BIOLOGY, MEDICINE, & NATURAL PRODUCT CHEMISTRY
Volume 12, Number 2, October 2023 | Pages: 663-669 | DOI: 10.14421/biomedich.2023.122.663-669
ISSN 2089-6514 (paper)
ISSN 2540-9328 (online)

Prevalence and Biofilm-forming Potentials of Bacterial Uropathogens Among Primary School Pupils in Yola North, Adamawa State

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Manuscript received: 10 October, 2023. Revision accepted: 07 December, 2023. Published: 04 February, 2024.

Abstract

This investigation aimed to determine the prevalence and biofilm-forming potentials of bacterial uropathogenic among primary school pupils in Yola North, Adamawa State. A total of 120 clean mid-stream urine samples were collected from apparently healthy children to determine the antimicrobial susceptibility of the isolated pathogen by the Kirby and Bauer disc diffusion method while the biofilm-forming potential by the standard methods. The result showed 26 % of the samples had significant bacteria growth with the Gram-negative as the highest. The infectivity pattern among the age group showed 8-10 had the highest infectivity percentage (35%) followed by 5-7 and 11-13 with 22.5% and 20% respectively. Six bacteria pathogens were isolated which are *E. coli* (41.9%) which is the most prevalent isolate followed by *Staphylococcus aureus* (29.0%), *Pseudomonas* sp. (9.7%), *Klebsiella* sp. (9.7%), *Enterobacter* sp. (6.5%), *Proteus* sp. (3.3%). The antibiotic sensitivity test showed an alarming resistance level to nearly all the tested antibiotics showing multi-drug resistant strains. The Biofilm-forming potentials depict *E. coli* with the strongest potential followed by S. *aureus*. A high occurrence of asymptomatic UTIs and antimicrobial resistance observed poses a public health concern. Thus, routine diagnostic exercise is recommended for early detection and prompt treatment of the pathogens.

Keywords: Bacteria; Biofilm; Gram negative; Gram positive; Prevalence; Uropathogens.

Abbreviations: AB (Asymptomatic bacteriuria), CLED (Cysteine Lactose Electrolyte Deficient), Genitourinary (GU), UTI (Urinary tract infection).

INTRODUCTION

Urinary tract infection (UTI), indicates the presence of microorganisms within the urinary tract, extending from the distal urethra to the kidney. UTIs constitute the second most prevalent type of infection, resulting in approximately 8.1 million annual visits to healthcare professionals. These infections are the most frequent bacterial ailment among children, affecting 8% of girls and 2% of boys (Daniel *et al.*, 2023). Urinary tract infections are a common occurrence among secondary school students, afflicting individuals of both genders and typically necessitating prompt medical attention (Behzadi *et al.*, 2021). It is also worth noting that UTIs rank as one of the leading causes of morbidity, particularly renal disorders, and mortality in children, particularly among those from the most economically disadvantaged backgrounds (Anigilaje and Elike, 2022). UTIs can exhibit diverse manifestations depending on the infection's location and duration. In the kidney, it is termed pyelonephritis; in the bladder, cystitis; and in the urethra, urethritis. The presence of bacteria in the urine is referred to as bacteriuria.

UTIs can manifest with symptoms or without them, known as asymptomatic UTIs (Colgan *et al.*, 2020). Asymptomatic UTI, also termed asymptomatic bacteriuria (AB), is characterized by the presence of a significant bacterial load (≥105 cfu/ml) in an individual's urine without any accompanying signs or symptoms of UTI (Colgan *et al.*, 2020). The prevalence of asymptomatic bacteriuria varies widely, influenced by factors such as age, gender, sexual activity, and the presence of genitourinary abnormalities (Shpunt *et al.*, 2021). In children, the prevalence of asymptomatic bacteriuria varies by geographic location. Developed countries have reported rates ranging from 2 to 5.4% (Jain and Schroeder, 2020), whereas developing countries, especially among those with the lowest socioeconomic status, have reported rates between 10 to 48% (Sorkhi *et al.*, 2019). UTIs can be attributed to a variety of organisms, with bacterial colonization of the urinary tract being primarily linked to Gram-negative species. Common culprits include *Escherichia coli*, *Klebsiella species*, *Proteus species*, and *Pseudomonas aeruginosa*. Gram-positive organisms, such as *Staphylococcus aureus* and hemolytic *Streptococci* are less frequently responsible for UTIs (Ali *et al.,* 2018).

