INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN 2278 – 0211 (Online)

Microbiology in Nigeria: Navigating Challenges, Exploring Prospects

Dr. Vivian Nonyelum Anakwenze
Senior Lecturer, Department of Applied Microbiology and Brewing,
Nnamdi Azikiwe University, Awka, Nigeria
Amarachukwu Bernaldine Isiaka
Laboratory Technician, Department of Qatar Airways Medical Division,
Qatar Airways, Doha, Qatar, Nigeria
Uzoma Odinakachi Okoli
Lecturer, Department of Applied Microbiology and Brewing,
Nnamdi Azikiwe University, Awka, Nigeria
Dr. Chito Clare Ekwealor
Reader, Department of Applied Microbiology and Brewing,
Nnamdi Azikiwe University, Awka, Nigeria
Dr. Chinyere Constance Ezemba
Reader, Department of Chychy Gilgal Laboratory and Consultancy Services, Nigeria
Chychy Gilgal Laboratory and Consultancy Services, Nigeria
Dr. Chikodili Gladys Anaukwu
Senior Lecturer, Department of Applied Microbiology and Brewing,
Nnamdi Azikiwe University, Awka, Nigeria
Chidimma Linda Osilo
Lecturer, Department of Applied Microbiology and Brewing,
Nnamdi Azikiwe University, Awka, Nigeria
Ikechukwu Amechi Ekwealor
Professor, Department of Applied Microbiology and Brewing,
Nnamdi Azikiwe University, Awka, Nigeria

Abstract:
Microbiology, as a scientific discipline, plays a pivotal role in unraveling the mysteries of the microscopic world, shaping our understanding of life at its most fundamental level. In the context of Nigeria, a nation with a rich tapestry of diverse ecosystems and health challenges, microbiology has been gaining increasing importance over the years. As Nigeria strides towards technological and scientific progress, microbiology plays a pivotal role in addressing pressing issues such as infectious diseases, food safety, and environmental sustainability. However, the journey is not without hurdles. Infrastructure limitations, funding constraints, and educational gaps present formidable challenges to the growth and development of microbiological research and applications in the country. This discourse delves into the intricacies of microbiology in Nigeria, examining the barriers that impede its progress and the boundless potential it carries for advancements in academia, healthcare, industry, agriculture, and environmental sustainability. From the laboratory to the field, microbiology in Nigeria stands at the crossroads of obstacles and opportunities, presenting a narrative of scientific resilience and the quest for innovative solutions to societal challenges.

Keywords: *Microbiology, funding, education, disease, curricula, biotechnology*

1. Introduction

Microbiology stands at the forefront of scientific inquiry, playing a pivotal role in unraveling imperceptible realms. As a branch of biological sciences dedicated to exploring life processes (Ugwuanyi, 2016), it has yielded numerous critical insights, particularly in molecular biology, genetics, and biochemistry. The foundational principles of these disciplines have often emerged from research involving microorganisms. Undoubtedly, microbes constitute the fundamental underpinning of the biosphere, serving as the cornerstone for all life forms and acting as the ancestors of every living entity. Beyond their foundational role, microbes significantly influence human health and Earth's ecosystems.

Consequently, the study of microbes becomes integral to understanding all living organisms, making microbiology indispensable for comprehending and exploring life on our planet.

The landscape of microbiological research is undergoing rapid transformations, influenced by events that reshape public perceptions of microbes. Factors such as the emergence of specific diseases, antibiotic resistance, environmental contamination, bioterrorism, large-scale food safety issues, and advancements in therapies for microbial diseases contribute to this evolving terrain. Microbial research is capitalizing on technological progress, particularly in genomics, transcriptomics, and proteomics, which has opened new avenues for exploration. There is a wide spectrum of rapid microbiological methods available, albeit some are at a more advanced stage than others. Technologies vary, although they generally share the ability to capture data digitally, and they offer greater accuracy and specificity. Such methods also shift the traditional skill sets found in microbiology laboratories towards biochemistry and biomedical engineering (Miller, 2019). Fundamental biological complexities, such as infectious diseases and the engineering of microbes for biotechnological applications, represent areas poised for significant advancements. Growing attention is directed towards understanding the ecology and evolution of microorganisms, with researchers delving into relationships between microbes and their habitats and exploring linkages between these microbes and their phylogenetic origins. There is an increasing effort among researchers to integrate their findings, aiming for a comprehensive understanding of biological phenomena across all levels.

