of these wastes especially the plant and micro-organism-based ones are composed mainly of cellulose (9).

Cellulose is one of the most abundant and most useful polymers on earth owing to their availability in reasonable percentages in plant and **some** micro-organisms such as the oocyte bacteria. It's been estimated that cotton which contains the purest and largest percentage of cellulose has close to 99% cellulose composition. Hard wood contains about 50%, soft wood about 45% while other plant parts can contain as much as 30%. Usually, celluloses are found in combination with other components such as the Lignin and Hemicelluloses (9).

Cellulose and its numerous derivatives have been used for several applications due to the special qualities which includes, biocompatibility, good mechanical properties, high thermal properties, low density as well very good tunable properties (10). The amorphous part of cellulose can be broken down by hydrolysis to obtain Micro or Nano crystalline form of cellulose depending on the duration of hydrolysis to obtain cellulose materials with higher thermal properties due to their well-ordered crystalline nature. The importance of cellulose in its various forms cannot be overemphasized as it has found its way into all areas of life and it is being projected to replace most of the non-biodegradable petroleum feed stocks in the future.(11). The practice of processing cellulose from **agricultural** or industrial wastes into useful raw materials can be summarized as " **Taking abandoned materials from nature, processing it, and giving it back to nature in a better form for the benefit of man**". This work therefore seeks to contribute to the reduction of wastes in the environment by focusing on the treatment of cellulosic wastes and converting them into useful raw materials for better applications.

Methods

Materials, Reagents And Solvents

Materials used in this research is the Native cellulosic wastes. Solvents and Reagents were purchased from Central Drug House (CDH) Mumbai, India are were of analytical grade and used without further purification. They include: 98% Ethanol, distilled water, potassium bromide (KBr), Sublimated Iodine (I_2), Potassium Hydroxide (KOH), Sodium chlorite (NaOCl), Hydrochloric acid (HCl) and Acetic acid (CH_3COOH).

Sample Collection

The Cellulosic wastes were collected at a wood milling factory in Kwara state, North central region of Nigeria. The tree species were identified by the factory workers and documented immediately at the site of collection in their local names. Their botanical names were subsequently sourced from the internet and confirmed at the **herbarium** of the University of Ilorin, Ilorin, Nigeria.

Extraction and Purification of Alpha Cellulose

The method employed by Arowona *et al.*, 2018 **(12)** was adopted in the isolation of cellulose as well as the preparation of MCCs with slight modifications. In this method;

A 100 g of the sample was weighed and transferred into a 2L quick fit flask containing a 1L solution of 200 g sodium chlorite adjusted to a pH 4.0 using 10% acetic acid and stirred under

reflux at 75^{O}C for 3 *h*. The resulting solution was filtered, the residue was washed with distilled water and ethanol **(98%)** until its pH became neutral, and then dried in an oven at 60^{O}C for 5 *h*. Afterwards, the dried residue was treated with 10% potassium hydroxide for 6 *h* to complete the delignification process. The cellulose obtained was washed with distilled water and ethanol and dried for 3 *h* at 60^{O}C. Thereafter, it was treated with Sodium hypochlorite, washed with distilled water and ethanol and dried in an oven at 80^{O}C for 6 *h* to get rid of excess water that might be trapped in the cellulose backbone. The cellulose was blended to obtain a smooth powdery texture, weighed and stored for further treatment.

Preparation of Microcrystalline Cellulose

Known quantity of alpha cellulose obtained above was transferred into a quick fit flask and 500 mL of 2 M HCl was added and then refluxed at 60^{O}C for 3 *h*. The microcrystalline cellulose obtained was then washed with distilled water and ethanol, dried in the oven, blended, weighed and then stored for further characterization.

Starch Test

A 0.1g amount of each **sample** were placed in 50mLs beaker, about 5mLs of iodine solution was added to each sample. For comparison**,** 0.1g of starch was also placed in separate 50mLs beaker and the same quantity of iodine solution was added. Absence of blue-black coloration means positive result **for cellulose**.

ph Determination

Exactly **0.2g** each of the samples **was** placed in a 10ml clean measuring cylinder. Few mLs of distilled water was added to the samples, shaken together and the volume of the sample and water were made up to 10 **mLs.** The mixture was left to settle and the pH of the supernatant liquid were taken with a digital pH meter.