Several common factors contribute to an increased risk of developing UTIs. In women, the heightened risk is primarily attributed to the relatively short length of the urethra, which measures around 1.5 inches compared to approximately 8 inches in men. This anatomical difference makes it easier for bacteria from fecal matter near the anal opening to migrate to the urethral opening. Furthermore, older schoolgirls, as suggested by Shaikh *et al.* (2014), may be at a higher risk due to factors such as engagement in premarital sexual activity, which can introduce uropathogenic bacteria into the urinary tract. Poor hygiene practices also play a role in UTI risk. Additionally, compromised health conditions that weaken the immune system can render individuals more susceptible to UTIs. Dysfunctional voiding, where urine is retained for extended periods after the bladder signals fullness, can also contribute to infections (Dobrek, 2023). Dehydration, by promoting bacterial growth, is another factor that can lead to the development of UTIs.

Bacterial virulence factors play a crucial role in determining whether an organism can invade the urinary tract and the severity of the resulting infection. These virulence factors encompass various elements, including adhesins, type 1 pili, P fimbriated pili, cell receptivity, and biofilms. Adhesins, often in the form of fimbriae or pili, enhance bacterial adherence to the uroepithelium by binding to specific receptors on its surface (Davis and Flood, 2011). This interaction between fimbriae and mucosal receptors triggers several events, such as the internalization of the bacterium into the epithelial cell, which can lead to apoptosis, hyperinflation, invasion into nearby epithelial cells, or the establishment of a bacterial focus that contributes to recurrent UTIs. Biofilms are structured communities of microbes encased in extracellular polymeric substances (EPS) that form on the surfaces of the urinary tract. Although certain proteins and enzymes serve as targets in antibacterial therapy (Dahiru *et al.,* 2023), resistance to the drugs can complicate the treatment of UTIs and contribute to their persistence. These biofilms often exhibit complex structural and functional characteristics, making the microbial communities highly resistant to many antimicrobial agents (Hamzah *et al.,* 2020).

It is imperative to understand the variations in antimicrobial resistance among microorganisms isolated from UTI, as resistance patterns can vary by region and even from one patient to another. To address this issue, our primary focus is to gain a comprehensive understanding of the community-acquired microorganisms prevalent in our population. This study aims to investigate the distribution, antibiotic resistance profiles, and biofilm formation capabilities of bacteria isolated from urinary tract infections (UTIs). The ultimate goal is to enhance the effectiveness of empirical treatment for these infections, ensuring that patients receive the most appropriate and successful treatment interventions.

MATERIALS AND METHODS

Study Area

The research was conducted in Yola North, the capital of Adamawa State in North-eastern Nigeria. The study focused on a group of apparently healthy children who were attending primary school, ranging in age from 5 to 12 years. A total of five primary schools were selected for the study, from which a combined total of 100 samples were collected. To ensure gender equity, an equal number of samples were obtained from both male and female students. Among the participating pupils, twenty (20) samples were randomly selected from each of the five primary schools.

The inclusion criterion for participation in the study was limited to children currently enrolled in primary schools. Conversely, the exclusion criteria encompassed children who were either younger or older than the primary school age range and those who had recently used antibiotics. These criteria were established to maintain consistency and relevance in the research population and to prevent potential confounding factors that could affect the study's outcomes.

Sample Collection

Urine specimens were collected following the established and highly recommended approach for children aged three and older, as outlined by Welsh (2007). After collection, the clean catch mid-stream urine sample in sterile containers was transported immediately to the laboratory for analysis. In cases of potential delays, the samples were safeguarded by refrigeration at temperatures between 4 and 8 °C as recommended by Welsh (2007).

Microbiological Analysis

Each sample was cultured on Cysteine Lactose Electrolyte Deficient (CLED) agar and Blood agar as described by Vandepitte *et al.* (2003) and Cheesbrough (2002). Incubation was carried out for 24 h at 37 °C. Enumeration of colonies was carried out as described by (Olutiola *et al.,* 1991). Cultures with 105 CFU/ml were considered significant (Younis *et al.,* 2010). Biochemical tests to identify individual organisms were conducted from plates with a positive result as described by Prescott, (2002) and Cheesbrough, (2002). Antimicrobial susceptibility testing was been performed using the disk diffusion method as described by the National Committee for Clinical Laboratory Standards (N.C.C.L.S, 2000).