However, while many areas of the microbiological sciences are ready for exploration, microbiology must overcome an array of hurdles before it can fully accomplish its potential. From inadequate funding to a dearth of infrastructure, challenges have cast a shadow on the field. Moreover, issues such as limited education and training opportunities, coupled with poor remuneration and restricted job prospects, have added complexities. However, amidst these challenges lie promising prospects. The potential for healthcare advancement, environmental solutions, agricultural innovations, collaborative efforts, and the burgeoning field of biotechnology development presents a compelling narrative of hope and progress. This discussion aims to delve into the nuances of microbiology in Nigeria, navigating through challenges and exploring the manifold prospects that hold the promise of a brighter future.

2. Challenges Facing Microbiology in Nigeria

The COVID-19 experience serves as a significant lesson and a stern warning for microbiologists in Nigeria concerning our readiness for pandemics. It is evident that the virus will persist, and future pandemics will demand swift responses. Microbiologists must acquire knowledge accessible to many, addressing immediate and long-term threats like food security, pandemics, antimicrobial resistance, and environmental sustainability. While the microbiology community acknowledges these challenges, in Nigeria, we grapple with serious obstacles in our research endeavors. Some of these challenges are discussed below:

2.1. Inadequate Funding

Education is one of the most valuable tools for building a sustainable future. Since 2015, the United Nations Educational Scientific and Cultural Organizations (UNESCO) Member States to which Nigeria belong to agreed on a level of educational funding of 4 to 6% of GDP or 15 to 20% of public expenditure (annual budget), but most countries, Nigeria inclusive, have not yet reached this threshold (Ojo, 2023). Figure 1 shows the percentages of annual budget allocation to education in Nigeria after the UNESCO agreement. The inconsistencies in the allocations to education show that the country is not giving the sector the needed priority.

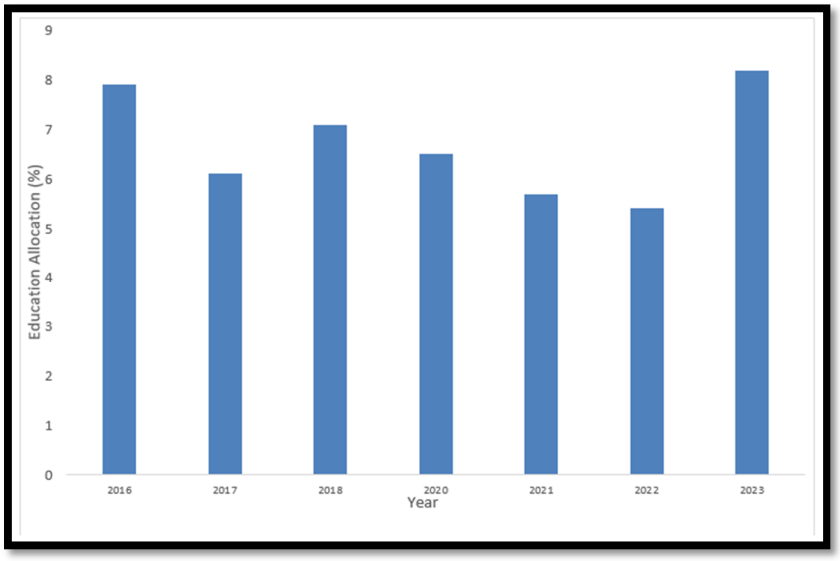

Figure 1: Percentage Allocation to Education in Nigeria Since 2016

One of the major challenges facing microbiology education in Nigeria is inadequate funding. In 2022, lecturers under ASUU embarked on an eight-month strike to protest poor funding of tertiary institutions and better working

conditions. The government has not been providing enough funds to support research and development in this field. This inconsistent allocation to education has made it difficult for microbiology departments and institutions to perform at their optimal level as it contributes significantly to lack of modern equipment and facilities for research.