Moisture Content

About 1g each of the samples were placed independently in a white porcelain crucible with cover. The samples were dried in an oven for 3hrs at 105ºC. During drying, the weight of the samples was taken at 30 min intervals until constant weight was obtained. The moisture content was calculated using the equation proposed by Kharismi *et. al*, 2018:(7)

$$\frac{\{(\boldsymbol{A}-\boldsymbol{B})\}}{\boldsymbol{A}} * \mathbf{100} - - - - - - - - - - (\mathbf{1})$$

A= initial weight of MCC, B= final weight of MCC after drying

Swelling Capacity (Sc)

A desired amount of the samples were placed in a measuring cylinder of known volume. The measuring cylinder was tapped until there was no further increase in volume. This volume was noted as V**t** . A dispersion of the powder was made by adding water up to the highest mark on the cylinder. The measuring cylinder was left undisturbed for 24hrs and the volume of the sample sediment was noted as V**s**. The swelling capacity, Sc. was calculated using the equation:

$$\boldsymbol{Sc} = \frac{\boldsymbol{Vs}-\boldsymbol{Vt}}{\boldsymbol{Vt}} - - - - - - - - - (\mathbf{2})$$

Sc. = Swelling Capacity; Vs = Volume after Swelling; Vt = Tapped volume

Fourier Transform Infrared Spectroscopy (Ftir)

The FT-IR spectroscopy was used to identify the chemical composition of each sample by defining the functional groups. To achieve this, **a 25mg** sample of dried cellulose and microcrystalline

cellulose (MCC) samples were mixed with potassium bromide (1:90) and compressed into transparent tablets using a hydraulic press (M-15, Technosearch) to enable electromagnetic radiation to pass through easily. Then, in the range of 4000–400 cm^{-1}, the FT-IR machine, (ALPHA-II, Bruker, Germany) was used to analyze the transparent tablets.

Scanning Electron Microscopy (Sem)

Surface morphology of the cellulose fibers and metal oxides composites was investigated using Phenom ProX Scanning Electron Microscopy, USA. Before the analysis, the composites were sputtered with thin gold layer to avoid electrostatic charging during examination. The micrographs with a magnification of 500 times were obtained by back scattered electron detector (BSE) in order to register both topography and compositional contrast.

Thermogravimetric Analysis/ Differential Thermal Analysis (Tga/Dta)

The TGA machine, STA449 F3, Netzsch, Germany was used to determine the degradation temperature and weight loss (TGA and DTA) of the samples under a nitrogen atmosphere (40 mL/min), while heating at 10 °C/min from 25 °C to 800 °C. The weight loss (%) was evaluated by measuring the residual weight at 800 °C.

X-Ray Diffraction (Xrd) Spectroscopy

The degree of crystallinity of the MCC samples were determined using X-Ray Diffractometer machine **(PANalytical, X'pert PRO, Netherlands)** powered by a 40 kilovolt X-Ray generator at an input of 30Ma with Cu K alpha radiation.

Results and Discussion

Appearance

The cellulose obtained were white to off white in color with smooth to rough appearance while the microcrystalline cellulose obtained were smooth white to off white fine powder. The appearances of the cellulose samples are due to the presence of both the amorphous and crystalline region while MCC samples appeared smooth due to the breakdown of the amorphous region of cellulose leaving behind fine powdery crystalline region.

Starch

There was an immediate change of colour of the starch sample to deep black while the colours of the MCC samples remained the same (brown) in iodine solution. Iodine coloration disappeared from the cellulose samples after about 20 min while the blue-black coloration of the starch sample persisted. This result show that starch was completely absent in the samples.