Data Analysis

The values obtained were expressed as a percentage of the mean ± standard error of triplicate determinations' mean (± SEM) and evaluated with Statistical Package for the Social Sciences (SPSS) version 22 Software.

RESULTS AND DISCUSSION

A total of one hundred and twenty (120) urine samples were collected from selected primary school children, out of which 31 (26%) of the school children showed significant bacteriuria, while 89 (74%) of the children were negative. Figure 1 shows the result of the infectivity pattern among different sexes out of the 60 male pupils 12 are positive giving 20% while 19 females are positive out of 60 females which also gives 32%.

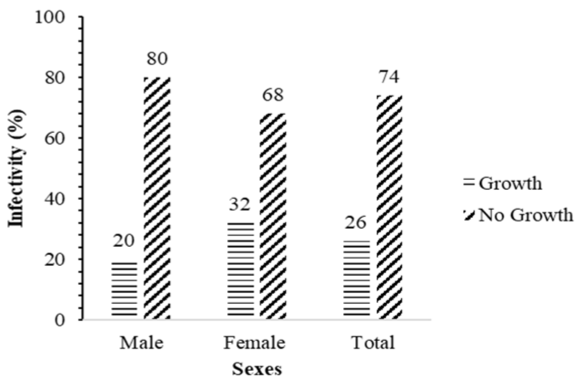

Figure 1. Infectivity Pattern Among the Sexes

Figure 2 shows the result for the infectivity pattern among the different age groups sampled. Age group 8-10 showed the highest percentage of growth with 14 (35%), followed by 5-7 with 9 (22.5%), and age group 11-13 showed the lowest percentage of growth with 8 (20%).

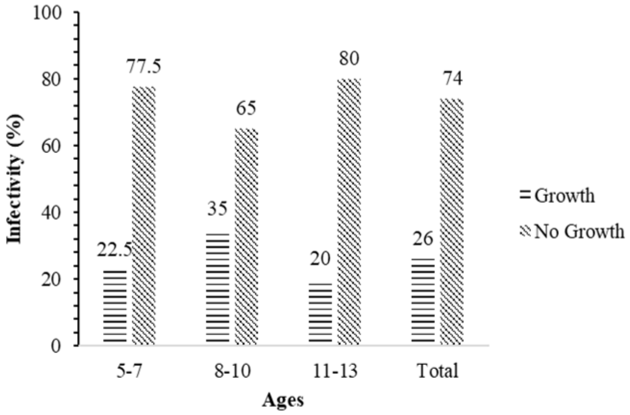

Figure 2. Infectivity Pattern Among the Different Age

The distribution pattern of the isolates among different sexes is shown in Figure 3. A total of 31 isolates represented six different organisms, including *E. coli*, *Proteus* sp., *Enterobacter* sp., *Pseudomonas* sp., *Klebsiella species*, and *S. aureus*. Specifically, *E. coli* was the most commonly isolated organism, accounting for 41.9%, followed by *S. aureus* at 29.0%, *Pseudomonas* sp. and *Klebsiella* sp. each at 9.7%, *Enterobacter* sp. at 6.5%, and *Proteus* sp. at 3.3%.

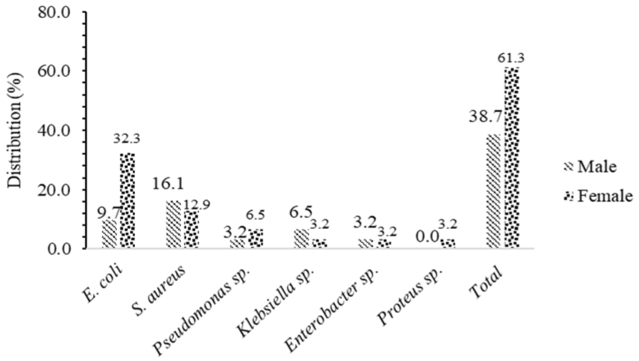

Figure 3. Distribution Pattern of the Isolates Among Different Sexes

The antibacterial susceptibility profile of Gram-negative bacteria uropathogens showed susceptibility against Ciprofloxacin, Pefloxacin, Ofloxacin, and Chloramphenicol. However, they exhibited resistance to Cotrimoxazole, Nalidixic acid, and Ampicillin. The result is presented in Table 1.