2.1.1. Lack of Adequate Teaching Facilities and Infrastructure

Educational facilities and infrastructure are in dilapidated condition – both at basic, secondary and tertiary institutions across the country. Nigeria's educational landscape faces a persistent challenge in providing comprehensive teaching facilities for microbiology. Teaching in numerous Nigerian institutions tends to be conceptual and theoretical due to the absence of essential teaching equipment, particularly in government-owned training institutes (Amusan & Agunyai, 2021). Insufficient laboratories equipped with modern tools and technologies hinder students' practical understanding of microbiological concepts. Without proper laboratory equipment and outdated facilities, students miss out on appropriate practical hands-on experience, limiting their ability to apply theoretical knowledge to real-world scenarios. The deficiency extends to basic tools like incubators, autoclaves, ovens, microscopes, and fume hoods, which are crucial for effective microbiology education. Many microbiology laboratories resort to makeshift solutions during practical sessions, such as using stoves and pressure pots instead of autoclaves for sterilizing glassware and media due to limited or nonexistent budgets. Discussing advanced equipment like a Thermocycler, Gel electrophoresis apparatus, electron microscope, and sequencing machine might be comparable to asking for the impossible, akin to requesting the sun, moon, and stars. Consequently, graduates from these laboratories may lack global competitiveness and might not be motivated to pursue advanced degrees in the field (Aishat, 2019).

While universities, especially the older ones, possess some tools and equipment, they are often insufficient, and some are in poor states. In practical sessions, there is a scarcity of equipment for students, leading to overcrowded and inattentive learning environments. Moreover, universities often admit more students than their facilities can accommodate, exceeding allotted admission quotas, particularly for programs lacking regulatory bodies like microbiology (Amini-Philips & Akpoyowaire, 2016).

Presently, there are no companies in Nigeria manufacturing consumables and reagents essential for practical sessions. The necessity to import these items makes them challenging to obtain, rendering practical sessions ineffective. The prolonged processing time for orders and quotes, coupled with the time-sensitive nature of scientific professions, results in decreased productivity for tutors and limited exposure for students.

Another challenge, though not peculiar to microbiology education, is inadequate power supply. This makes the use of electrical devices such as projectors and electronic laboratory equipment difficult. This also limits students, for example, restricting studying at night.

Furthermore, the availability of current textbooks and digital resources in many Nigerian institutions is woefully inadequate. Even in private institutions that offer some online resources, the challenge of poor internet connectivity significantly hampers access. A dependable Internet connection plays a crucial role in enhancing learning and teaching, facilitating out-of-class engagement. Without reliable internet access, face-to-face learning remains the primary mode of interaction (Sofola, 2014). Additionally, the Internet serves as a platform for open educational resources (Mishra, 2017). Accessing the Internet for relevant microbiology learning materials, as suggested by Guarner and Niño (Guarner & Niño, 2016), can significantly augment student comprehension. Although there is increased access due to the sale of internet data by telecom providers, students often find this cost-prohibitive. Some universities in countries like Nigeria are making efforts to establish internet bandwidth on their campuses, but this is currently limited to specific locations (Sofola, 2014). Lastly, importing books is an expensive endeavor, emphasizing the need to develop locally relevant educational materials and ensure they stay current with contemporary content (Aishat, 2019).

2.1.2. Education and Training

In Nigeria, microbiology education faces a significant challenge due to a shortage of qualified experts to teach aspiring microbiologists (Aishat, 2019). The effectiveness of universities in producing competent graduates hinges on the availability and calibre of instructors. Public universities in Nigeria grapple with a high student-to-faculty ratio, resulting in inadequate supervision during lectures, practical sessions (Sofola, 2014), and examinations. Microbiology graduates often fall into three categories: those leaving the field for non-microbiology careers, those practising microbiology, and those pursuing postgraduate degrees due to job scarcity. The predominant trend is graduates opting for non-microbiology paths. The migration of skilled microbiologists abroad for further studies exacerbates the brain drain, with Nigerian professionals contributing to microbiology abroad (Bassioni et al., 2016).

Academic staff also bear heavy administrative burdens, straining their capacity and impeding self-development, leading to diminished productivity. Additionally, a major challenge stems from the absence of dedicated funds for microbiology training in Nigeria, although there is the Tertiary Education Trust Fund (TETFund), which is being used to fund research, conference attendance and postgraduate training (Sofola, 2014); however, it is highly competitive, and there are reports of nepotism and corruption in its application processes (Balogun et al., 2018). This lack of financial resources makes training and further education difficult. Over the past two decades, there has been a noticeable decline in the quality of microbiology staff in Nigeria, evident to anyone cognizant of microbiology's societal significance (Longe et al., 2005).