Figure 1a: Appearance of cellulose and starch in iodine solution

Figure 1b: Disappearance of Iodine from cellulose solution after about 30mins

pH, Moisture Content and Swelling Capacity

The pH is the measure of neutrality, acidity or basicity of samples. The pH of pure MCCs should fall within the standard values of 6-7.5 (13). The moisture content indicates the amount of water the MCCs are able to absorb from the atmosphere. The lesser the moisture content, the better is the suitability of the MCC to be used as excipient. The swelling capacities of a sample is the increase in volume of water taken up by sample after absorption. The values obtained in this research falls within the standard range of less than 7% as reported by Kharismi and Suryadi (7). The results of the pH for the samples showed that they are neutral and falls within the 6-7.5 standard acceptable limit values for pH of neutral MCCs (13). Comparing the results of the three different samples, *Gmelina aborea* MCC had the highest pH value and this is connected to its highest water holding capability which was evident in its moisture content and swelling capacity values as compared to others. Therefore, pH of MCC samples can be said to be affected by the amount of water held in the sample provided there are no anionic or cationic materials embedded in the molecule backbone.

Table 1: Table showing the pH, Moisture content and Swelling Capacities of the MCCs

S/No	SAMPLE	pH values	Moisture content	Swelling capacity
1.	Gmelina	6.98	11.70	122.22
2.	Ficus	6.53	03.00	027.8
3.	Planatus	6.17	08.40	045.45

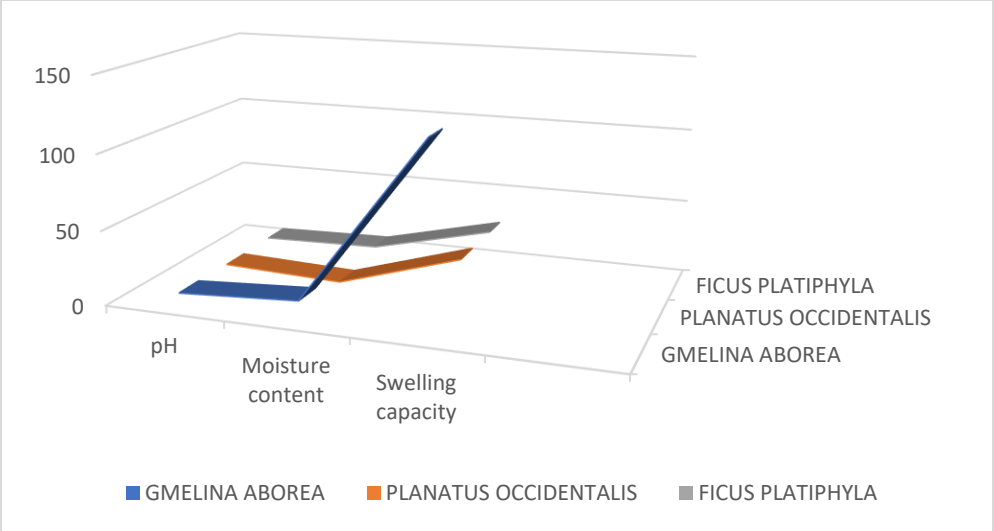


Figure 2: Relationship between pH, Moisture content and Swelling capacities of MCC samples