Table 1. Antibiotic Sensitivity Patterns of Gram-Negative Isolates

Bacteria (n)	CPX	PEF	OFX	AU	CN	SXT	NA	PM	S	CH
E. coli n=13	13 (100)	13 (100)	12 (92.3)	6 (46.1)	9 (69.2)	2 (15.4)	2 (15.4)	0 (0.0)	4 (30.7)	13 (100)
Pseudomonas sp. n= 3	3 (100)	3 (100)	3 (100)	1 (33.3)	2 (66.6)	0 (0.0)	1 (33.3)	1 (33.3)	0 (0.0)	3 (100)
Klebsiella sp. n=3	3 (100)	3 (100)	3 (100)	0 (0.0)	3 (100)	0 (0.0)	0 (0.0)	1 (33.3)	0 (0.0)	3 (100)
Enterobacter sp. n=2	0 (0.0)	2 (100)	2 (100)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (100)
Proteus sp. n=1	1 (100)	1 (100)	1 (100)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (100)
Total n=22	20 (90.9)	22 (100)	21 (95.5)	7 (31.8)	14 (63.6)	2 (9.0)	3 (13.6)	2 (9.0)	4 (18.2)	22 (100)

CPX- Ciprofloxacin, SXT- Cotrimoxazole, PEF-pefloxacin, NA- Nalidixic acid, OFX- ofloxacin, PM- Ampicillin, AU- Augmentin, S- streptomycin, CN- gentamycin, CH- chloramphenicol

Figure 4 shows the antibacterial susceptibility profile of Gram-positive bacteria uropathogens, particularly *S. aureus*. The result obtained indicates that *S. aureus* was susceptible to Pefloxacin and Ciprofloxacin, as these antibiotics completely inhibited the growth of the bacteria. However, *S. aureus* exhibited complete resistance against Septrin, Rocephin, and Erythromycin.

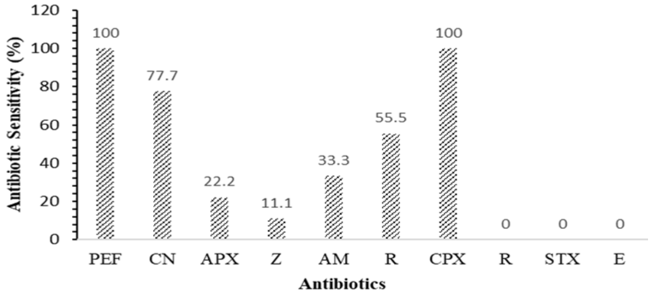

Figure 4. Antibiotic Sensitivity Patterns of Gram-Positive Isolates (*Staphylococcus aureus* n=9). PEF- Pefloxacin, AM- Amoxicillin, CN- Gentamycin, CPX- Ciprofloxacin, APX- Amplicox, S- Streptomycin, Z- zinnacef, SXT- Septrin, R- Rocephin, E- Erythromycin

Table 2 shows the result for the Biofilm-forming potential of the bacterial uropathogens isolated. The result obtained showed that *E. coli* showed the strongest potential for biofilm production next to *S. aureus* and *Klebsiella* sp.

Table 2. Biofilm-formation by the isolated Bacteria Uropathogens

Bacteria	**Biofilm**		
	Strong	**Weak**	**None**
E. coli (n =13)	9	3	1
S. aureus (n =9)	2	5	1
Pseudomonas sp. (n = 3)	1	2	-
Klebsiella sp. (n =3)	2	1	-
Enterobacter sp. (n =2)	1	1	-
Proteus sp. (n =1)	1	-	-

Discussion

Antimicrobial drug resistance poses a global challenge that carries significant implications for public health. UTIs are prevalent across all age groups and have a considerable clinical impact due to their exuberant rates of morbidity and mortality (Madrazo *et al.*, 2023). study. UTIs rank highest among all diseases concerning the number of antibiotic prescriptions issued for empirical treatment, as highlighted by (Paul *et al.*, 2022). Over time, the high prevalence of antimicrobial resistance amongst uropathogens has steadily risen on a global scale, rendering UTIs one of the most frequently encountered infectious diseases in medical practice, resulting in significant morbidity, as reported by Medina and Castillo-Pino, (2019). Understanding microorganisms, their response to antimicrobials, and local resistance patterns is vital for tailoring more personalized and effective treatment strategies, as emphasized by Ahmad *et al.* (2021).