2.1.3. Outdated Curricula

Many educational institutions persist in using outdated curricula established since the inception of their programs. Lecturers often fail to update their teaching materials, relying on obsolete notes that do not align with current realities

(Jiboyewa & Umar, 2015). Additionally, several institutions neglect to cover contemporary microbiology topics like genomics, transcriptomics, proteomics, and synthetic biology, either due to a lack of expertise or insufficient teaching resources. These subjects embody essential knowledge crucial for the future development of microbiologists. By investing in microbiology education, particularly in areas such as bioremediation and waste management, Nigeria could equip future professionals to address environmental challenges like the contamination in Ogoniland and other regions of the Niger Delta. This proactive approach would not only save the country significant financial resources but also alleviate health and environmental issues stemming from improper waste disposal.

2.1.4. Poor Numeration

In Nigeria, poor remuneration stands out as a significant challenge in the field of Microbiology. Professionals in this field often face inadequate financial compensation, which can demotivate individuals and hinder the attraction and retention of skilled talent. Insufficient salaries impact not only the livelihoods of microbiologists but also the overall growth and advancement of the discipline in the country, as it may discourage dedication and investment in this crucial scientific field. Addressing this issue is crucial for fostering a robust and effective microbiology education in the country.

2.1.5. Limited Job Opportunities

The recruitment of microbiologists for careers in Nigeria is a significant problem exacerbated by changes in career expectations due to COVID-19 and post-COVID scenarios. Limited job opportunities in microbiology and the inability of the job market to absorb all graduates contribute to unemployment or underemployment. In response, the Nigerian government mandated entrepreneurship education in university curricula to equip students with skills for starting their own businesses. However, the non-professionalization of microbiology prevents graduates from practising their learned skills independently. Microbiology is not recognized as a professional course in Nigeria, leading to restrictions on establishing independent laboratories without a license from the Medical Laboratory Science Council of Nigeria (MLSCN) or Institute of Public Analysts of Nigeria (IPAN). This lack of professional status denies microbiology students opportunities for Industrial Attachment, pushing many graduates into alternative career paths. Recognizing this challenge, the Nigeria Society of Microbiology (NSM) initiated the professionalization process, resulting in the passage of a bill to establish the Microbiological Council of Nigeria (MCN) through the National Assembly. The bill awaits the President's assent.

2.1.6. Public Perception/Lack of Awareness

Misconceptions and lack of awareness can hinder the progress of microbiological research and applications. There is a need to enhance public understanding and appreciation of microbiology. Let us take the issue of antimicrobial resistance, for example. According to a study on public awareness of antimicrobial resistance in Nigeria, only 8.3% of the respondents had good knowledge of antimicrobial resistance (Chukwu et al., 2020). The study also revealed that 66.8% of the respondents had taken antibiotics in the last six months, out of which 31.3% were without a prescription. This indicates a lack of awareness of the proper use of antibiotics and the dangers of antimicrobial resistance.

Since issues that deal with microbes have a direct bearing on the human condition, it is critical that the public at large become better grounded in the basics of microbiology. Public literacy campaigns must identify the issues to be conveyed and the best avenues for communicating those messages.

2.1.7. Disease Control and Surveillance

Disease control and surveillance are critical components of public health microbiology in Nigeria. The country has been plagued by several infectious diseases, including malaria, tuberculosis, and HIV/AIDS, among others. Microbiology plays a significant role in the diagnosis, treatment and prevention of these diseases.

However, disease control and surveillance in Nigeria face several challenges. According to a study published in the Global Health Journal, the lack of integration of new approaches, such as the use of Big Data, mobile health approaches, and cutting-edge quantitative methods, makes them unsustainable or unrealistic for most national control programs. The gulf between academia and policymakers remains a significant barrier to their implementation (Buckee et al., 2018).

Another study published in the Infectious Diseases of Poverty Journal highlights the need for highly sensitive and specific diagnostic tools to target mass screening of asymptomatic gametocyte reservoirs in low/moderate endemic areas, sub-microscopic parasitaemia, and intensive integrated management of hotspots linked to environmental, climatic, and ecological appropriateness for Anopheles vectors and transmission (Tambo et al., 2014).

To improve our disease control and surveillance capabilities as well as reduce the burden of endemic infectious diseases and prepare for emerging epidemic threats, Nigeria must integrate the use of big data, mobile health approaches and cutting-edge quantitative methods to enable early detection of outbreaks, tracking of disease patterns and monitoring of disease trends. There must be a collaboration between academia and policymakers to help bridge the gap between research and policy implementation. We should also gear towards the development of highly sensitive and specific diagnostic tools for early infection detection.

To overcome these challenges, it is important for microbiology students to seek internships, engage in practical learning, develop transferable skills, and actively network during their education. Additionally, government and educational institutions can play a role in improving the quality of education, research opportunities, and job market prospects for microbiology graduates.