Fourier Transform Infrared Spectroscopy

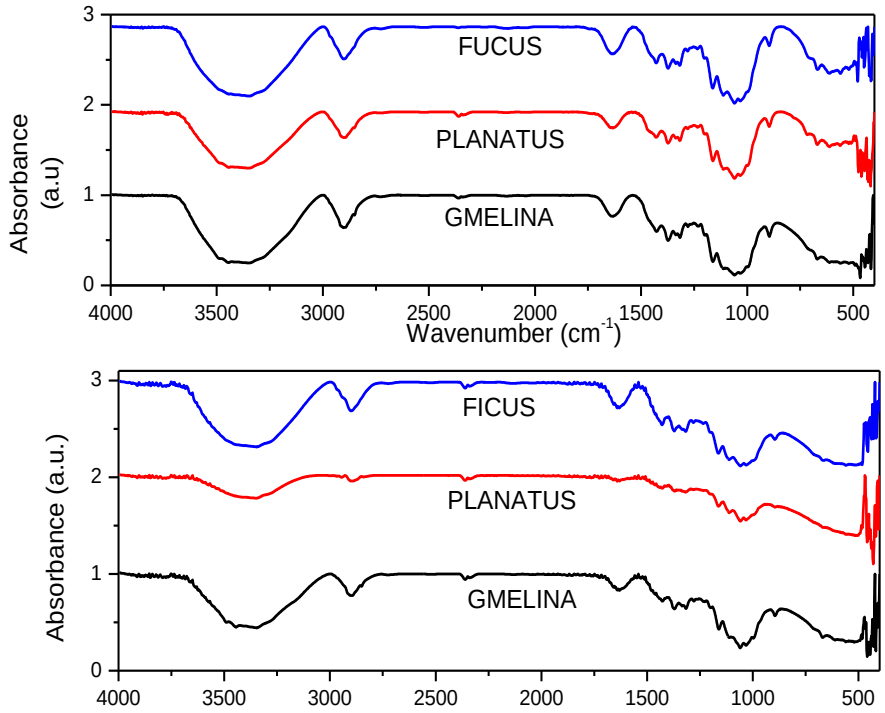
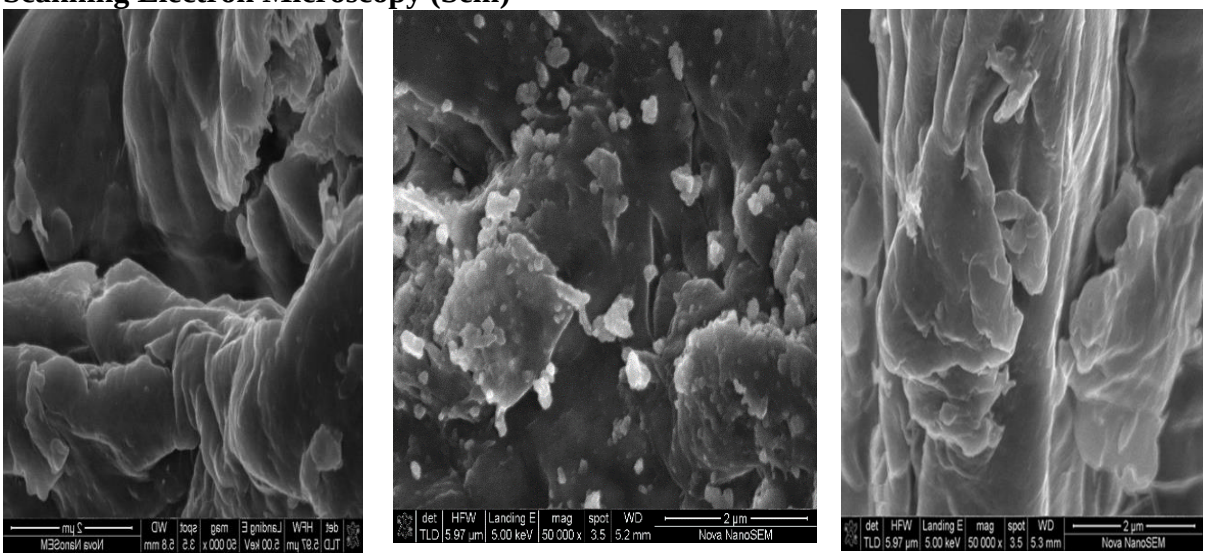


Figure 3: FTIR Spectra of Cellulose and Microcrystalline Cellulose from Different Wood Dusts

In the spectra above, the FT-IR spectra of cellulose and MCC samples are shown (A and B). The absorption bands at around 3300,2900, 1430, 1374, 1100, 1050, 890 cm^{-1} are all associated with native cellulose(14). The stretching of O-H groups and aliphatic saturated C-H are responsible for absorbance peaks in the ranges of 3450–3300 cm^{-1} and 2900–2800 cm^{-1}(14–16). The C-O-C pyranose ring skeletal vibrations are responsible for the peaks that appeared at about 1050cm^{-1}. The absorption bands at about 1374 cm^{-1} are responsible for the C-O asymmetric bridge stretching.(14). Furthermore, the spectra absorption peak at 1429 cm^{-1}, which is due to a symmetric CH_2 bending vibration and is known as the "crystallinity band" (17,18). The crystallinity of the sample is further proven with the absorption bands at 897 cm^{-1} (19,20). All these regions found in all the spectra, suggested that the cellulosic compositions are identical. In MCC, there was an improvement in strength at the 897 cm^{-1} absorbance peak, suggesting improved crystallinity, this was also observed by Zhao *et al.* 2018(15). The absorption peak at 1624 $cm^{-1}$is responsible for water absorption due to the hydrophilic nature of cellulosic material (5). The absence of peaks at 1512 cm^{-1} and 1735 cm^{-1} which are assigned to the C-C vibration as well as the aromatic C-O stretching in hemicelluloses and lignin respectively, suggested that the pretreatment method adopted suitably eliminated non-cellulosic component of the raw materials (18,20–22).