Antimicrobial resistance is a global challenge with serious implications for public health. UTIs affect people of all ages and have a substantial clinical impact due to their high rates of illness and death, as demonstrated in Madrazo *et al.* (2023). UTIs stand out as the utmost common reason for prescribing antibiotics for empirical treatment (Paul *et al.*, 2022). To develop more personalized and effective treatment strategies, it is essential to have a deep understanding of microorganisms, their reaction to antimicrobials, and resistance patterns in the local environment (Ahmad *et al.*, 2021).

This study recorded a prevalence level of 26% for uropathogens, which was notably lower than the 67.2% reported in a similar hospital-based study conducted in Yola, a location within the same geographical region (El-Mohmood, 2009). These findings are in tandem with multiple studies carried out in Nigeria, with rates comparable to the 31.7% incidence reported by Isa *et al.* (2013) and the 24.1% documented by Musa-Asien *et al.* (2003). The results indicate a high incidence when contrasted with earlier reports, such as Ogomaka *et al.* (2013), which found an incidence of 8.1%, as well as the 3.0% reported by Muoneke *et al.* (2012), and the 9% reported by Ibadin and Abiodun, (2004).

However, it's important to note that similar studies conducted in other parts of the world have reported varying UTI incidence rates, ranging from 3.7% (Mobasheri *et al.*, 2002) to 28% (Hamdan *et al.*, 2011) and 22.7 % (Kibret and Abera, 2014). These differences could be ascribed to variations in UTI awareness, screening methods, and the amalgamation of risk factors, such as the socio-economic status of families, age, personal hygiene standards, and education levels, across different geographical locations.

The study's recorded bacteriuria prevalence of 26% indicates that a noteworthy portion of the children in the research study carry urinary tract pathogens, potentially serving as a source for transmitting and spreading these pathogens. The elevated incidence of UTI amongst seemingly healthy children could be multifactorial. These include inadequate healthcare access, home-based treatments, suboptimal dietary practices, insufficient health education, inadequate local hygiene practices, issues related to circumcision, colonization of the bladder and urethra, and improper catheterization techniques (Larcombe, 1999).

The high prevalence of UTIs amongst primary school children, especially females, was notably high in this study. The results highlight that the higher incidence of UTIs in females can be attributed to various factors. These factors include the anatomical structure of the female genitourinary (GU) tract, which is near the vaginal and anal areas, making it more susceptible to potential contamination by fecal coliforms due to inadequate hygiene practices. Additionally, incomplete and irregular voiding of urine, often associated with constipation in schoolgirls, can result in urinary tract infections. Furthermore, the presence of uropathogens in the male urethra can also be found in the vaginal flora of female sexual partners (Belete and Saravanan, 2020). These findings align with the studies conducted by Onuoha and Oko, 2015 and Allamin, 2015, which similarly reported a high prevalence rate of UTIs among female primary school children.

The current study revealed that the uppermost prevalence of UTIs was reported amongst children aged 8 to 10 years, whereas the lowest prevalence was among those aged 11 to 13 years. This finding is unswerving with the results of studies conducted in Nigeria and other countries (Onuoha and Fatokun, 2014; Adeleke *et al.*, 2013). The higher incidence of UTIs among children in this age group could be attributed to delayed voiding of urine and poor personal hygiene. The consequences of retaining urine include the multiplication and growth of urinary tract pathogens, which can lead to the development of UTIs. On the other hand, the lower incidences of UTIs among the younger age group could be due to their frequent urination, as they tend to empty their bladders whenever they feel the urge, which serves as a natural defense mechanism against the development of UTIs (Ogoamaka *et al.*, 2013).