2.1.8. Prospects for Microbiology in Nigeria

In the diverse landscape of scientific disciplines, microbiology stands as a beacon of exploration and innovation. Nigeria, with its rich tapestry of challenges and opportunities, finds itself at the precipice of transformative possibilities in the realm of microbiological advancements. Some of these prospects include:

2.2. Increased Funding

Increased funding is one of the most important prospects for Microbiology in Nigeria. With more funding, the field can make significant strides in research and development, which can lead to better healthcare outcomes and a stronger economy.

According to the Nigerian Institute of Medical Research, the Microbiology Department recently reviewed its strategic plan and set targets for the next 5 years (2022-2026) for improved performance. The department has obtained several internal and external research grants, which will help to fund research of public health importance in collaboration with numerous partners in the field of HIV, HPV, drug-resistant tuberculosis, antimicrobial resistance, emerging and re-emerging infectious diseases (https://nimr.gov.ng/microbiology-department/).

In addition, there are several funding opportunities available for microbiology research in Nigeria. For instance, ScientifyRESEARCH provides funding for microbiology research and medical researchers, including research grants, fellowships, and awards (*RESEARCH FUNDING DATABASE*, 2024).

In addition, increased funding can help improve the quality of education in Microbiology. About 110 tertiary institutions in Nigeria offer Microbiology as a course of study. However, these institutions still lack vital research skills and technology. With increased funding, these institutions can acquire the necessary equipment and technology to provide students with a more comprehensive education (Mohammed et al., 2015).

2.2.1. Healthcare Advancement

Microbiology research holds significant potential to contribute to healthcare advancement and disease control in Nigeria. The identification of emerging diseases has consistently risen over the years, facilitated by tools like high throughput sequencing, PCR, and MALDI-TOF mass spectrometer, coupled with innovative sampling and culture approaches, thereby transforming clinical microbiology (Fournier & Raoult, 2011; Jones et al., 2008). The Centers for Disease Control and Prevention (CDC) established an office in Nigeria in 2001 to combat HIV, tuberculosis, malaria, and vaccine-preventable diseases, collaborating with the Federal Ministry of Health (FMOH), state ministries, government agencies, and partners to address these health challenges and enhance healthcare in Nigeria (Njidda et al., 2018).

Microbiology research plays a pivotal role in enhancing healthcare in Nigeria by innovating new treatments and diagnostic tools for infectious diseases. CDC Nigeria actively supports laboratory systems, risk communication, and vaccine deployment. Through the study of pathogen biology and the development of effective treatments and vaccines, microbiologists contribute to the prevention and control of infectious disease outbreaks (Njidda et al., 2018). Additionally, microbiology research aids in curbing the spread of infectious diseases in Nigeria, as evidenced by CDC Nigeria's support for COVID-19 surveillance, epidemiology, emergency response operations, case management, laboratory systems, and vaccine deployment. The CDC also assists in establishing and managing National and state-level Emergency Operation Centers.

2.2.2. Environmental Solutions

Reliance on culture-based growth methods has resulted in delays in implementing necessary preventive and corrective measures to address contamination within ecological environments. Progress in high throughput methods enables culture-independent assessments of microbial communities in contaminated sites. As highlighted by Cui *et al*. (Cui et al., 2021) and Mali *et al*. (Mali et al., 2023), microbial diversity at contamination sites is a key factor driving the bioremediation of both inorganic and organic matter. Although microorganisms can metabolically break down complex pollutants into simple degradable compounds, the mixture of these pollutants hampers their biodegradation ability (Singh & Mishra, 2021).

The escalating energy demands linked to urbanization and industrialization, coupled with global sustainable development policies, have intensified the focus on renewable energy projects (Kılıç & Özdemir, 2018). Environmental microbial research has yielded breakthroughs, including the restoration of fragile soil ecosystems, simultaneous bioremediation during biofuel production, the utilization of soil microorganisms as eco-friendly chemical alternatives, and the exploration of soil microbes as potential sources of industrial products.

In Nigeria, microbiology research can play a pivotal role in addressing environmental challenges by developing innovative microbial products and technologies to mitigate pollution and degradation (Krueger et al., 2015). For example, microbiologists can devise microbial solutions to combat environmental pollution caused by plastics. Synthetic polymers, commonly known as plastics, stand out as widespread anthropogenic pollutants in marine, limnic, and terrestrial ecosystems. Microorganisms emerge as the most promising candidates for the eventual bioremediation of environmental plastics. While laboratory studies have reported various effects of microorganisms on many types of polymers, often through enzymatic hydrolysis or oxidation, most common plastics have proven highly resistant even under conditions favorable for microbial degradation (Krueger et al., 2015).