Scanning Electron Microscopy (Sem)



a **b** **c**

Figure 4: SEM Micrographs for MCCs of (a) Gmelina (b) Ficus (c) Planatus

The SEM images of the microcrystalline cellulose samples show non- uniformly dense microcrystalline particles thereby forming microcrystals from the overall view. They are densely packed and sponge-like revealing large surface area of the samples. This appearance is due to the breakdown of the amorphous region during hydrolysis affording the microcrystalline structure with large surface area. All three samples displayed similar surface area pattern showing cellulose from each of these samples could be employed as raw starting materials for further processing.

TGA/DTA

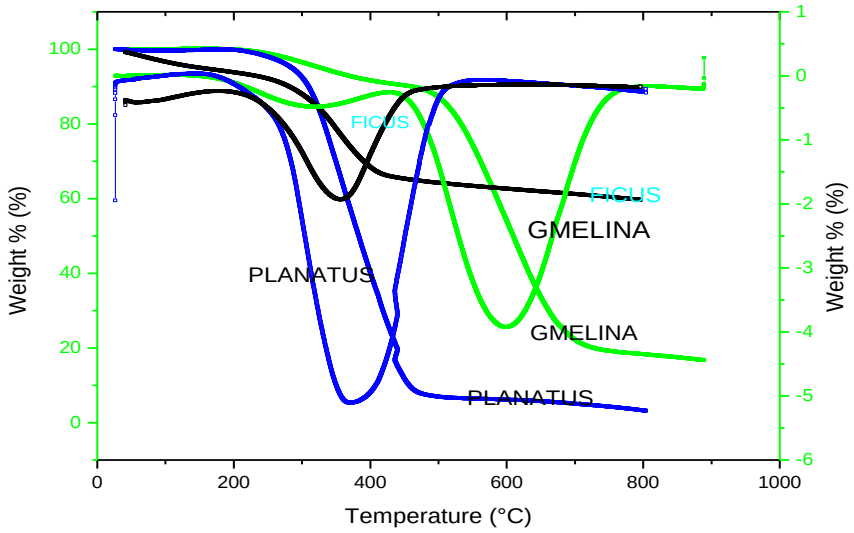


Figure 5: TGA/DTA thermogram of the MCCs

The thermogravimetric curve revealed a single step thermal degradation pattern **(Figure 5)** of the samples from 430 to 550 ^{o}C . Gmelina MCC however showed higher thermal stability with degradation temperature of about 700 ^{o}C. which might be attributed to its high swelling capacity. Overall, the thermal degradation pattern exhibited by the samples confirmed the absence of hemicelluloses, lignin as well as little or no traces of impurities in its core structure. Therefore, the MCCs are thermally stable ones. The Differential thermal analysis (DTA) revealed that the Tmax (temperature at which maximum weight loss occurs) was 440 ^{o}C as an average for the samples except for Gmelina with Tmax at about 610^{o}C. It can be said that these samples are thermally stable and can serve as good raw materials for future materials functionalization and applications.