Consistent with most studies in the field, our findings also indicate that Gram-negative bacteria account for the predominant uropathogens, comprising 78.3% of the total isolates, whereas Gram-positive bacteria account for 21.6%, as reported by Oumer *et al.* (2022). An overall total of 31 bacteria isolates represented six different organisms, including *E. coli, Proteus species, Enterobacter species*, *Pseudomonas species*, *Klebsiella species,* and *S. aureus*. Specifically, *E. coli* was the most frequently isolated organism, accounting for 41.9% of cases, followed by *S. aureus* at 29.0%, *Pseudomonas* sp. and *Klebsiella* sp. each at 9.7%, *Enterobacter* sp. at 6.5%, and *Proteus* sp. at 3.3%. This pattern and frequency of bacterial isolates reported in this study align with previous reports, such as those by Medina and Castillo-Pino, (2019) indicating that Gram-negative bacteria, particularly *E. coli*, are the most commonly encountered pathogens in children with urinary tract infections. The high prevalence of *E. coli* in urine samples is a well-documented phenomenon. Numerous authors have identified *E. coli* as the foremost uropathogen in children (Meštrović *et al.*, 2020). In Nigeria specifically, many studies on UTIs have consistently reported the predominance of *E. coli* in positive urine cultures (Dibua *et al.*, 2014). Following *E. coli*, the second most frequently occurring organism is *S. aureus*, which has been recognized as a key Gram-positive pathogen associated with urinary tract infections (Shrestha *et al.*, 2019).

Regarding the antibacterial susceptibility profile of Gram-negative bacteria, the isolates in our study displayed susceptibility to antibiotics such as ciprofloxacin, pefloxacin, ofloxacin, and chloramphenicol. However, they exhibited resistance to Nalidixic acid, Cotrimoxazole, and Ampicillin. This pattern of resistance aligns with the findings of Onuoha and Oko, (2015). The high degree of resistance observed to certain antibiotics could potentially be attributed to the extended period these drugs have been available on the market, allowing microorganisms ample time to develop resistance mechanisms. Additionally, the ease of obtaining antibiotics over the counter, particularly in developing nations like Nigeria where prescriptions may not always be required, and the operation of pharmacies by unlicensed personnel could also facilitate to the observed high surge of antibiotic resistance.

The analysis of the antibacterial susceptibility profile of Gram-positive bacteria, in this study indicates that *S. aureus* was susceptible to Pefloxacin and Ciprofloxacin, as these antibiotics completely inhibited its growth. However, *S. aureus* exhibited resistance against Septrin, Rocephin, and Erythromycin. These findings are in tandem with the work of Mava *et al.* (2012), who also observed the effectiveness of ciprofloxacin, pefloxacin, and ofloxacin against their isolates, while noting resistance to nalidixic acid, Septrin, and Erythromycin.

It's imperative to note that different studies may report varying antimicrobial susceptibility patterns due to several influencing factors. These factors include the antibiotic pattern of consumption by patients, geographical locations, clinical conditions (whether the UTIs are untreated, recurrent, or complicated), and the laboratory methodologies employed. Consequently, comparing data from different studies can be challenging due to these multifaceted variables.

CONCLUSIONS

The result of this study revealed a high occurrence of asymptomatic UTIs among apparently healthy school children which poses a public health concern. The study also indicates a high incidence of antimicrobial resistance to many of the common antibiotics used in the study. Based on this, routine urine screening exercises should be reinvigorated in primary schools to ensure early detection of those that carry the pathogens for adequate and swift treatment of the infection. Consistent monitoring is required also to unveil reliable information about resistance patterns for optimum empirical therapy of patients with UTIs.

***Acknowledgments*:** The funding of this research by the Tertiary Education Trust Fund (TETFUND) through the Institutional Base Research Fund has been duly acknowledged by the authors and they are really grateful for the funding. Special appreciation goes to the Pharmaceutical Technology Department of Adamawa State Polytechnic Yola for institutional support.

***Authors' Contributions*:** Example: Abdulazeez Mumsiri Abaka & Mubarak Muhammad Dahiru designed the study. Abdulazeez Mumsiri Abaka, & Ibrahim Ya'u carried out the data collection and laboratory work. Abdulazeez Mumsiri Abaka, & Tukur Baba Abdullahi analyzed the data. Abdulazeez Mumsiri Abaka & Mubarak Muhammad Dahiru wrote the manuscript. All authors read and approved the final version of the manuscript.

***Competing Interests*:** The authors declare that there are no competing interests.

***Funding*:** This research was sponsored by the Tertiary Education Trust Fund (TETFUND) through the Institutional Base Research Fund.

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