Moreover, microbiology research in Nigeria can contribute to environmental solutions by developing microbial strategies to address the issue of oil spills, a significant environmental problem causing severe damage to the environment and human health. Microbial bioremediation stands out as a promising technology for cleaning up oil spills, where

microorganisms can break down hydrocarbons in oil spills into less harmful substances such as carbon dioxide and water (Ezeonu et al., 2012).

2.2.3. Agricultural Innovations

Globally, artificial chemicals predominantly govern agricultural practices. The indiscriminate application of chemical pesticides and fertilizers has significant repercussions on soil quality, human health, and the environment (Glick, 2012). With the continuous rise in the world population, there is a pressing need to enhance agricultural productivity while mitigating adverse effects on the environment. Sustainability, as an integrated approach, offers a solution to food production challenges in an environmentally friendly manner (Lal, 2008).

Microbiological techniques present a valuable means to enhance crop yields sustainably by improving nutrient acquisition, managing insect pests, and promoting plant growth (Barea et al., 2013). Innovations in microbiology, such as the use of biofertilizers and biopesticides, play a pivotal role in agriculture. The careful selection, application, and screening of stress-tolerant microorganisms are crucial for effectively managing abiotic stress, offering a viable solution to overcome limitations associated with plant production in stress-prone regions.

2.2.4. Collaborations

Certainly, research collaboration is an important aspect of microbiology in Nigeria. The collaboration between researchers, institutions and industries holds the potential to address challenges, enhance knowledge dissemination and propel the field towards new frontiers.

Microbiology researchers collaborate with several organizations to ensure that the STEM (science, technology, engineering and mathematics) agenda is pushed forward. Access to a global network introduces new methodologies, technologies, and perspectives, contributing to a more robust understanding of microbial systems. In the wake of global health concerns like pandemics, such collaboration becomes even more critical. By pooling resources and expertise, researchers can develop sustainable solutions using microbiota for waste management, soil health improvement, and bio-energy production and accelerate the development of biotechnological applications, ranging from the production of pharmaceuticals to the improvement of agricultural practices. Co-authored publications with renowned researchers contribute to the recognition of Nigeria's scientific contributions and strengthen its position in the global scientific community.

2.2.5. Biotechnology Development

Biotechnology has transcended numerous challenges, evolving into a scientific discipline that influences various aspects of human activities. It has become a cornerstone in addressing diverse human challenges, with heightened research focus in pharmaceuticals, medicine, biology, agriculture, and environmental sciences. Delving into the intricacies of cellular interiors, particularly in molecular biochemistry and biology, has yielded valuable contributions, such as new drugs and chemicals, proving beneficial in addressing complex health issues like cancer, hypertension, and heart diseases. The traditional reliance on animal cells to produce hormones, growth factors, and insulins has shifted to utilizing fermentation processes involving yeasts and bacteria (Walsh, 2005). Tissue cultures are now the source of monoclonal antibodies, contributing to the expanding array of biotechnological drugs that have achieved substantial commercial success, making them more accessible and affordable.

Beyond pharmaceutical applications, biotechnology extends into microbiological realms, presenting opportunities for the production of biopesticides, biofertilizers, environmental controls, and more. Microbiologists are urged to harness these advancements, delving deeper into the molecular intricacies of cells and unlocking the vast potential of microorganisms to sustain human survival on Earth.

2.2.6. Educational Reforms

Collaborative efforts between educational institutions and industries can ensure that microbiology curricula align with the demands of the job market, producing graduates with practical skills. Moreso, encouraging partnerships between microbiology programs and relevant industries can provide students with valuable industrial attachments, preparing them for real-world challenges.

3. Data Management and Artificial Intelligence Systems

Efficient data management is pivotal for the progress of microbiology in Nigeria. The proper handling and organization of data resulting from microbial research empower scientists to derive meaningful insights, fostering a deeper understanding of microbial ecosystems. This encompasses databases containing crucial information on microbial diversity, drug resistance patterns, and epidemiological data. The development of robust data management systems holds the potential to amplify collaboration among researchers, streamline infectious disease tracking, and bolster evidence-based decision-making in public health.