X-Ray Powder Diffraction Specrtroscopy (Xrd)

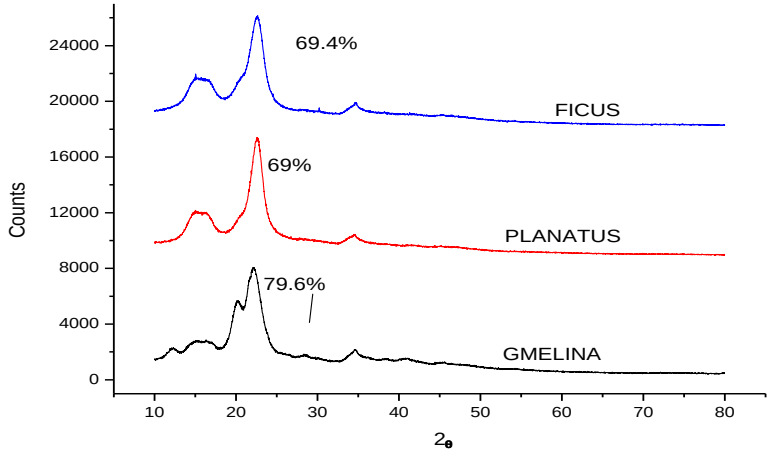


Figure 6: XRD Pattern of MCCs

The X-ray diffraction pattern of the MCC samples **(Figure 6)** revealed that *Gmelina aborea* sample had the highest value of degree of crystallinity. The crystallinity index of the samples

suggested the amorphous region of the cellulose is broken down, leaving behind the crystalline region of the cellulose material, yielding microcrystalline cellulose. The crystallinity index values of the MCC samples ranged from 68.7% to 79.6% percent which is a good value for microcrystalline cellulose. The diffraction patterns of all the MCCs samples showed sharp peaks of the 2θ angles at about 14.5°,17°, 22.7°, and 35.5° for all the samples are assigned to the typical reflection planes of Cellulose I. The values obtained are identical to those reported by Hu *et. al* and Rahman *et. al* for carbon nanocellulose and microcrystalline cellulose respectively.(9,23–25) The crystallinity indices of the samples are shown in the bar chart below for better comparison. The origin soft ware was used to calculate the areas of crystalline regions as well as the areas of the crystalline and the amorphous region of the XRD spectra. The crystallinity index of each sample was thereafter calculated using the equation below:

$$\boldsymbol{CI = \left\{\frac{Ic}{I(c+a)}\right\} * 100 - - - - - - - - (3)}$$

CI= crystallinity index
Ic= Area of Crystalline region
I(c+a)= Area of crystalline and amorphous region.