The integration of artificial intelligence presents promising avenues for microbiology in Nigeria. AI applications, including machine learning algorithms, exhibit the capacity to swiftly analyze extensive datasets and discern patterns that may pose challenges for conventional methods. In the realm of microbial genomics, AI proves invaluable by aiding in the prediction of antimicrobial resistance, the identification of potential pathogens, and the analysis of intricate interactions within microbial communities. This acceleration of the research process contributes significantly to more effective disease management strategies. Additionally, AI's capacity to analyze diverse data sources, encompassing clinical records and

environmental factors, enhances disease surveillance, enabling the prediction and mitigation of disease outbreaks in Nigeria and allowing for proactive public health measures.

Moreover, AI contributes to personalized treatment approaches by accounting for individual variations in microbial responses. This approach leads to more precise and effective treatment strategies for patients in Nigeria, acknowledging the diversity of microbial strains and patient demographics. In the agricultural sector, AI optimizes soil microbial management, predicts crop diseases, and enhances crop yield—a particularly relevant application in Nigeria, where agriculture holds substantial economic significance. AI also plays a role in monitoring and managing environmental microbiota, contributing to strategies for pollution control and sustainable environmental practices.

However, challenges such as data privacy, ethical considerations, and the necessity for a skilled workforce in both data management and AI implementation necessitate attention. Collaborative endeavors involving microbiologists, data scientists, and policymakers are imperative to fully leverage the potential of data management and AI in advancing microbiology in Nigeria.

4. Conclusion

In the realm of microbiology in Nigeria, the journey through challenges has been arduous, yet not devoid of optimism. The inadequacies in funding, infrastructure, and educational avenues have tested the resilience of the scientific community. However, as we navigate these obstacles, the prospects for microbiology in Nigeria emerge as beacons of promise. The potential for healthcare advancement, environmentally sustainable solutions, innovative strides in agriculture, collaborative ventures, and the ever-expanding horizon of biotechnology development collectively paint a picture of a field poised for transformation. As we conclude this exploration, it becomes evident that the challenges faced are not insurmountable barriers but rather stepping-stones towards a future where microbiology in Nigeria thrives, contributing significantly to scientific advancements and societal well-being.

5. References

i. Aishat, A. (2019). Microbiology education in Nigeria: Common training deficits could be addressed with modern educational tools. *Journal of Microbiology & Biology Education, 20*(1), 10.1128/jmbe. v1120i1121. 1595.

ii. Amini-Philips, C., & Akpoyowaire, M. S. (2016). Policy of carrying capacity and access to university education in Nigeria: issues, challenges and the way forward. *International Journal of Learning, Teaching and Educational Research, 15*(9), 55–70.

iii. Amusan, L., & Agunyai, S. C. (2021). The COVID-19 pandemic and the crisis of lockdowns in Nigeria: The household food security perspective. *Africa's Public Service Delivery & Performance Review, 9*(1), 10.

iv. Balogun, W. G., Cobham, A. E., & Amin, A. (2018). Neuroscience in Nigeria: the past, the present and the future. *Metabolic brain disease, 33*, 359–368.

v. Barea, J. M., Pozo, M. J., Azcón, R., & Azcón-Aguilar, C. (2013). Microbial interactions in the rhizosphere. *Molecular microbial ecology of the rhizosphere, 1*, 29–44.

vi. Bassioni, G., Adzaho, G., & Niyukuri, D. (2016). Entice Africa's scientists to stay. *Nature, 535*(7611), 231–231.

vii. Buckee, C. O., Cardenas, M. I., Corpuz, J., Ghosh, A., Haque, F., Karim, J., Mahmud, A. S., Maude, R. J., Mensah, K., & Motaze, N. V. (2018). Productive disruption: Opportunities and challenges for innovation in infectious disease surveillance. *BMJ Global Health, 3*(1).

viii. Chukwu, E. E., Oladele, D. A., Awoderu, O. B., Afocha, E. E., Lawal, R. G., Abdus-Salam, I., Ogunsola, F. T., & Audu, R. A. (2020). A national survey of public awareness of antimicrobial resistance in Nigeria. *Antimicrobial Resistance & Infection Control, 9*(1), 1–10.

ix. Cui, M., Guo, Q., Wei, R., & Wei, Y. (2021). Anthropogenic nitrogen and phosphorus inputs in a new perspective: Environmental loads from the mega economic zone and city clusters. *Journal of Cleaner Production, 283*, 124589.