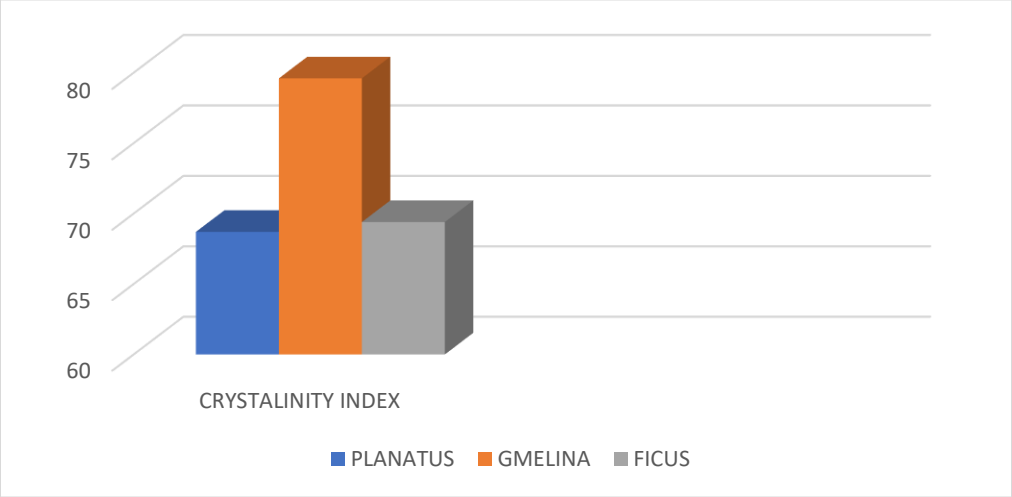


Figure 7: Bar Chart Illustration of the C.I of the three samples

Conclusion

In this study, pure, high-grade cellulose were successfully extracted from rejected wood dusts wastes from sawmills. Microcrystalline cellulose samples were subsequently prepared from the extracted cellulose and characterized. The results from this study revealed that quality raw materials that can be employed for several applications could be obtained from abandoned materials in the environment. This practice will not only help in eliminating wastes from the environment, but will also serve as source of revenue generation if practiced on a commercial scale. It can therefore, be concluded that the Gmelina microcrystalline cellulose sample due to its good swelling property, can be grafted onto other polymer samples like starch, chitin, polyvinyl pyrolidone, Polyethylene glycol, Polymethylmetacrylate and a host of others to obtain cationic or anionic hydrogels depending on the dissolution solvent for enhanced applications in pharmaceutical, biomedical as well as the agricultural fields. The Ficus and Planatus samples due to their moderate swelling ability are good candidates as direct **compression** excipient in drug formulation. Overall, 'waste materials were obtained from nature, purified and processed into

useful raw materials that are ecofriendly for several applications which will serve **beneficially** to human'.

Conflict of Interest

The authors of this research hereby declare no conflict of interest in this work

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BOOK REVIEW

Healthcare Education in Nigeria: Evolutions and Emerging Paradigms.

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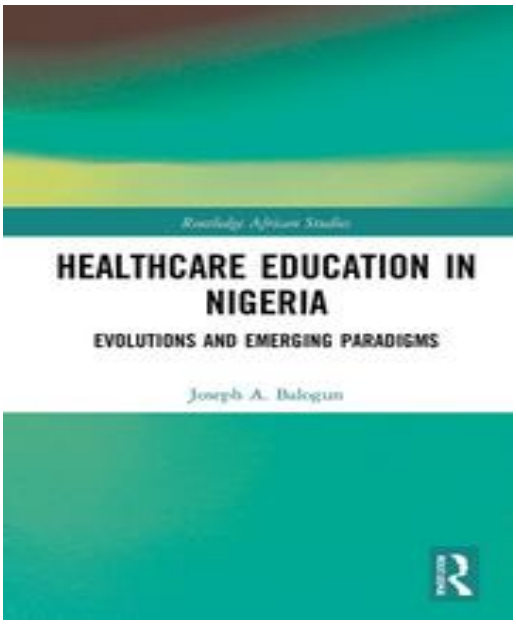

The above book published by Professor Joseph Balogun, an accomplished clinician, researcher, educator, and administrator, who doubled as a participant-observer while working on this book, is a compelling masterpiece. As a former Senior Lecturer and Vice-Dean at Obafemi Awolowo University, Ile-Ife three decades ago, a retired Distinguished Professor at Chicago State University, faculty, and administrator at several universities around the world, made Professor Balogun uniquely qualified to author this book. He is familiar with the global education and healthcare systems. As a patriotic Nigerian who has devoted his life to giving back to his homeland, Professor Balogun authored this book to address the curriculum deficits he observed during one of his many visits to Nigeria. At a national workshop he gave at the University of Medical Sciences, Ondo City in 2018 to faculty, heads of academic departments, and university administrators, he observed that most of his audience had no formal training on their roles and responsibilities.

The ten-chapter publication is a fulfilled dream of concerned healthcare educators and policymakers who for long have yearned for a textbook of this nature that suits this contemporary times. From the onset and throughout the publication, the author promotes the interprofessional education philosophy by using the term “healthcare education” instead of a discipline-specific genre. Chapters 2 through 4 addressed the core objectives of writing the book, while the other chapters addressed the emerging trends and challenges within the Nigerian academy.

The first chapter examines the evolution of the major health disciplines and provides insights into the global trends on instructional methods, quality, and efficiency in the education accreditation process and the unequal global distribution of the healthcare workforce, including the "brain drain" phenomenon. Professor Balogun offered a panacea for addressing many of the problems in the Nigerian healthcare and education systems by recommending international accreditation. He argued that this engagement would strengthen clinical practice and attract top clinicians and educators into the country while simultaneously keeping the Nigerian elites at home to meet their healthcare needs.