x. Ezeonu, C. S., Tagbo, R., Anike, E. N., Oje, O. A., & Onwurah, I. N. (2012). Biotechnological tools for environmental sustainability: prospects and challenges for environments in Nigeria—a standard review. *Biotechnology research international, 2012*.

xi. Fournier, P.-E., & Raoult, D. (2011). Prospects for the future using genomics and proteomics in clinical microbiology. *Annual review of microbiology, 65*, 169–188.

xii. Glick, B. R. (2012). Plant growth-promoting bacteria: mechanisms and applications. *Scientifica, 2012*.

xiii. Guarner, J., & Niño, S. M. (2016). Microbiology learning and education online. *Journal of Clinical Microbiology, 54*(5), 1203–1208.

xiv. Jiboyewa, D., & Umar, M. A. (2015). Academic Achievement at the University of Maiduguri: A Survey of Teaching-Learning Environment. *Journal of Education and Practice, 6*(36), 146–157.

xv. Jones, K. E., Patel, N. G., Levy, M. A., Storeygard, A., Balk, D., Gittleman, J. L., & Daszak, P. (2008). Global trends in emerging infectious diseases. *Nature, 451*(7181), 990–993.

xvi. Kılıç, M., & Özdemir, E. (2018). Long-term energy demand and supply projections and evaluations for Turkey. In *Exergetic, Energetic and Environmental Dimensions* (pp. 115–132). Elsevier.

xvii. Krueger, M. C., Harms, H., & Schlosser, D. (2015). Prospects for microbiological solutions to environmental pollution with plastics. *Applied microbiology and biotechnology, 99*, 8857–8874.

xviii. Lal, R. (2008). Soils and sustainable agriculture. A review. *Agronomy for Sustainable Development, 28*, 57–64.

xix. Longe, O., Uwadia, C., & Longe, F. (2005). An x-ray of potentials for collaboration between the academia and the IT industry. *Proceedings of the 8th International Conference of the Nigerian Computer Society*.

xx. Mali, H., Shah, C., Raghunandan, B., Prajapati, A. S., Patel, D. H., Trivedi, U., & Subramanian, R. (2023). Organophosphate pesticides an emerging environmental contaminant: Pollution, toxicity, bioremediation progress, and remaining challenges. *Journal of Environmental Sciences, 127*, 234–250.

xxi. Miller, M. J. (2019). Rapid microbiological methods. *Pharmaceutical Microbiological Quality Assurance and Control: Practical Guide for Non-Sterile Manufacturing*, 429–458.

xxii. Mishra, S. (2017). Open educational resources: Removing barriers from within. *Distance education, 38*(3), 369–380.

xxiii. Mohammed, Y., Zailani, S., Galadima, G., & Saidu, K. (2015). Perception of final year medical students about the choice of medical microbiology as a speciality. *Orient Journal of Medicine, 27*(1–2), 28–33.

xxiv. Njidda, A. M., Oyebanji, O., Obasanya, J., Ojo, O., Adedeji, A., Mba, N., Oladejo, J., & Ihekweazu, C. (2018). The Nigeria centre for disease control. *BMJ global health, 3*(2).

xxv. Ojo, J. (2023). Matters arising: Despite growing concerns, Nigeria's education allocation still below recommended benchmark. *The Cable: Online*.

xxvi. RESEARCH FUNDING DATABASE. (2024). https://www.scientifyresearch.org/

xxvii. Singh, A., & Mishra, V. K. (2021). Biodegradation of organic pollutants for its effective remediation from the environment and the role of various factors affecting the biodegradation process. In *Sustainable Environmental Clean-up* (pp. 1–27). Elsevier.

xxviii. Sofola, S. (2014). Challenges of teaching and researching physiology in Sub-Saharan Africa. *Physiology, 29*(3), 150–152.

xxix. Tambo, E., Ai, L., Zhou, X., Chen, J.-H., Hu, W., Bergquist, R., Guo, J.-G., Utzinger, J., Tanner, M., & Zhou, X.-N. (2014). Surveillance-response systems: the key to elimination of tropical diseases. *Infectious diseases of poverty, 3*(1), 1–11.

xxx. Ugwuanyi, R. (2016). A review of the problems and challenges in the study of microbiology in Nigeria's tertiary institutions. *Journal of Advances in Health and Medical Sciences, 2*(1), 10–17.

xxxi. Walsh, G. (2005). Therapeutic insulins and their large-scale manufacture. *Applied microbiology and biotechnology, 67*, 151–159.