Chapter 2 focuses on the art of teaching by examining the differences between pedagogy, andragogy, and heutagogy. It provides a template for developing a course syllabus, including program assessment, curriculum mapping, evidence-based teaching and practice in healthcare education, and online instructions in contemporary times. The core characteristics and attributes of professionalism and relevance in healthcare education and the behavioral expectations of healthcare professionals were presented in Chapter 3. It also discusses how to teach professionalism and strategies for managing "hidden curriculum" behaviors, the methods and psychometric inventories used to assess it, and the core components of the ethical code of conduct within the health professions.

Chapter 4 delved into university governance and organizational structure, including the roles and responsibilities of major university personnel. It also examines effective leadership traits and managerial skills, program assessment, including students and teacher evaluations. The evolution of healthcare professions in the country and how they progressed at varying paces in establishing educational programs and in their quest for true professional identity and prestige were explored in Chapter 5. The following chapter identifies the pioneer Nigerian healthcare academics in the various health fields and discusses their service and scholarship contributions.

Chapter 7 examines the significant developments in Nigeria's healthcare education in the last decade, but the author expressed disappointment that the growth and transformation did not come with high-quality programming. Chapter 8 discusses the contemporary challenges in healthcare education, highlighting faculty shortages, faculty limited grant writing skills, antiquated resources, high faculty-student ratio, unethical academic conduct, incessant university closures, and poor academic policies and corruption, underfunding, and the conflict between Faculty of Health Sciences/College of Medicine and their sister University Teaching Hospitals.

Professor Balogun discusses in Chapter 9 the previous attempts in Nigeria to revise the medical and dental curricula at the national level and presents the findings of the formative and summative evaluations he conducted between 2015 and 2019. He used the results as the basis for his recommendations for reforming the Nigerian healthcare education system. His proposal includes adopting an interprofessional education model, integrating entrepreneurship education in the curriculum, and building workforce capacity. He also underscores the need for the National Universities Commission and the professional regulatory boards to upgrade the accreditation process to include a self-study report on specific standards and criteria such as mission, integrity, instruction and learning, and institutional effectiveness, resources, planning. The last chapter identifies and celebrates the Nigerian academics in Diaspora who are making waves in their respective healthcare disciplines worldwide.

As an educator who has often expressed frustrations on the country's healthcare education and health systems, I sometimes find myself close to giving up but see the contents of this book as thought-provoking and a fresh start. While the book's focus is on Nigeria, it also presents transnational perspectives, making it appealing to audiences in West Africa and beyond,

particularly to officials and expatriates desirous of first-hand information about Nigeria's education and healthcare systems.

This book fills the void created by the lack of published materials on healthcare education in Nigeria. The evidence-based format adopted by the author and the solid empirical data provided in several of the chapters is an innovation that makes the book a must-read publication. It is well structured and can be read from chapter to chapter as presented. Alternatively, each chapter stands alone, and readers who desire it can go directly to any section. I personally find the book a delight to read.

Recently the National Universities Commission (NUC) and the central accrediting agency for academic programs in the Nigerian universities engaged experts in a curriculum reviewing process that is still ongoing. As a reviewer, I found the book a valuable resource for the content enrichment and assessment of the doctor of physiotherapy curriculum approved for implementation by the NUC. It specifically provided the focus on competencies, ability-based and learning outcomes, and professional training behavior expectations.

As a faculty, my initial concern was affordability. The cost of the book will no doubt be a primary factor for other faculty members, students, and lay readers in deciding to purchase the book. I would encourage every stakeholder in healthcare education to take advantage of the heavily discounted price offer while it lasts. The book is currently sold for $160, but African scholars, professionals, and students can purchase the book for £24, including shipping, by entering the discount code AFAU230 at the website checkout: https://www.routledge.com/Health-care-Education-in-Nigeria-Evolutions-and-Emerg-in-g-Paradigms/Balogun/p/book/9780367482091

This seminal publication, written in clear prose, will appeal to a seasoned educator and broad audience. I, therefore, recommend the book to all stakeholders in healthcare education, including students and practitioners, university administrators, and heads of departments in the Colleges of Health Sciences and Teaching Hospitals in Nigeria. Policymakers, senior civil servants in the Federal Ministry of Health, and politicians serving on education and healthcare oversight committees will find the book engaging to read.